University of Arkansas, Fayetteville
ScholarWorks@UARK

Theses and Dissertations

5-2013

Effects of Using Canola Meal as a Protein Source in Broiler Diets

Charles Danny Bradley Jr
University of Arkansas, Fayetteville

Effects of Using Canola Meal as a Protein Source in Broiler Diets

Effects of Using Canola Meal as a Protein Source in Broiler Diets

A dissertation submitted in partial fulfillment
Of the requirements for the degree of
Doctor of Philosophy in Poultry Science

By

Charles Danny Bradley Jr.
Henderson State University
Bachelors of Science Education, 2004

May 2013
University of Arkansas

ABSTRACT

Six experiments were conducted to evaluate the response of broilers fed canola meal. Experiment 1 assessed performance and carcass yields when broilers were fed various combinations of canola and soybean meal in nutritionally balanced diets based on digestible amino acid values. The results suggested that canola meal can be used in isocaloric diets as a partial replacement for Soybean meal.

Experiment 2 assessed broiler performance and carcass yields when using various levels of canola meal in broiler diets with a constant level of supplemental poultry oil. The resulting data suggested when diets are formulated with a constant level of supplemental fat; the level of CM should not exceed 10%.

Experiment 3 and 4 were conducted simultaneously which examined two diet types Corn-Soy (CS), Corn-Soy-Canola (CSC) and four amino acid (AA) levels (80, 85, 90, and 95% of suggested level). ProAct and Cibenza protease enzymes were added at 3 different levels (0, 1, and 2 times suggested amount). The resulting data suggested performance for birds fed incrementally higher percentages of AA and the CSC improved. The addition of enzymes did not significantly improve BW. However, the addition of ProAct at 2 times suggested level improved FCR within the three-way interaction.

Experiment 5 was conducted to evaluate pellet quality, broiler performance, and carcass characteristics of birds fed diet combinations of DDGS, SBM, and CM. These results concluded that 15 % DDGS and 20% CM can be used in combination without significantly affecting pellet quality. However, performance and parts yield displayed undesirable characteristics.

Experiment 6 was conducted using two diet types; isocaloric and optimum nutrient density, two amounts of DDGS (0 and 15%) and six levels of canola meal (CM) (0, 5, 10, 15,

20, and 25%). The resulting data suggest if diets are maintained isocalorically any combinations of ≤ 15% DDGS and ≤ 25% CM without significantly decreasing performance. If diets are maintained at optimum nutrient density and 15% DDGS, CM can be added at 10, 15 and 20% levels without depressing BW or FCR. However, if diets are maintained at optimum nutrient density and 0% DDGS are added, CM cannot be added without depressing BW.

This dissertation is approved for recommendation

to the Graduate Council.

Dissertation Director:

____

Dr. Susan E. Watkins

Dissertation Committee:

____

Dr. Michael T. Kidd

____

Dr. William E. Huff

____

Dr. Charles F. Rosenkrans

DISSERTATION DUPLICATION RELEASE

I hereby authorize the University of Arkansas Libraries to duplicate this dissertation when needed for research and/or scholarship.

Agreed _____________________________________

Charles Danny Bradley Jr.

Refused _____________________________________

Charles Danny Bradley Jr.

ACKNOWLEDGEMENTS

I would like to express appreciation to my advisors Dr. Park Waldroup and Dr. Susan Watkins and committee members Dr. Kidd, Dr. Huff, and Dr. Rosenkrans. I know this has been an extremely difficult period of transition for everyone as Dr. Waldroup entered retirement and Dr. Watkins continued my mentorship. Thank you for your patience and for all the lessons I have learned.

I would like to recognize the Poultry Federation and its members for their devotion to newcomers in the poultry industry and for the scholarships they provided me. The contributions you made allowed me to continue my education. Without your help and financial assistance this educational opportunity would have not been possible.

Thanks to the crew on Dr. Waldroup's team, Sarah Goodgame, Franco Mussini, Changji Lu, Savanna Fiscus, and Nezaket Comert. The support and commitment you gave to my research projects was un-measurable.

I would also like to pay tribute to my neighbors, Ray and Ann Ennis, Pat and Mary Ellen Egleston, Gail and Mike Kidder, and my in-laws for their help and support while I was in Fayetteville. Thanks for holding my fort down through tornadoes, floods, droughts, cows getting out, heifers calving, etc. It is unbelievable the love and work you have given to our family and you will always be a part of this success.

My Family, Mary, Asher, and Josh. There are no words to express how much I appreciate your love for me. Your support and belief in me helped to accomplish the dream of a better future for our family. Mary, thanks for the hundreds of thousands of miles you have logged in the last few years in financially supporting our family. You are my rock, I can depend

on you to not be shaken. Mom and Dad, Thanks for the examples you have given me in many areas of my life.

Lastly, praise to God for the doors he is opening and the opportunities he is creating for me in my life. The guidance and direction he is giving to our family has headed us down a pathway some prophesied was impossible but, in him, I can do all things when he strengthens me (Phil 4:13).

TABLE OF CONTENTS

Part I. LITERATURE REVIEW

PART II. RESEARCH STUDIES

Chapter 1. Use of Canola Meal in High Energy Broiler Diets. 1. Isocaloric Diets

LITERATURE REVIEW

1. Introduction

Since the early 1940's, broiler diets have become increasingly dominated by a grain and an oilseed mixture of corn and soybean meal (SBM). The role of each these ingredients in the broiler diets are as different as the ingredients themselves. Grains like corn most characteristically provide energy in the form of starch while oilseed meals like SBM or canola meal (CM) provides a source of protein. Approximately 48% of SBM produced in the United States in 2011 was used in chicken diets (Soy Stats, 2012). For almost seven decades, the link between the poultry broiler and the SBM industries resembled a perfect match. SBM offers excellent availability, total protein content, amino acid (AA) composition, AA digestibility, and if processed properly, very low anti-nutritive properties. However, in recent times the poultry industry has experienced financially lean years, many companies have recorded slim profit margins that have been magnified by escalating prices of feed, especially for SBM. The rising cost of SBM can be attributed to the basic business principle of supply and demand. Despite an increase of over 500% in soy production in the last 40 years (Soyatech, 2012a), the supply can't adequately keep up with the demand. The craving for SBM and the consequential rising costs have been fueled by several factors, such as; major urbanization in China, search for alternative fuels in America such as biodiesel and ethanol, the ever increasing need for livestock feed, and aggressive speculation of investors on Wall Street. The declining profit of poultry companies has generated exploration for less expensive feed ingredients and alternative protein sources for broiler diets. CM if used as a substitute for SBM in broiler diets may be able to provide liberation to the broiler and soybean industry.

Part 2. HISTORY

2.1 Rapeseed

Canola was developed through conventional plant breeding from rapeseed, an oilseed plant, previously used as long ago as the ancient civilization for fuel in lamps and cooking. The word "rape" in rapeseed comes from the Latin word "rapum," meaning turnip. Turnip, cabbage, brussel sprouts, mustard, and many other vegetables are related to the two natural canola varieties commonly grown today, which are cultivars of *Brassica napus* and *Brassica rapa*. Brassica crops are among the oldest cultivated plants, with many species and cultivars being raised for food production. Some of the earliest writings reported mustard, cabbage, and turnips being used in Europe and in India as early as 2000 B.C. In the 18th century, the bright yellow flowering member of the family *Brassicaceae* was studied by Swedish botanist, Carolus Linnaeus. The turnip and the oilseed-producing variants were seen by Linnaeus as being a different species of crop, he then named them B. rapa and B. campestris (Canola Council of Canada, 2011). However, 20th-century taxonomists found that the two plants belonged to the same species and were cross-fertile. Since the turnip had first been named *Brassica rapa* by Linnaeus, the name *Brassica rapa* was permanently adopted (Canola Council of Canada, 2011).

Aside from the forage rape (B. napus) already grown during the pioneering days as an annual pasture crop in Canada, in 1936, the oilseed rape, B. rapa, was first introduced in Canada by a Polish immigrant, Fred Solvonik (Bell, 1982). This material subsequently became the source of the seed used by the Canada Department of Agriculture just prior to and during World War II for testing at the research centers across Canada. Seed from the cultivar, B. napus, had been obtained from Argentina. Consequently the B. napus and B. rapa seeds possessed a variety of agronomic characteristics that were suited for different geographic and climatic conditions, the two types of rapeseed became more commonly known as Polish and Argentine seeds (Bell, 1982).

Rapeseed is known as Canada's Cinderella Crop because of the remarkable transformation it underwent in this North American country. The 20th century interest in rapeseed production centered on its oil production properties as a marine engine lubricant. During World War II, the uncertainty of transatlantic transportation led to a shortage of marine lubricants. Because of its natural high content of erucic acid, which sticks to metal even under extreme heat and humidity, rapeseed oil proved to be a suitable alternative. Its oil has the property of adhering well to moist metal, making it an ideal lubricant for marine engines (Oplinger et al., 1989). The world's shortage of marine lubricants led the Canadian government to encourage the planting of rapeseed through a subsidy program (Busch, 2003).

However, the end of World War II also meant the end of the market for most rapeseed that was produced in Canada. The demand for marine lubricants fell sharply, because of the reduction in the size of the navy and the switch from steam to a new, more efficient diesel engine (Busch et al., 1994). Subsidies from the Canadian government also ended. The rapeseed farming community was soon devastated by the drastic decline in demand for the oil. Within a very short period of time the need for production of rapeseed went from a very high demand to virtually ceasing to exist. Although rapeseed had been used previously in Europe and the Middle East as edible oil, it was known to have some detrimental properties. The oil was greenish yellow in color and had a strong mustard-like odor. Traditional rapeseed contains several anti-nutritional factors that can be responsible for low utilization of nutrients and poor palatability. At the top of the list for the most concerning naturally occurring toxins in rapeseed are erucic acid and glucosinolates (GLS). Therefore, it required considerable post-harvest processing to prepare it for consumption for both human and animals.

2.2 Transformation of Rapeseed

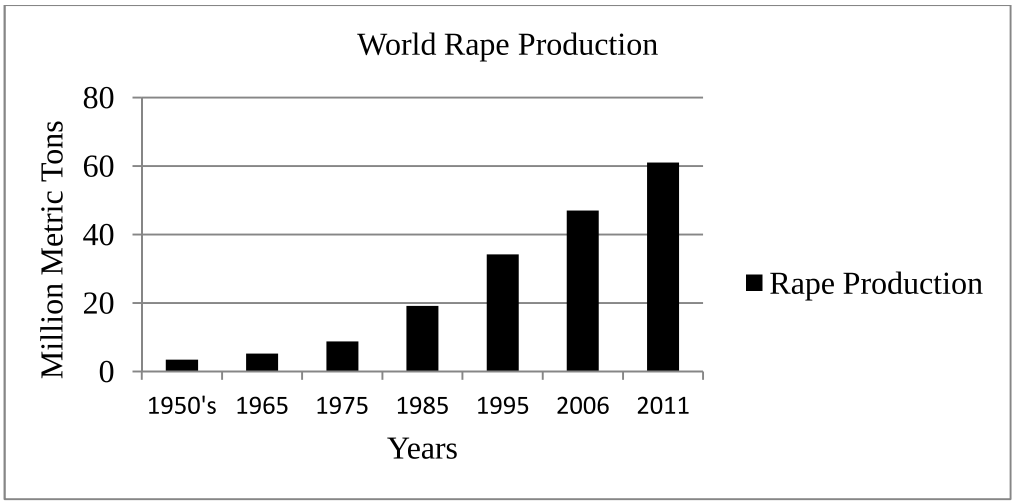
In 1952, in the midst of the Cold War, the Associate Committee on Fats and Oils of the Canadian National Research Council (CNRC) was organized and Chaired by R. K. Larmour. The committee would meet once a year to review imports, exports, and production of fats and oils. In an effort to diversify crops, oil meal, and to make Canada more self-sufficient on edible oils, Mr. Larmour suggested the committee investigate the possibilities of using the already available rapeseed crop as edible oil (Busch et al., 1994). In the same time frame as the committee on fats and oils was meeting about future possibilities with rapeseed, Kenneth Carroll at the University of Western Ontario had been exploring long chain fatty acids, specifically, erucic acid in pharmaceutical uses. Carroll and another scientist Beare discovered a link between rats with reduced growth that consumed erucic acid and low digestibility issues related to the acid (Busch et al., 1994). The digestibility concerns were not the only ones, it appeared there was also a link between erucic acid and heart lesions that appeared in rats fed high levels of the acid. Based on the experiments, the committee concluded that erucic acid needed to be eliminated in rapeseed before it could be used for human or animal consumption. Researchers began to selectively breed rape until its seed contained tolerable levels of erucic acid. The first low erucic acid rapeseed (LEAR) variety was released in 1968 (Bell, 1982)

While drastically lowering the erucic acid level relieved one area of concern for the committee, another area of concern emerged, glucosinolates (GLS). Swine and poultry that were fed rations containing high levels of rapeseed meal (RSM) and GLS showed signs of an enlarged thyroid condition. It had been known since the 1940's that mustard oils were the cause of thyroid goiters (Bell, 1982) and apparently RSM was triggering the same response. These goiters were a source of great concern not only for animal farmers, but for Canadian economists, and the committee members who knew of the potential economic loss from not being able to use the RSM in a way that SBM was being used. In 1967, a visiting polish scientist Jan Kryzmanski discovered a low GLS cultivar. Because of this discovery, in 1974, the first low GLS variety was released (Bell, 1982).

2.3 Canola

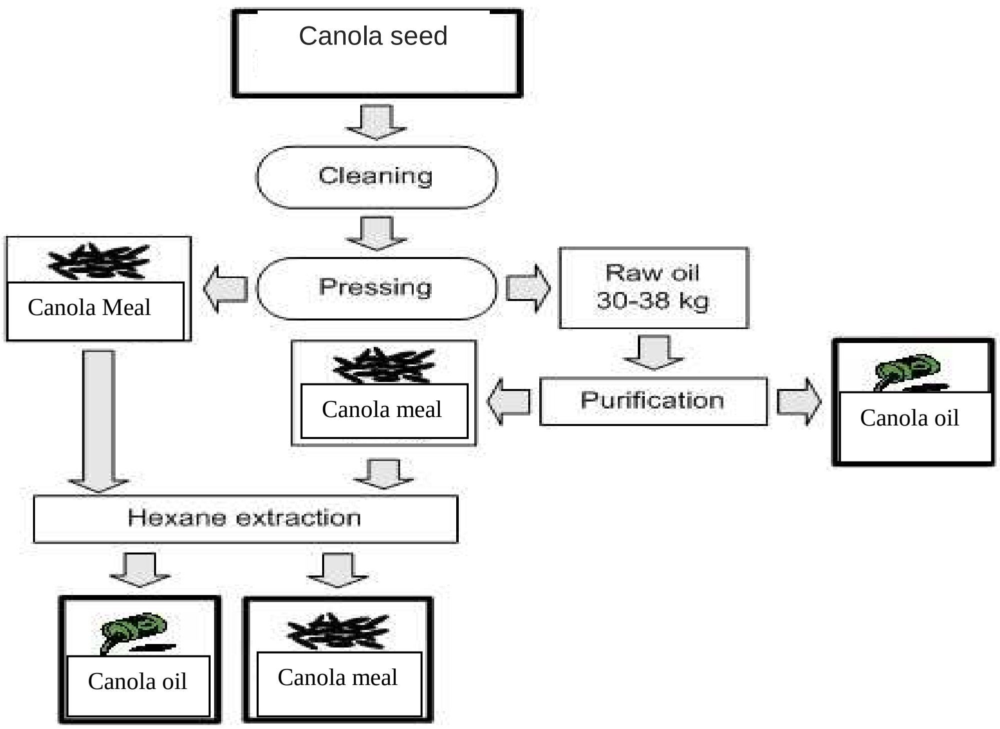
The two varieties (zero erucic acid and zero glucosinolates) represented the beginning of the new "double low" strain that brought both canola oil and meal quality into a new era. The chemical differences between the old and new forms were so significant nutritionally, that a new commercial name seemed justifiable: hence "canola" (Bell, 1982). Canola took its new name in 1978 and origin of the name Canola is derived from CAN "Canada" and OLA from "oil low acid". The success that has been shown by all involved in the development of this oilseed has left a blueprint and an example for all others to follow. The economic impact of canola along with its contributions towards human health has led some to claim the canola story is one of agriculture's greatest successful narratives of all time. Because of the efforts of many scientists, committees, and seemingly a major percentage of Canadian growers, production of rapeseed has experienced a drastic incline from 3.5 million metric tons (MT) in the decade of the 1950s to 2011 when global harvest of rapeseed extended to a record high of approximately 61 million MT (Table 1). Economically in Canada alone from the year 2007 to 2010, canola contributed an annual average of $8.22 billion in wages to 228,000 Canadian jobs. The total monetary benefit to the Canadian economy was $15.4 billion per year (LMC International, 2011). While the economic benefits from canola are no doubt substantial, the impact that canola oil has on human health and heart disease maybe even greater. Eating foods with or cooking by way of greases or oils that contain saturated fats has long been linked with high cholesterol and coronary heart disease.

Table 1. Progression in worldwide production of rapeseed meal adapted from (Soyatech, 2012b).



The alternative to consuming these saturated fats is to replace foods high in saturated fats with foods high in monounsaturated and/or polyunsaturated fats. This means eating foods made with liquid vegetable oil, but not tropical oils (American Heart Association, 2010). Canola oil has the ability to reduce the risk of heart disease when used in place of saturated fat because it has the least saturated fat of any common cooking oil. In fact, it has less than half the saturated fat of olive or soybean oil (canolainfo.org, 2012). Canola seeds by volume contain approximately 45 percent oil. Canola oil is extracted most commonly from the crushed seed in a hexane solvent process (figure 1). After extraction, the oil is used in two very different ways. One way is for human consumption where the oil is refined additionally and bottled to be used for cooking oil (canolainfo.org, 2012). Secondly, canola oil is used to create biodiesel. The oil for human consumption is regulated and must contain less than 2% erucic acid to be considered canola oil (Hoffman, 1990). The remains of the canola seeds after oil is extracted are further processed to produce the by-product canola meal (CM).

Figure 1. Canola oil extraction process adapted from (Baquero et al., 2011).



Part 3. CANOLA MEAL

3.1 Uses

The vast majority of CM produced is used in animal feeds specifically, the primary recipients has been cattle and swine producers with poultry, horse, fish, and others benefiting only on a very limited basis. Globally, the only oilseed meal that has more significant usage in animal feeds is SBM (Newkirk, 2009). The majority of canola meal in the United States is fed to dairy cows because the meals high fat content enhances milk production (Ash, 2012). Another use for canola meal includes high-quality organic fertilizer. In the future, CM may also be used as a protein isolate for human nutrition (Canola Council of Canada, 2011).

3.2 Production

Canada produces greater than half of the world's CM, seed, and oil. Canadian growers are continuing to expand the amount of acreage designated to produce canola because of the rising demand. China and India have budding interest in the health benefits of vegetable oils while Europe and the United States are developing bio-diesel industries that use canola oil. As production of canola oil rises, the availability of CM also rises. Major importers of Canadian grown canola meal include the EU, China, United States, Mexico, South Korea, Indonesia, Thailand, Vietnam, and Taiwan. Significant interest in CM in the United States did not occur until 1985 when Generally Recognized as Safe (GRAS) condition was approved by the FDA. In the United States, California is the largest consumer of CM because of the vast dairy industry found in that state. California is followed very distantly by Idaho in consumption of CM. Regions of the United States that import the most Canadian CM are the extreme northern and western states (Hickling, 2010). The areas of the United States growing canola are limited because most are growing soy or corn but, recently interest has increased in canola as a winter rotational crop in zones below the Mason-Dixon line that were previously reserved for soybeans.

3.3 Processing

Most CM is processed by means of pre-press solvent extraction. A flow chart of pre-press solvent processing of canola seed is shown in Figure 2.

> The initial step in processing is the removal of major non-canola seed materials (screenings, often added back to meal after processing). The seed is then pre-conditioned

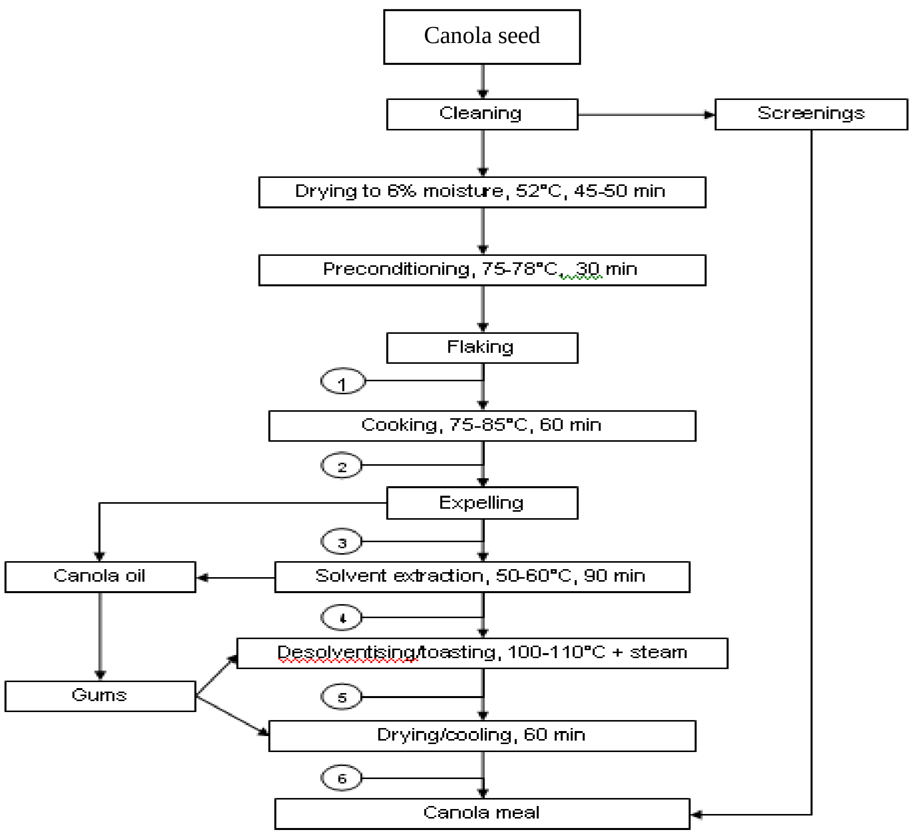
by drying (to 6-7% moisture) and heated to 75-78°C to prevent seed shattering and improve processing. Flaking then ruptures the seed coat and some oil cells prior to cooking (75-85°C for 20 to 60 min). The latter step denatures hydrolytic enzymes such as myrosinase and further ruptures oil cells. Destruction of myrosinase is essential to prevent hydrolysis of glucosinolates to more toxic and undesirable sulfur compounds. Pressure expelling then removes from 60 to 70% of the oil prior to solvent extraction with hexane. Meal exiting hexane extraction has low levels of oil and is laden with hexane (35%). The meal then enters the desolventization / toasting (DT) stage of processing which uses a vertical column with multiple trays to heat the meal. Hexane is evaporated from the meal as a result of the indirect heat of the heated trays as well as by direct heat from the injection of steam (sparge steam) into the meal in the final lower trays. The temperature increases as meal proceeds from tray to tray, being relatively low at higher trays because of hexane evaporation but reaching temperatures of 100 to 110°C in the final trays due to steam injection. Condensation of steam increases the meal moisture content to 16-18%. Moisture can also enter the DT stage via water sprayed on the upper tray to control dust and water found in gums that may be returned to the meal at this stage. This stage also "toasts" the meal to reduce the level of anti-nutritional glucosinolates and possibly other undefined factors. The meal is then dried and cooled, and possibly ground and pelleted. Pre-press solvent processing of canola seed is referenced from Classen et al., (2005)

For years, CM was considered to be a byproduct in the pursuit of oil extraction of the canola seed. However, because of livestock feed, the value of the meal itself has greatly increased and CM can now be considered a co-product. Processing of the canola seed is conceivably one of the most important steps in the use of oilseed meal in poultry diets. The rapeseed or canola meal quality is a major function of the rapeseed variety used and conditions during the manufacturing process, which are mainly related to temperature, moisture level, and time of treatment (Dakowski et al., 1996). CM quality is very sensitive to temperature and it is very important to get the best out of the heat handlings during processing to decay the remaining glucosinolates while trying to avoid decreasing protein quality and digestibility. It was discovered in 1957 by Dr. Clandinin, a poultry nutritionist at the University of Alberta that RSM contains the enzyme, myrosinase and high temperatures during crushing trigger the enzyme to react with glucosinolates increasing their toxicity (Busch et al., 1994), and also revealed meals toxicity correlated with the destruction of the amino acid (AA) lysine. Both of these findings helped to refine the crushing techniques and help reduce the destruction of lysine and the release of myrosinase (Busch et al., 1994). Destruction of the enzyme myrosinase is vitally important in preventing the hydrolysis of glucosinolates which forms anti-nutritional factors such as; Nitriles; Thiocyanates; and Isothiocyanates. The reduction of lysine in over processed CM is a classic symptom of the Maillard reaction. The Maillard reaction occurs when the amino group in an AA forms a condensation product with an aldehyde; it is triggered by heat; is believed to cause the browning reaction in cooking; and is especially detrimental to the AA lysine. Color of CM is an indicator of proper processing, CM upon entering the desolventizer/toaster (DT) is yellow but, at exit is brown indicating the Maillard reaction is occurring in the process (Newkirk and Classen, 2002). The lighter in color CM is after leaving the DT processing, conceivable, the better the processing was on the AA content and the less Maillard reaction occurred. Processing later evolved to using heat treatment prior to extraction for reducing toxicity of RSM by inactivating the enzymes myrosinase, lipase, and for improving the crushing capacity and oil yields of the seeds (Jensen et al., 1995).

The amount of time CM is processed also has an influence on the protein solubility of CM. Jensen et al. (1995) reported in their experiment that protein solubility decreased linearly from 85% on unprocessed CM to 40% after 120 minutes of toasting. The decrease in protein solubility was found to be associated with a decrease in lysine content as other amino acids remained relatively unchanged. Time also seems to be correlated with temperature, the longer the meal is exposed to the high temperatures required in processing the more protein quality and availability of some AA deteriorates.

Moisture content of the seed also has an effect on the quality of the meal. Moisture of the seed before processing should be 6-10%. Above 10% moisture, glucosinolates hydrolysis will proceed rapidly, and below 6% moisture, the myrosinase enzyme is only slowly inactivated by heat (Newkirk, 2009). Because the process of removing the hexane involves sparge steam which increases the moisture content of the CM, excess moisture becomes a concern. Moisture may contribute to undesirable digestibility and loss of important AA in CM. Therefore, elimination of additional moisture in the form of sparge steam during DT may result in yellow meal with an elevated concentration of AA and enhanced digestibility (Newkirk and Classen, 2002).

Figure 2. Flow Chart of pre-press solvent extraction of canola seed adapted from (Newkirk et al., 2003).



Part 4. ANTINUTRITIONAL FACTORS OF CANOLA

4.1 Erucic Acid

Erucic acid is a long chain monounsaturated fatty acid with 22 carbon atoms but, only one unsaturated carbon to carbon bond. (Figure 3).

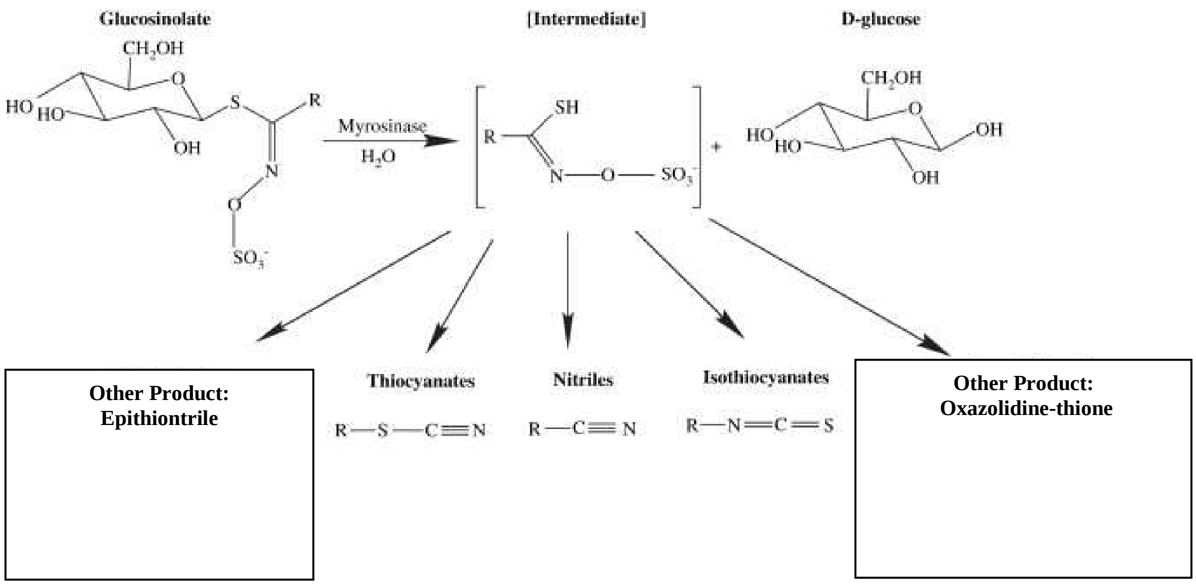
Figure 3. Chemical structure of erucic acid $C_{22}H_{42}O_2$ adapted from (Lookchem, 2013)

This type of chemical structure has been linked to lipidosis or fat build-up in the heart. Conventional rapeseed was known to contain a high level of erucic acid, which in some varieties composed between 20 to 55% of the total fatty acids present in the oil. Animal experiments have shown when it is consumed at the concentrations that are typically found in the original rapeseed the compound can cause lesions in the heart, leading to significant heart damage. This oil is therefore considered unsafe for consumption by humans (Stewart, 2013). Erucic Acid is bitter tasting and has been known to contribute to a low digestibility coefficiency, reduce feed intake, weight gain, and overall performance. Genetically modified varieties of the rapeseed plant were developed to give the oil extracted from the plant a low content of erucic acid or LEAR (low erucic acid rapeseed). LEAR oils contain low concentrations of erucic acid less than 2% and are therefore considered safe to consume.

4.2 Glucosinolates

While the removal of erucic acid from rapeseed alleviated the fears that rapeseed was harmful, it did nothing to solve other problems. GLS has been known to; reduce palatability; suppress growth, and production. The toxicity of GLS had been recognized as early as the 1950's to be a hindrance to the more extensive use of RSM. When the meal was fed in large quantities to farm animals, especially pigs and chickens, the meal was goitrogenic, having the ability to cause goiters or growths on the thyroid gland (Busche et al., 1994). GLS are organic compounds that contain sulfur and nitrogen, they are commonly found in the members of the plant family known as *Brassicaceae*. They are found in several oilseeds and can cause poisoning or toxicity. Symptoms of poisoning in poultry can include thyroid goiters, liver impairment, depressed growth, decreased egg laying, off-flavored eggs for hens that produce brown eggs, and perosis. Traditional rapeseed cultivars were known to contain high amounts of GLS (β-thioglucoside-N-hydroxysulfates). Although GLS have antibacterial, antifungal properties, and cancer-chemoprevention activity, their anti-nutritional effects have limited the use of meals from oilseed rape for human food and animal feed (Szydlowska-Czerniak, et al., 2011). Intact GLS are biologically inactive, however following disruption of the plant cell walls and organelles that contain them, the GLS's are released. When chewed or processed, they undergo enzymatic hydrolyses by a β-thioglucosidase (myrosinase), which is also present in GLS containing plant species stored in different cell organelles (Holst and Williamson, 2004). Depending on the reaction conditions and the structure of the individual GLS, they will form structurally different breakdown products with very diverse biological activities mainly isothiocyanates, thiocyanates, and nitriles (Figure 4). The majority of problems with GLS in CM have been considerably reduced by requiring maximum levels to be lower than 30 micromoles per gram.

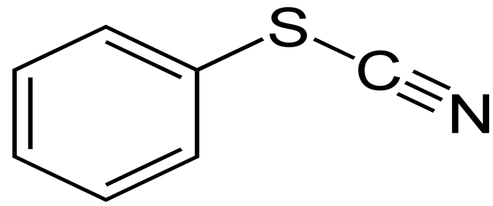
Figure 4. Hydrolysis of glucosinolates by the enzyme myrosinase and their different hydrolysis adapted from (Pal Vig et al., 2009).



4.3 Thiocyanates

Thiocyanates are contributors to goiters and are a SCN- complex anion. (Figure 5). They are a potent inhibitor of iodine uptake by the thyroid which leads to reduced iodination of tyrosine and therefore resulting in a decreased production of the important thyroid hormone thyroxine (Cornell, 2013). Thiocyanates are a product of the hydrolysis of GLS and have largely been reduced by limiting the allowable amount of GLS in CM. Thiocyanates are also a detoxification product of cyanide and are commonly found in humans that smoke cigarettes.

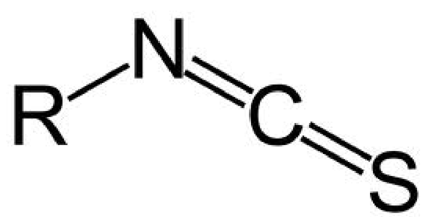
Figure 5. Chemical structure of Phenyl-thiocyanate C_7H_5NS adapted from (Chemspider, 2013).



4.4 Isothiocyanates

Isothiocyanates (figure 6) are also known as mustard oil, they are formed from the hydrolysis of GLS and they irritate the mucous membranes but, are not readily consumed in sufficient quantities to be toxic. However, if they are consumed as glycosinolates and then hydrolyzed to isothiocyanates in the gut, they can have powerful anti-thyroid effects and interfere with the synthesis of necessary thyroid hormones (Cornell, 2013). However, Isothiocyanates can have an anti-cancer effect by neutralizing carcinogens.

Figure 6. Chemical structure of Isothiocyanates C_4H_5NS adapted from (PubChem, 2013)



4.5 Nitriles

Nitriles were formerly known as cyanides and they contain a –CN group. These compounds often contribute a bitter, "hot" taste much like the condiments mustard or horseradish and may exhibit goitrogenic or anti-thyroid activity. Nitriles depress growth, can cause liver and kidney lesions, and in severe cases even liver necrosis, bile duct hyperplasia, and megalocytosis of tubular epithelium in the kidney (Cornell, 2013).

4.6 Tannins

The title Tannins comes from the old tradition of tanning animal skins as wood or plant tannins were used in this time honored tradition. Tannin compounds are found in a variety of plants as a natural occurring protection against insects. The tannins found in rapeseeds or canola is mostly concentrated in the hulls of the seeds. They are not only responsible for the tainting of eggs, but are also considered potent enzyme inhibitors due to their complexation with enzyme proteins (Naczk et al., 1994). Tannic acid is found in various drinks including wine, beer, and tea.

4.7 Sinapine

Sinapine is an amine found in black mustard seeds including canola it contributes a hot-bitter taste that drastically reduces palatability. Sinapine is responsible for the two major problems currently limiting the use of RSM in poultry diets: the production of a fishy off-flavor in the eggs of certain birds from brown egg laying flocks; and the increased incidence of liver hemorrhage (and associated mortality) which results from high intake of certain varieties of rapeseed and its products (Fenwick and Curtis, 1980).

4.8 Phytic acid

Hulls of grains, nuts, beans, and seeds are typically where phytic acid is found. Phytic acid is also known as phytate. Phytate is a storage molecule for phosphorus but, it is generally unavailable to poultry and other non-ruminants because they lack the digestive enzyme phytase to break it down. The problem with undigested phytate is two-fold; excess phosphorus is passed through the digestive tract and excreted in waste where it becomes an environmental concern especially to water quality; and phytate also has a strong propensity to bind many essential minerals. Phosphorus has to be added to the poultry diet to meet requirements for the chicken because the phytate is bio-unavailable, thus adding significantly to the cost of the diet. A solution that contributes to many problems that phytate presents in non-ruminant animals has come by the creation of supplemental phytase. Phytase can now be produced in large quantities through fermentation of yeasts and added to poultry and swine diets. The addition of phytase in animal diets; increases availability of phosphorus in diets; lowers the amount of supplemental phosphorus required in the diet; and decreases phosphorus in excreta (Jacela et al., 2010).

Part 5. COMPARISON OF CANOLA MEAL AND SOYBEAN MEAL

5.1 Stability

Before serious consideration can be given to canola meal as a replacement for SBM in broiler diets, many aspects need to be evaluated. Among the areas to be assessed further are stability, metabolizable energy (TME), and digestible AA content. The use of CM contains a disadvantage, stability. SBM is known to be the most stabile protein source for boiler diets because of intense regulation. SBM is regulated to meet specific standards such as; minimum crude protein level 44%, minimum fat level 0.5%, maximum fiber content 7%, and maximum moisture content of 12% and rebates are offered to the customer if minimum standards are not meet. Even though regulations have also been established for trading CM in the United States and Canada, the rules require CM must contain less than 30 micromoles of GLS per gram; less than 12% moisture; less than 12% crude fiber; and at least 36% protein (Newkirk, 2009). There are no rebates offered and there is more variance within the production of CM.

5.2 Amino Acids

As all living creatures progress through the cycle of life, their bodies have specific nutrient requirements that have to be met. Water, minerals, vitamins, oxygen, carbohydrates, fats, and proteins are all essential nutrients to preserve life or for growth. Most of these nutrients are provided by the diet, making the role of the nutritionist enormously important. Protein is the major component for the growing body and is the major factor of consideration in the poultry diet. Protein constitutes approximately 75% of the nutritionist decisions and contributes greater than 25% of the cost in the diet. However, the importance placed on CP levels in the broiler diet is slightly misleading. What is of more importance than protein level is total AA content and the digestibility of those AA's. Broilers require each AA at precise levels during each phase of growth in order to achieve the desired rate of growth (Table 2). Though no single protein source is considered a complete balance of AA's, SBM is considered the yardstick that all other protein sources are measured. In comparison to SBM , CM has a good balance of AA (Table 3) including, more of the total sulfur amino acids (TSAA) methionine and cystine. Methionine is one of the eleven "essential AA" to broilers meaning their body is un-able to synthesize methionine, therefore, it has to be included in the diet. Methionine is also very important in the broiler diet because it is the first limiting AA. The term "limiting AA" is one that is generally accepted for the requirement of each amino acid is proportionally linked to the requirement for the others. Increasing the supply of one amino acid will improve performance only if no other amino acid is limiting (Schutte and Jong, 1999). However, CM falls short in comparison to SBM in all AA levels except methionine including, the remainder of the limiting AA's, in numerical order they are methionine, lysine, arginine, tryptophan, and glycine. Though the total AA content of a protein source is critical in diet formulation, not all AA's in the feed source are bioavailable to the broiler. Bioavailability or digestibility is classically defined as the difference between the amounts of AA's consumed and that excreted in the feces, divided by the amount consumed (McNab and Boormann, 2002). The measurement of digestibility in AA's for a particular feedstuff is significant because it takes into consideration digestion and absorption. A comparison for SBM and CM AA digestibility is shown in (Table 4).

Table 2. Nutritional requirements of broilers. (NRC, 1994).

Broiler Nutrient Requirements				
Amino Acid	**Unit**	**0-3wks**	**3-6 wks.**	**6-8wks**
Metabolizable Energy (ME)	Kcal/kg	3200	3200	3200
Crude Protein	%	23.00	20.00	18.00
Arg	%	1.25	1.10	1.00
Gly+Ser	%	1.25	1.14	0.97
His	%	0.35	0.32	0.27
Iso	%	0.80	0.73	0.62
Leu	%	1.20	1.09	0.93
Lys	%	1.10	1.00	0.85
Met	%	0.50	0.38	0.32
Met+Cys	%	0.90	0.72	0.60
Phe	%	0.72	0.65	0.56
Phe+Tyr	%	1.34	1.22	1.04
Pro	%	0.60	0.55	0.46
Thr	%	0.80	0.74	0.68
Try	%	0.20	0.18	0.16
Val	%	0.90	0.82	0.70

Table 3. Chemical composition, energy values, and total amino acid content of canola meal and soybean meal for poultry. (Rostagno et al., 2011).

Chemical Composition and Energy Values				
Nutrient	**Unit**	**Canola Meal**	**Soybean Meal**	**% difference**
Crude Protein(CP)	%	37.97	48.1	- 21.06
Digestible CP	%	29.62	43.96	- 32.62
Fat	%	1.21	1.45	- 16.55
Digestible Fat	%	0.85	0.73	+16.44
Crude Fiber	%	11.20	4.19	+167.30
True Met.Energy	Kcal/kg	1900	2590	- 26.64
Total Amino Acids				
Lys	%	2.01	2.93	- 31.40
Met	%	0.78	0.65	+ 20.00
Met+Cys	%	1.64	1.36	+ 20.59
Thr	%	1.57	1.87	- 16.04
Trp	%	0.49	0.67	- 26.87
Arg	%	2.32	3.47	- 33.14
Gly+Ser	%	3.43	4.47	- 23.27
Val	%	1.84	2.31	- 20.35
Iso	%	1.56	2.26	- 30.97
Leu	%	2.65	3.66	- 27.60
His	%	1.01	1.25	- 19.20
Phe	%	1.45	2.46	- 41.06
Phe+Tyr	%	2.36	4.20	- 43.81

.

Table 4. Digestible amino acid content and digestible coefficients of canola meal and soybean meal for poultry. (Rostagno et al., 2011)

Total Digestible Amino Acids					
Nutrient	Unit	Canola Meal 38% CP		Soybean Meal 48% CP	
		AA Content	Digestible Coefficient	AA Content	Digestible Coefficient
Lys	%	1.72	85.4	2.71	92.5
Met	%	0.70	90.0	0.6	92.5
Met+Cys	%	1.48	90.1	1.22	89.8
Thr	%	1.30	83.0	1.65	88.7
Trp	%	0.42	86.0	0.61	90.9
Arg	%	2.10	90.4	3.26	93.8
Gly+Ser	%	2.91	85.0	4.23	89.2
Val	%	1.59	86.2	2.08	90.1
Iso	%	1.24	79.8	2.05	90.8
Leu	%	2.20	82.9	3.40	92.9
His	%	0.90	89.3	1.14	91.2
Phe	%	1.27	87.8	2.31	93.8
Phe+Tyr	%	2.02	85.7	3.86	91.9

5.3 Metabolizable energy

Energy is not a nutrient, but a property of a nutrient. Energy is released from nutrients when they are oxidized during metabolism in the form of heat. SBM is known to provide energy from its nutrients at a considerable higher amount when compared to CM. One form of energy measurement is True metabolizable energy (TME), for poultry this is the gross energy of the feed consumed minus the gross energy of the excreta of feed origin (NRC, 1994). A comparison of TME between the SBM and CM reveals 2590 kcal/kg of TME for 48% CP SBM versus 1900 kcal/kg for 38% CP CM (Table 2). (Rostagno et al., 2011). Most of the difference in TME is not understood as the two oilseeds contain similar amounts of sugars, starches, and moderately high amounts of sucrose. However, differences do occur between the two in levels of oligosaccharides (5.6% vs. 2.0%) and fiber content (5.3% vs.11.2%) (Khajaili and Slominski, 2012) that could explain the difference. Even though rules established for trading, CM require the contents to be less than 12% crude fiber it is still considerable higher than the less than 7% required for SBM. High dietary fiber content may accelerate the digesta passage rate, which in turn, may result in reduced time for digestion and thus reduced nutrient utilization (Khajaili and Slominski, 2012). The use of CM in poultry rations could increase greatly if TME values were increased to those similarly found in SBM. The Canadian CM industry has set goals that include increasing the TME of CM by 10% by the year 2015 (Hickling, 2010). Possible methods of increasing TME of CM include; reducing fiber and other low energy components through selective breeding; developing strains of seeds with easier de-hulling and thinner hulls; larger seed size; and altered carbohydrate composition; improving processing; and explore the use of digestive enzymes in feed (Hickling, 2010).

6.0 Conclusion

Primarily based upon the rising costs of SBM, broiler production and feed cost have risen dramatically. Because of this increase a search for an alternative protein source needs to be conducted. As of April 2013, the commodities prices reflected SBM was being traded at $420/ton, while CM was $285/ton. The decrease in expenses if CM could be substituted for SBM might represent financial relief for some poultry companies who are teetering on the brink of failure due to large overhead costs. CM availability appears to be mounting as canola is now being grown in Canada, United States, EU, Russia, Asia, and Australia. Growing interest in using CM as a rotational crop in poultry producing areas of the United States appears to be expanding its accessibility as an oilseed meal. Even though CM does not quite stack up to SBM in a lot of the nutritional areas like TME, Crude Fiber, TAA or DAA, it is still considered to be an adequate protein source. CM appears to be an attractive alternative protein substitute for SBM, but research needs to be conducted, exploring broiler performance and carcass characteristics when birds consume CM instead of SBM in diets.

REFERENCES

American Heart Association, 2010. Getting healthy, Saturated fats Q&A, Accessed 02/04/13. http://www.heart.org/HEARTORG/GettingHealthy/ FatsAndOils/-Fats101/Saturated-Fats_UCM_301110_Article.jsp.

Ash, M. 2012. Canola. Soybean and Oil crops. USDA Economic Research Service. Accessed 02/09/13. http://www.ers.usda.gov/topics/crops/soybeans-oil-crops/canola.aspx#Consumption.

Baquero, G., Esteban, B., Riba, J.R., Puig, R., and A. Rius, 2011. Use of Rapeseed Straight Vegetable Oil as Fuel Produced in Small-Scale Exploitations. Accessed 02/15/13. http://www.intechopen.com/books/biofuel-s-engineering-process-technology/use-of-rapeseed-straight-vegetable-oil-as-fuel-produced-in-small-scale-exploitations.

Bell, J.M. 1982. From rapeseed to canola: A brief history of research for superior meal and edible oil. Poult. Sci. 61:613-622.

Busch, L., V. Gunter, T. Mentele, M. Tachikawa, and K. Tanaka. 1994. Socializing Nature: Technoscience and the transformation of rapeseed into canola. Crop Sci. 34:607-614.

Busch, L. 2003. Canola: A Cinderella Story. Farm communities at the crossroads. challenge and resistance. Canadian plains research center. University of Regina.

Canola Council of Canada. 2011. Canola growers manual, Canola Varieties, chapter 2, Accessed 10/11/12. http://www.canolacouncil.org/crop-production/canola-grower's-manual-contents/chapter-2-canola-varieties/.

Canolainfo, 2012. What is canola oil? Canola oil good for every body, Accessed 12/20/12 http://www.canolainfo.org/canola/index.php.

Chemspider.com, 2013. Chemical structure of Phenyl-thiocyanate. Accessed 02/09/13. http://www.chemspider.com/Chemical-Structure.20074.html.

Classen, H.L., Newkirk R. W. and D. D. Maenz. 2005. Effects of conventional and novel processing on the feed value of canola meal for poultry. Accessed 02/16/13. http://www.thepoultrysite.com/articles/307/effects-of-conventional-and-novel-processing-on-the-feed-value-of-canola-meal-for-poultry.

Cornell, 2013. Plants Poisonous to Livestock. Cornell University Department of Animal Science. Accessed 02/09/13. http://www.ansci.cornell.edu/plants/ toxicagents/glucosin.html.

Dakowski, P., Weisbjerg, M.R., and T. Hvelplund. 1996. The effect of temperature during processing of rape seed meal on amino acid degradation in the rumen and digestion in the intestine. Anim. Feed Sci. Technol., 58:213–226.

Fenwick, G.R. and R.F. Curtis, 1980. Rapeseed meal and its use in poultry diets. A review Anim. Feed Sci. Technol., 5:255–298.

Hickling, D. 2010. Canola Meal and its Uses and Opportunities to increase value. USCA Canola end uses symposium. November 2, 2010. Long Beach, California.

Hoffman, P.C. 1990. Canola Meal**.** Dairy feed ingredients. University of Wisconsin-Extension, Cooperative extension.

Holst, B., and G. Williamson. 2004. A critical review of the bioavailability of glucosinolates and related compounds. Natural Product Reports. Issue 3, 2004.

Jacela J.Y., DeRouchey J.M., Tokach M.D., Goodband R.D., Nelssen, J.L., PhD; Renter, D.G., and S.S. Dritz. 2010. Feed additives for swine: Fact sheets – high dietary levels of copper and zinc for young pigs, and phytase. J. Swine Health Prod. 18:87–91.

Jensen, S.K., Liu, Y.G., and B.O. Eggum. 1995. The effect of heat treatment on glucosinolates and nutritional value of rapeseed meal in rats. Anim. Feed Sci. Technol., 53:17-28.

Khajaili, F. and B.A. Slominski, 2012. Factors that affect the nutritive value of canola meal for poultry. Poult. Sci., 91:2564–2575

LMC International, 2011. The Economic Impact of Canadian Grown Canola and its End Products on the Canadian Economy. Report for: Canola Council of Canada Winnipeg, Canada.

Lookchem.com, 2013. Chemical structure of erucic acid. Accessed 02/09/13. http://www.lookchem.com/Product_2107/CasNo_112-86-7/Erucic-acid.html.

McNab, J.M. and K.N. Boormann, 2002. Poultry Feedstuffs: Supply, Composition, and Nutritive Value. Poultry Science Symposium Series Vol. 26.

Naczk, M., Nichols, T., Pink, D., and F. Sosulski. 1994. Condensed Tannins in Canola Hulls. J. Agric. Food Chem., 42:2196–2200.

Newkirk, R. 2009. Canola Council. Canola meal, Feed industry guide, 4th edition, 2009.

Newkirk, R and H.L. Classen. 2002. The effects of toasting canola meal on body weight, feed conversion efficiency, and mortality in broiler chickens. Poult. Sci. 81:815-825

Newkirk, R.W., Classen, H.L. and Edney, M.J. 2003. Anim. Feed Sci. Technol., 104:111-119.

NRC. 1994. Nutrient Requirements of Poultry, 9th rev ed. Natl. Acad. Press, Washington, DC.

Oplinger, E.S., L.L. Hardman, E.T. Gritton, J.D. Doll, and K.A. Kelling. 1989. Canola (Rapeseed). Alternative field crop manual. University of Wisconsin-Extension, Cooperative extension.

Pal Vig, A., Rampai, G., Singh Thind, T., and S. Arora. 2009. Bio-protective effects of glucosinolates- A review. Food sci. technol. 42:1561-1572.

PubChem, 2013. allyl isothiocyanate - Compound Summary. National Center for Biotechnology Information, U.S. National Library of Medicine**.** Accessed 02/11/13. http://pubchem.ncbi.nlm.nih.gov/summary/summary.cgi?cid=5971.

Rostagno, H.R., L.F. T. Albino, J. L. Donzele, P. C. Gomes, R.F. de Olveira, D. C. Lopes, A.S. Firiera, S. L. de T. Barreto, and R.F. Euclides, 2011. Brazilian Tables for Poultry and Swine. Composition of Feedstuffs and Nutritional Requirements. 2nd ed. H. S. Rostagno, ed.

Schutte, J.B. and J.D. Jong. 1999. Ideal amino acid profile for poultry. In : Bru fau J. (ed.), Tacon A. (ed.). Feed manufacturing in the Mediterranean region: Recent advances in research and technology. Zaragoza CIHEAM, 259 -263.

Soyatech. 2012a. Growing opportunities. Accessed 10/11/12. http://www.soyatech.com/soy_facts.htm.

Soyatech. 2012b. Growing opportunities. Accessed 10/11/12 http://www.soyatech.com/rapeseed_facts.htm.

Soy Stats. 2012. American Soybean Association, Accessed 10/11/12. http://www.soystats.com/2012/Default-frames.htm.

Stewart, D. 2013. The Side Effects of Rapeseed Oil. Accessed 02/09/13. http://www.ehow.com/info_7996591_side-effects-rapeseed-oil.html.

Szydłowska-Czerniak,A., Bartkowiak-Broda, I., Karlović, I., Karlovits, G., and E. Szlyk. 2011. Antioxidant capacity, total phenolics, glucosinolates and colour parameters of rapeseed cultivars. Food Chem. 127:556–563.

Part II. RESEARCH STUDIES

Use of Canola Meal in High Energy Broiler Diets.
1. Isocaloric Diets

D. Bradley, S. Goodgame, F. Mussini, N. Comert, C. Lu, and P.W. Waldroup
Poultry Science Department, University of Arkansas, Fayetteville AR 72701

ABSTRACT

The objective of this study was to evaluate various combinations of canola and soybean meal to determine possible usage levels of canola meal in nutritionally balanced diets based on digestible amino acid values. In this study, diets were formulated to meet digestible amino acids suggested by Rostagno et al., (2005) with no protein minimum. One diet, within each time period, contained no CM, but another completely replaced soybean meal with CM (49.7, 45.8, and 41.9% CM in start, grow, and finish respectively). Diets were blended to provide 0, 10, 20, 30, and 40% CM and one full replacement for a total of six diets, each of which was fed to four pens of 25 male chicks for a 42 day period. Diets were maintained isocaloric with the 0 diet containing 1% poultry oil (PO) increasing as the level of CM increased, requiring 7.0, 6.6, and 6.2% PO in start, grow, and finish diets, respectively. At both 35 and 42 days, birds fed diets with up to 40% CM did not differ significantly in body weight (BW) from those fed 0% CM diets; however, birds fed with a complete replacement of soybean meal (SBM) by CM had significantly lower BW than those fed 0% CM diets. The feed conversion worsened with each increasing increment of CM. Breast meat yield tended to follow a linear reduction as CM increased. These data suggest that canola meal can be used in isocaloric diets as a partial replacement (< 40%) for SBM in broiler diets when formulated on a digestible amino acid basis without significantly effecting BW, Fi, FCR, or Mortality. However, processing data suggests CM cannot exceed 10% without significantly impacting breast weights. More work is needed to define proper usage levels in diets without excessive levels of supplemental fats.

Key words: Broiler, canola, isocaloric, energy

INTRODUCTION

There has been growing interest in the production of alternative oilseeds such as canola for production of biodiesel. Canola can produce three times more oil per acre than soybeans (Addison, 2001) and can be grown as a winter crop alternating with soybeans in the southern United States. Therefore, it is likely that increasing amounts of canola meal will be available for use in poultry feeds in the primary broiler producing areas of the United States.

Canola is an offspring of rapeseed which was bred to have low levels of erucic acid (<2%) in the oil portion and low levels of glucosinolates (<30 µmol/g) in the meal portion Hickling, (2001). Canola meal is a widely used protein source with good balance of amino acids but has a lower amino acid digestibility than soybean meal (Larbier and Chagneau, 1992). The nutritive value of canola meal is limited by the presence of a number of anti-nutritive factors, including indigestible non-starch polysaccharides (Slominski and Campbell, 1990; Bell, 1993; Dale, 1996). Canola meal has typically been fed at low levels to replace portions of soybean meal in broiler diets. Few studies have utilized canola meal in diets formulated on digestible amino acid basis. The objective of this study was to evaluate various combinations of canola and soybean meal to determine possible usage levels of canola meal in nutritionally balanced diets based on digestible amino acid values.

MATERIALS AND METHODS

Dietary treatments

Two basal diets were formulated within each age group to meet the minimum digestible amino acid needs suggested by Rostagno et al., (2005) with no minimum protein level imposed. One diet utilized soybean meal as the primary source of protein while the other diet utilized canola meal. Supplemental amino acids included sources of lysine, methionine, and threonine. A dietary energy level was selected that required approximately 1% additional poultry oil for the diet with soybean meal and nutrients adjusted to this energy level. The canola meal diets were maintained isocaloric by manipulation of levels of corn and poultry oil. Diets were formulated on a digestible amino acid basis, using total amino acid values for corn, soybean meal, and canola meal determined by analysis of the products used in mixing by a commercial laboratory specializing in amino acid analysis, with amino acid digestion coefficients suggested by Ajinomoto Heartland Lysine. Composition of the diets is shown in Table 1 with calculated nutrient content in Table 2. All diets were supplemented with complete vitamin and trace mineral premixes obtained from commercial sources.

After mixing sufficient amounts of the two diets within each age period, aliquots of the soybean meal and canola meal diets were blended in proportions to provide 0, 10, 20, 30, 40% and one total replacement of soybean meal (49.68, 45.81, and 41.97% in starter, grower, and finisher diets, respectively). The resulting diets were fed as mash. The varied diets were fed to four pens of 25 male chicks each.

Birds and management

Male chicks of a commercial broiler strain (Cobb 500) were obtained from a local hatchery where they were vaccinated in ovo for Marek's disease and had received vaccinations for Newcastle Disease and Infectious Bronchitis post hatch via a coarse spray. Twenty- five chicks were placed in each 24 litter floor pens in a house of commercial design. Feed and water were provided for ad libitum consumption. Automatic heaters and ventilation fans controlled temperature and airflow; incandescent lights provided 23 hours of light daily. Supplemental feeders and waters were used for the first seven days. Care and management of the birds followed recommended guidelines (FASS, 2010). All procedures were approved by the University of Arkansas Institutional animal care and use committee.

Measurements

At one day of age, chicks were group weighed by pen and placed on test diets. At 21, 35, and 42 d of age, the remaining birds were weighed and feed consumption for the period was determined. Chicks were checked twice daily; any bird that died or was removed to alleviate suffering was weighed with the weight used to adjust feed conversion ratios. At the conclusion of the study, five representative birds per pen were processed in a pilot processing plant using automatic evisceration as described by Fritts and Waldroup, (2006).The two basal diets within each age series were analyzed for crude protein, amino acids, calcium, total phosphorus, and sodium content by commercial laboratories specializing in these assays.

Statistical Analysis

Pen means served as the experimental unit for statistical analysis. Data were subjected to ANOVA using the General Linear Models procedure of the SAS Institute (1991). When significant differences among treatments were found, means were separated using repeated t-tests using the LSMEANS option of the GLM procedure. Mortality data were transformed to

$\sqrt{n+1}$ prior to analysis; data are presented as natural numbers. All statements of statistical significance are based on $P \leq 0.05$.

RESULTS

All diets were calculated to meet the minimum needs for digestible lysine (Table 2). Diets with soybean meal typically met minimum levels of digestible TSAA, threonine, and valine. In contrast, diets with canola meal typically met minimum levels of digestible methionine and isoleucine; threonine was at a minimum level only in starter diets.

Performance

Mortality was not significantly affected by inclusionary levels of CM at 21 d (Table 3), 35 d (Table 4), and 42 d (Table 5).

Body weight was significantly affected by level of CM at 21 d (Table 3), 35 d (Table 4) and 42 d (Table 5). The BW of birds fed diets with full replacement of CM was significantly the lightest compared to those fed the other diets. Inclusion of up to 40% CM, where diets were formulated on a digestible amino acid basis had no adverse effect on BW in this study.

Feed conversion at 21 d was not significantly affected by level of CM (Table 3); however at 35 d (Table 4) and 42 d (Table 5) the feed conversion ratio increased as the level of CM increased. This may have been due to an overestimation of the metabolizable energy content of the CM or to some adverse effect of some of the anti-nutritive factors in the CM such as tannins or glucosinolates.

Feed intake by broilers was significantly reduced at 21d by birds fed the diets with complete replacement of SBM by CM (Table3). Feed intake did not differ significantly among treatments at 35 d (Table 4) or 42 d (Table 5) although being numerically lower for the group fed diets with full replacement of CM. These diets contained high levels of supplemental poultry oil and the birds may have had physical problems with consuming the diets.

Processing

Dressing percentage, yield of leg quarters, and yield of wings was not significantly affected by levels of CM inclusion (Table 6).

Breast meat yield, expressed as a percentage of live weight was significantly reduced by birds consuming diets of 20, 40, or 100%. However, breast yield as percentage of carcass weight was only significantly reduced when birds were fed the diet of full replacement of SBM with CM (Table 6). Although some significant differences existed between the breast yields of birds fed the various levels of CM compared to those fed the SBM diet, these were not consistent related to CM inclusion levels.

Processing parts yield results as related to weight (Table 7) showed significant differences in all categories. Carcass weight revealed a substantial decline in weight for the birds consuming diets greater than 40% CM. Breast meat and leg quarter results disclosed reduction in weight for broilers fed diets with the two highest levels of CM. Wing weight was significantly reduced in birds fed the full replacement of CM.

DISCUSSION

Performance

The performance outcomes for broilers in this experiment indicated that CM can be fed as a partial replacement ($\leq$ 40%) of soybean meal without significantly decreasing BW or FI if energy values are maintained at a level consistent with that of a typical corn-soy diet. BW data did not reveal a significant decrease over these levels although a trend was noted. This trend showed a slight improvement in growth for birds eating 10% CM rates and then slight reductions as CM rates increased as compared to the control group. As for FCR, though none of the treatments showed significant differences for the first stage of development (starter), the final two stages (grower and finisher) did exhibit significant differences. Birds consuming the control diet consistently achieved the lowest FCR and birds consuming the full CM replacement diets had the highest. All three growth periods showed no developmental trends in FCR results for birds within the intermediate levels (10, 20, 30 and 40%) of CM inclusion groups.

While some research has been conducted with CM as a replacement for SBM, few trials have evaluated levels of 40 and 100% inclusion rates. Even fewer researchers have examined processing parts yield of broilers fed CM as a protein source. A summary of other research studies containing CM in broiler diets is found in Table 10.

Body Weight, Feed Intake, Feed Conversion Ratio, and Mortality

Results for this study were compared with the previous findings from the following scientists for BW, FI, FCR, and MORT. Elwinger and Saterby, (1986) reported in their 35 day-experiment that feeding diets with 12 to 20% of a low glucosinolate rapeseed meal did not adversely affect BW, FI or MORT. Our findings disagreed with Elwinger and Saterbys' findings for FCR. They reported no significant difference for CM inclusion diets as compared to the control, however, our findings showed differences occurring between the control group and the CM inclusion groups. Salmon et al., (1981) evaluated the use of canola meal in broiler diets with low and high crude protein and nutrient density. These researchers incorporated canola meal into wheat-based broiler diets at up to 28.1% in starter diets (0-4 wks.) with either 21 or 23% crude protein (CP) and up to 12.1% in finisher diets (4-8 wks.) with either 17 or 19% CP. Confirming our results, Salmon reported that live weight gain and MORT were unaffected by canola meal when diets were maintained isocalorically. Thomke et al., (1983) conducted numerous studies using a low-glucosinolate rapeseed meal (RSM) of Swedish origin. Our results were in agreement with Thomke et al., (1983) findings who reported that feeding meal from solvent extraction processing to broilers in two separate experiments resulted in unaltered BW or FI as compared to soybean meal. However, Thomke et al., (1983) found depressed growth for broilers fed RSM at a 20% substitution amount from prepress solvent processing. Prepress solvent processing resulted in an incomplete oil extraction and Thomke et al., (1983) accredited this reduction in weight to activity of the enzyme myrosinase that would be inactivated with proper processing of the RSM. Our findings are in agreement with Perez-Maldonado et al., (2003) who reported that 20% of a solvent extracted or a solvent extracted-extruded canola meal could be used during the starter phase and 30 % could be used in finisher diets formulated on a digestible amino acid basis without adverse effect on BW. However, our findings disagreed with Perez-Maldonado et al., (2003) for FCR and FI. Our data showed significant differences in FCR occurring between the control group and the CM inclusion groups. Perez-Maldonado et al., (2003) reported a reduction of FI compared to control during the finisher phase. The reduction in FI reported by Perez-Maldonado et al., (2003) could have been caused by a reduction in pellet quality that would have been present with additional supplemental fat to maintain diets isocalorically. Our findings were also in agreement with Ahmad et al., (2007) who reported that canola meal could be incorporated at 20% and fed 1 to 28 d without any adverse effects on broiler BW, FI, or MORT. However, the results observed in our experiment were in disagreement with Hickling, (2001) who recommended a maximum inclusion level of 15% canola meal in standard broiler diets. Nassar and Arscott (1986) reported satisfactory BW and FI when canola meal was used in both broiler starter (19.2%) and finisher (16.3%) diets replacing up to 50% of soybean meal and decreased performance at inclusion rates of 75 and 100% replacement.

Although the results are in agreement with the above scientists in the mentioned categories, the findings are in disagreement with Leeson et al., (1987) who reported canola meal could replace 100% of the soybean meal in broiler rations without any effect on feed intake, weight gain or feed efficiency.

Processing

Our results were in agreement with the findings for carcass dress percentages of Naseem et al., (2006), Khan et al., (2006), Ajuyah et al., (1991), and Montazer-Sadegh et al., (2008) who reported no significant differences for birds eating CM at inclusion rates ≤ 25% when compared to control diets. Taraz et al., (2006a) reported no significant differences in carcass weights for CM levels of 0, 25, 50, and 75% replacement. Ajuyah et al., (1991) reported a reduction in carcass weights with CM inclusion rates of 20%. Our findings of a reduction in carcass weight for broilers fed 40 and 100% replacement CM were in disagreement with both of these studies. Montazer-Sadegh et al., (2008) reported that CM up to 16% had no impact on carcass weights. For the parts yield category of breast weight, our findings related no significant decrease through the 30% group compared to control with improved breast weight in birds fed 10% CM, but McNeill et al., (2004) reported a linear decline as CM was included at 10 and 20%. The findings of our experiment disclosed noteworthy loss in breast weight as a percentage of carcass when birds were fed amounts of CM at 20% rate and this was in disagreement with Ajuyah et al., (1991)and Naseem et al., (2006) who reported similar breast percentage (%) carcass results with birds consuming 10, 20, and 25%.

CONCLUSION

These data suggest that canola meal can be used as a partial replacement for SBM (<40%) in isocaloric broiler diets when formulated on a digestible amino acid basis without significantly effecting BW, FI, FCR, or Mortality. However, processing data suggested CM cannot exceed 10% without significantly impacting breast weights. More work is needed to define proper usage levels in diets without excessive levels of supplemental fats.

REFERENCES

Addison, K., Handmade Projects, 2001. Retrieved from http://journeytoforever.org/biodiesel_yield.html

Ahmad, G., T. Mushtaq, M. A. Mirza, and Z. Ahmed. 2007. Comparative bioefficacy of lysine from L-lysine hydrochloride or L-lysine sulfate in basal diets containing graded levels of canola meal for female broiler chickens. Poult. Sci. 86:525-530.

Ajuyah, A., K. Lee, R. Hardin, and J. Sim. 1991. Changes in the yield and in the fatty acid composition of whole carcass and selected meat portions of broiler chickens fed full-fat oil seeds. Poult. Sci. 70:2304-2314.

Bell, J. 1993. Factors affecting the nutritional value of canola meal: a review. Can. J. Anim. Sci. 73:689-697.

Dale, N. 1996. Variation in feed ingredient quality: oilseed meals. Anim. Feed Sci. Technol. 59:129-135.

Elwinger, K., and B. Saterby. 1986. Continued experiments with rapeseed meal of a Swedish low glucosinolate type fed to poultry, 1: Experiments with broiler chickens. Swed. J. Agric. Res. 16.

FASS, 2010. Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching. 3rd ed. Federation of Animal Science Societies, Savoy IL.

Fritts, C., and P. Waldroup. 2006. Modified phosphorus program for broilers based on commercial feeding intervals to sustain live performance and reduce total and water-soluble phosphorus in litter. J. Appl. Poult. Res. 15:207-218.

Hickling, D., 2001. Canola Meal: Feed Industry Guide. Canola Council of Canada.

Khan, A., A. Azim, and M. Anjum. 2006. Effect of different levels of rapeseed meal and canola meal on broiler production performance and carcass characteristics. Pakistan Vet. J. 26:9-13.

Kocher, A., M. Choct, L. Morrisroe, and J. Broz. 2001. Effects of enzyme supplementation on the replacement value of canola meal for soybean meal in broiler diets. Aust. J. Agric. Res. 52:447-452.

Larbier, M., and A. Chagneau. 1992. Effect of age and sex on true digestibility of amino acids of rapeseed and soybean meals in growing broilers. Poult. Sci. 71:1486-1492.

Leeson, S., J. Atteh, and J. Summers. 1987. The replacement value of canola meal for soybean meal in poultry diets. Can. J. Anim. Sci. 67:151-158.

McNeill, L., K. Bernard, and M. MacLeod. 2004. Food intake, growth rate, food conversion and food choice in broilers fed on diets high in rapeseed meal and pea meal, with observations on sensory evaluation of the resulting poultry meat. Br. Poult. Sci. 45:519-523.

Min, Y., Z. Wang, C. Coto, F. Yan, S. Cerrate, F. Liu, and P. Waldroup. 2011. Evaluation of Canola Meal from Biodiesel Production as a Feed Ingredient for Broilers. Int. J. Poult. Sc. 10:782-785.

Montazer-Sadegh, R., Y. Ebrahim-Nezhad, and N. Maheri-Sis. 2008. Replacement of different levels of rapeseed meal with soybean meal on broilers performance. Asian J. Anim. Vet. Ad. 3:278-285.

Naseem, M., S. Khan, and M. Yousaf. 2006. Effect of feeding various levels of canola meal on the performance of broiler chicks. J. Anim. Plant Sc. 16.

Nassar, A., and G. Arscott. 1986. Canola meal for broilers and the effect of a dietary supplement of iodinated casein on performance and thyroid status. Nutr. Rep. Int. 34.

Perez-Maldonado, R. A., K. M. Barram, and D. N. Singh. 2003. How much canola or cottonseed meals can be used for commercial chicken meat production. Asia Pac. J. Clin. Nutr. 12 Suppl:S41.

Rostagno, H. S., B. G. Becker, and Universidade Federal de Viçosa. Departamento de Zootecnia. 2005. Brazilian tables for poultry and swine: composition of feedstuffs and nutritional requirements. . Universidade Federal de Viçosa, Departamento de Zootecnia.

Salmon, R., E. Gardiner, K. Klein, and E. Larmond. 1981. Effect of canola (low glucosinolate rapeseed) meal, protein and nutrient density on performance, carcass grade, and meat yield, and of canola meal on sensory quality of broilers. Poult. Sci. 60:2519-2528.

`SAS Institute, 1991. SAS® User's Guide: Statistics. Version 6.03 edition. SAS Institute Inc., Cary, NC.

Slominski, B. A., and L. D. Campbell. 1990. Non-starch polysaccharides of canola meal: Quantification, digestibility in poultry and potential benefit of dietary enzyme supplementation. J. Sci. Food Agric. 53:175-184.

Taraz, Z., S. Jalali, and F. Rafeie. 2006a. Effects of replacement of soybean meal with rapeseed meal on organs weight, some blood biochemical parameters and performance of broiler chicks. Int. J. Poul. Sci. 5:1110-1115.

Taraz, Z., S. Jalali, and F. Rafeie. 2006b. Effects of replacement of soybean meal with rapeseed meal on organs weight, some blood biochemical parameters and performance of broiler chicks. Int. J. Poult. Sci. 5:1110-1115.

Thomke, S., K. Elwinger, M. Rundgren, and B. Ahlström. 1983. Rapeseed meal of Swedish low-glucosinolate type fed to broiler chickens, laying hens and growing-finishing pigs. Acta Agric. Scand. 33:75-96.

Table 1. Composition (g/kg) of diets with soybean meal (SBM) or canola meal (CM) as the primary protein supplement for broilers

	0-21 d		22-35 d		36-42 d	
Ingredient	SBM	CM	SBM	CM	SBM	CM
Yellow corn	608.64	398.74	643.47	444.18	672.82	488.75
Soybean meal	340.00	0.00	308.53	0.00	281.38	0.00
Canola meal	0.00	496.81	0.00	458.05	0.00	419.66
Dicalcium phosphate	16.91	13.76	14.94	12.00	13.33	10.64
Poultry oil	10.75	70.14	10.52	66.11	10.93	62.08
Ground limestone	7.63	6.64	7.29	6.30	6.99	6.06
Vitamin premix[1]	5.00	5.00	5.00	5.00	5.00	5.00
Sodium chloride	4.00	4.00	4.00	4.00	4.00	4.00
MHA[2]	3.03	0.75	2.67	0.67	2.42	0.63
L-Lysine HCl	1.99	2.66	1.72	2.19	1.79	2.18
Mintrex P_Se[3]	1.00	1.00	1.00	1.00	1.00	1.00
L-Threonine	0.55	0.00	0.36	0.00	0.34	0.00
Coban 90[4]	0.50	0.50	0.50	0.50	0.00	0.00
TOTAL	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00

[1] Provides per kg of diet: vitamin A (from vitamin A acetate) 7715 IU; cholecalciferol 5511 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg.
[2]Methionine hydroxy analogue calcium salt. Novus International, St. Louis MO 63141.
[3]Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 40 mg; Zn (as zinc methionine hydroxy analogue complex) 40 mg; Cu (as copper methionine hydroxy analogue complex) 20 mg; Se (as selenium yeast) 0.3 mg. Novus International, Inc., St. Louis MO 63141.
[4] Elanco Animal Health division of Eli Lilly & Co., Indianapolis, IN 46825.

Table 2. Calculated nutrient content of diets with soybean meal (SBM) or canola meal (CM) as the primary protein supplement for broilers. Digestible amino acid values in bold italic are at minimum specified levels.

Nutrient	0-21 d		22-35 d		36-42 d	
	SBM	CM	SBM	CM	SBM	CM
Crude protein %	20.70	24.43	19.45	23.08	18.41	21.78
Calcium %	0.88	0.88	0.80	0.80	0.74	0.74
Total P %	0.71	0.88	0.66	0.82	0.62	0.76
Nonphytate P %	0.44	0.44	0.40	0.40	0.36	0.36
Sodium %	0.18	0.19	0.18	0.19	0.18	0.19
ME kcal/lb	1350.00	1350.00	1365.00	1365.00	1380.00	1380.00
Met %	0.61	0.55	0.57	0.52	0.54	0.49
Lys %	1.28	1.39	1.17	1.28	1.11	1.20
Thr %	0.85	0.96	0.79	0.90	0.74	0.85
TSAA %	0.96	1.06	0.89	1.00	0.85	0.95
Gly+Ser %	1.86	2.44	1.75	2.29	1.64	2.15
dMet %	0.53	***0.44***	0.48	***0.42***	0.45	***0.39***
dLys %	***1.14***	***1.14***	***1.04***	***1.04***	***0.98***	***0.98***
dThr %	***0.74***	***0.74***	***0.68***	0.70	***0.64***	0.66
dIle %	0.78	***0.74***	0.73	***0.70***	0.68	***0.66***
dHis %	0.49	0.50	0.46	0.47	0.44	0.45
dVal %	***0.85***	0.93	***0.80***	0.88	***0.75***	0.83
dLeu %	1.59	1.59	1.52	1.52	1.46	1.46
dArg %	1.25	1.23	1.16	1.16	1.08	1.09
dTSAA %	***0.81***	0.82	***0.75***	0.78	***0.71***	0.74

Table 3. Effect of levels of canola meal on live performance during the starter phase of 0 – 21 days (means of four pens of 25 male broilers each)

% CM	Body Weight (kg)	Feed intake (kg)	FCR (kg/kg)	% Mortality
0	0.727^{b}	1.073^{a}	1.503	0.000
10	0.789^{a}	1.099^{a}	1.458	3.750
20	0.761^{ab}	1.078^{a}	1.436	1.250
30	0.740^{ab}	1.082^{a}	1.468	0.000
40	0.750^{ab}	1.085^{a}	1.454	1.250
Full[1]	0.665^{c}	0.984^{b}	1.515	1.250
CV	5.178	4.134	4.063	1.002
SEM	0.020	0.022	0.03	0.005
P value	0.006	0.022	0.422	0.164

^{a,b,c} means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

[1] Full = full replacement of soybean meal with canola meal

Table 4. Effect of levels of canola meal on live performance during the grower phase of 0 – 35 days (means of four pens of 25 male broilers each)

% CM	Body Weight (kg)	Feed intake (kg)	FCR (kg/kg)	% Mortality
0	1.969[a]	2.930	1.557[c]	1.250
10	2.052[a]	3.020	1.603[b]	5.000
20	1.999[a]	3.010	1.603[b]	1.250
30	1.989[a]	3.100	1.593[b]	0.000
40	1.963[a]	3.100	1.611[b]	1.250
Full[1]	1.784[b]	2.830	1.655[a]	2.500
CV	4.147	5.467	1.488	1.316
SEM	0.041	0.091	0.012	1.350
P value	0.005	0.205	0.001	0.205

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

[1] Full = full replacement of soybean meal with canola meal

Table 5. Effect of levels of canola meal on live performance during the finisher phase of 0 – 42 days (means of four pens of 25 male broilers each)

% CM	Body Weight (kg)	Feed intake (kg)	FCR (kg/kg)	% Mortality
0	2.784[a]	4.298	1.625[d]	6.250
10	2.888[a]	4.551	1.653[cd]	10.000
20	2.790[a]	4.402	1.689[b]	7.500
30	2.784[a]	4.540	1.675[bc]	3.750
40	2.737[a]	4.561	1.704[b]	2.500
Full[1]	2.520[b]	4.190	1.740[a]	5.000
CV	3.388	4.584	1.271	2.435
SEM	0.0466	0.117	0.0107	2.602
P value	0.001	0.097	< 0.001	0.401

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

[1] Full = full replacement of soybean meal with canola meal

Table 6. Effects of levels of canola meal on processing characteristics of broiler (means of four pens of five birds)

% CM	Dress %	Breast % live weight	Leg quarters % live weight	Wings % live weight	Breast % carcass	Leg quarters % carcass	Wings % carcass
0	72.22	22.61[a]	22.02	7.63	31.44[ab]	30.57	10.58
10	71.79	23.00[a]	21.39	7.58	32.01[a]	29.83	10.57
20	72.20	20.57[bc]	21.40	7.42	28.96[bc]	29.99	10.46
30	71.70	22.05[ab]	21.67	7.78	31.05[ab]	30.52	10.90
40	69.45	20.68[bc]	20.64	7.85	29.70[abc]	29.29	11.25
Full[1]	71.99	19.98[c]	21.62	7.51	27.56[c]	29.99	10.34
CV	8.085	11.794	10.192	8.891	12.466	11.042	9.467
SEM	1.360	0.656	0.564	0.175	0.941	0.830	0.253
P value	0.676	0.002	0.503	0.375	0.005	0.855	0.080

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

[1] Full = full replacement of soybean meal with canola meal

Table 7. Effects of canola meal on processing characteristics parts yield (means of four pens of five birds)

% CM	Carcass weight (kg)	Breast weight (g)	Leg Quarters weight (g)	Wings weight (g)
0	1.952^{ab}	606.84^{b}	593.32^{a}	205.53^{a}
10	2.034^{a}	650.42^{a}	603.79^{a}	214.20^{a}
20	2.012^{a}	577.53^{bc}	599.95^{a}	208.95^{a}
30	1.937^{ab}	598.00^{b}	584.53^{ab}	209.80^{a}
40	1.874^{b}	554.65^{c}	553.05^{bc}	210.15^{a}
Full[1]	1.761^{c}	486.31^{d}	527.06^{c}	182.31^{b}
SEM	0.037	15.045	13.116	3.664
CV	8.512	10.354	9.073	7.116
P < 0.05	< 0.001	< 0.001	< 0.001	< 0.001

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

[1] Full = full replacement of soybean meal with canola meal

Table 8. Summary of trials to evaluate the replacement value of canola meal for soybean meal on broiler performance and processing characteristics

Author	Max level of CM	length of experiment	Total or digestible amino acids	Comment
Ahmad et al., (2007)	20%	42 days	Digestible	cornstarch and cane molasses were added to diets, diets were maintained isocalorically
Ajuyah et al., (1991)	13%	6 weeks	Total	performance and processing were evaluated, diets maintained Isocaloric, CM diets included 3.5 and 7% canola oil
Elwinger and Saterby, (1986) Experiment 3	18%	42 days	Total	Wheat based diets fed Isocaloric, included varying amounts of fish meal
Elwinger and Saterby, (1986) Experiment 4	20%	42 days	Total	Wheat base diets fed Isocaloric, included increasing amounts of peas in addition to RSM
Elwinger and Saterby, (1986) Experiment 5	12%	42 days	Total	Wheat based diets fed Isocaloric, included constant amounts of fish meal
Hickling, (2001)	N/A	N/A	N/A	recommends only 15% inclusion in broiler grower diets because of possible reduction in FI due to dietary cation and anion levels
Khan et al., (2006)	15%	50 days	Total	performance and processing were evaluated, diets maintained Isocaloric
Kocher et al., (2001)	35%	37 days	Total	performance and processing were evaluated, diets maintained Isocaloric, diets compared with and without addition of enzymes
Leeson et al., (1987)	100%	21 days	Total	corn-soy-CM diets maintained Isocaloric

Continued on next page

Continued from previous page
Table 8. Summary of trials to evaluate the replacement value of canola meal for soybean meal on broiler performance and processing characteristics

McNeill et al., (2004)	20%	42 days	Total	performance, processing, and sensory were evaluated, diets maintained Isocaloric
Min et al., (2011)	25%	28 days	Digestible	compared 5 CM inclusion levels to control, diets maintained Isocaloric
Montazer-Sadegh et al., (2008)	16%	49 days	Total	performance and processing were evaluated, diets maintained Isocaloric
Naseem et al., (2006)	25%	35 days	Total	performance and processing were evaluated, diets maintained Isocaloric
Nassar and Arscott, (1986)	100%	7 weeks	Total	evaluated 0, 25, 50,75 and 100% CM in CS based isocaloric diets
Perez-Maldonado et al., (2003)	20% starter, 30% finisher	43 days	Digestible	compared one level of CM to control, diets maintained Isocaloric
Salmon et al., (1981)	28.1% starter, 12.1% finisher	8 weeks	Total	wheat based diets compared Isocaloric and Optimum density diets.
Taraz et al., (2006b)	100%	49 days	Total	performance and processing were evaluated, diets maintained Isocaloric
Thomke et al., (1983) Experiment 2	18% solvent extracted, 7% press extracted	43 days	Total	compared RSM of varying extraction processes, cereal based diets maintained Isocaloric
Thomke et al., (1983) Experiment 1	15% on solvent extracted, 20% on prepress extracted	35 days	Total	compared RSM of varying extraction processes, cereal based diets maintained Isocaloric

Use of Canola Meal in High Energy Broiler Diets. 2. Optimum Density Diets

C. D. Bradley, S. D. Goodgame, F. J. Mussini, C. Lu, and P.W. Waldroup
Poultry Science Department, University of Arkansas, Fayetteville AR 72701

ABSTRACT

In a previous study where diets were maintained isocaloric by increasing the level of poultry oil (PO), it was found that 40% solvent extracted canola meal (CM) obtained from a biodiesel producer could be fed to broilers without loss of performance. However, the economics of feeding high levels of supplemental fats makes the use of CM in isocaloric diets difficult to justify. The objective of this study was to evaluate broiler performance and carcass yields when using various levels of canola meal in broiler diets with a constant level of supplemental poultry oil consistent with industry standards of fat supplementation. Within each age period, five diets were formulated ranging from 0 to 40% CM in 10% increments. These diets were formulated to digestible amino acid levels suggested by Rostagno et al. (2005), adjusted to a dietary energy level commensurate with 2% PO. Each of the varied diets was dispensed to six pens of 50 male (Cobb 500) chicks for a 42 day feeding period. Five birds from each pen were processed for dressing percentage and parts yield. At 42 days, birds fed diets with 30 and 40% CM were significantly lighter than those fed the control diet and also had significantly higher feed conversion ratio (FCR). Feed intake (FI) was negatively affected by increasing CM levels; however, calorie conversion (kcal ME / kg gain) was not significantly different among treatments. Dressing percentage and breast meat yield reduced linearly as the level of CM increased. These data suggest that when diets are formulated with a constant level of supplemental fat, the level of CM should not exceed 20%. More work needs to be done to see if

the digestibility of amino acids in CM can be improved by the addition of protease enzymes to the diets so CM inclusion rates can be greater than 20% without excessive amounts of PO.

Key words: Broiler, canola, isocaloric, energy, optimum density

INTRODUCTION

In our previous study with canola meal Bradley et al., (2013) the diets were kept isocaloric, which required high levels of supplementation with poultry oil as quantities of canola meal increased. While, from a technical standpoint, keeping diets isocaloric is one method of determining product utilization by removing the issue of differences in dietary energy, from a useful standpoint, questions arise as to chick performance with diets formulated to be realistic in regard to supplemental poultry oil. Therefore, the objective of this study concerned broiler performance evaluation and carcass part yields when using varied levels of canola meal in diets with a constant level of supplemental poultry oil consistent with industry standards of fat supplementation.

MATERIALS AND METHODS

Dietary treatments

Five basal diets were formulated within each age group to satisfy the minimum digestible amino acid needs suggested by Rostagno et al., (2005) with no minimum protein level imposed. One diet utilized soybean meal as the primary source of protein while the other diets employed varied levels of canola meal (10, 20, 30, and 40%). Supplemental amino acids included sources of lysine, methionine, and threonine. For each diet, a dietary energy level was selected that required approximately 2% additional poultry oil with nutrients adjusted to this energy level. Diets were formulated on a digestible amino acid basis, using total amino acid values for corn, soybean meal, and canola meal determined by analysis of the products used in mixing by a commercial laboratory specializing in amino acid analysis, with amino acid digestion coefficients suggested by Ajinomoto Heartland Lysine. All diets were supplemented with complete vitamin and trace mineral premixes obtained from commercial sources. Composition of the diets for starter (0-21 d), grower (22-35 d) and finisher (36-42 d) are shown in Tables 1, 2, and 3 with calculated nutrient content in Tables 4, 5, and 6. The resulting diets were fed as mash. Each of the diets was fed to six pens of 50 male chicks.

Birds and management

Male chicks of a commercial broiler strain (Cobb 500) were obtained from a local hatchery where they received vaccinations in ovo for Marek's Disease and vaccinations for Newcastle Disease and infectious bronchitis post hatch via coarse spray. Fifty chicks were placed in each of the 30 litter floor pens in a house of commercial design. Fresh softwood shavings over concrete floors served as bedding. Feed and water were provided for ad libitum consumption. Automatic heaters and ventilation fans controlled temperature and airflow; incandescent lights provided 23 hours of light daily. Supplemental feeders and waters were used for the first seven days. Care and management of the birds followed recommended guidelines (FASS, 2010). The University of Arkansas Institutional Animal Care and Use Committee pre-approved all procedures.

Measurements

At one day of age, chicks were group weighed by pen and placed on test diets. At 21, 35, and 42 d of age, the birds were weighed and feed consumption for the period determined. Chicks were inspected twice daily; birds that died or were removed to alleviate suffering were weighed with the weight used to adjust feed conversion ratios. In addition to feed conversion (feed: gain), calculations were also done for Calorie conversion (ME Kcal/kg gain). At the conclusion of the study, five representative birds per pen were processed in a pilot processing plant using automatic evisceration as described by Fritts and Waldroup (2006). Diets within each age series were analyzed for crude protein, amino acids, calcium, total phosphorus, and sodium content by commercial laboratories specializing in these assays.

Statistical Analysis

Pen means served as the experimental unit for statistical analysis. Data were subjected to one-way ANOVA using the General Linear Models procedure of the SAS Institute (1991). When significant differences among treatments were found, means were separated using the Duncan's multiple range test. Mortality data were transformed to $\sqrt{n+1}$ prior to analysis; data are presented as natural numbers. All statements of statistical significance are based on $P \leq 0.05$.

RESULTS

Performance

Mortality was not significantly affected by inclusionary levels of CM at 21 d (Table 7), 35 d (Table 8), and 42 d (Table 5).

At 21 d of age, the BW of birds fed the diet with 40% CM was significantly lower than that of birds fed the SBM diet and diets with other levels of CM (Table 7). Birds fed the diet with 10% CM were actually significantly higher than those fed the SBM control diet. Feed intake (FI) was significantly lower for birds fed the diet with 40% CM when compared to birds fed the control, 10, 20, or 30% CM diets. Broilers consuming the control or 20% CM replacement diets had significantly higher feed conversion ratio (FCR) than those of the birds fed 10, 30, or 40% CM inclusionary levels. The most efficient caloric conversion was observed for the birds eating the 40% CM diet, caloric conversion increased as birds consumed the diets with lower CM values of 30% then 20 or 10% and finally the SBM control diet.

At 35 d, birds fed diets with 40% CM had a significantly lower BW than those fed 30 or 20% CM diets, more significant increase in BW was observed by birds eating 10% or the SBM control with the highest BW being noted for birds eating the 10% CM diet (Table 8). FCR for the groups of birds fed 20, 30, and 40% CM was significantly higher than those fed 10% CM or the SBM control diets. Although the calorie conversion varied somewhat over the different levels of CM and few significant differences were noted among treatments, the groups of broilers fed the two highest levels of CM recorded the most efficiency for CCR.

At 42 d of age, birds fed differing CM inclusionary levels showed no significant differences in FI, Mortality, FCR, and CCR. However, The FCR did increase in a numerical linear manner as the level of CM increased. This should have been expected, as the dietary energy level was reduced, as the level of CM increased. Overall, the calorie conversion ratio was not significantly affected by the level by CM, indications that although the diet was lower in energy, the birds utilized the dietary energy effectively. BW of birds fed 40 or 30% CM was significantly less than that of birds fed the remainder of the diets (Table 9). Generally, BW showed a numerical linear decline as CM inclusion rates increased throughout all treatments.

Processing

Dressing percentage tended to be reduced in a linear manner as the level of CM increased (Table 10). The dressing percentage of birds fed diets with 20 and 40% CM was significantly lower than that of birds fed the SBM control, but did not differ significantly from that of birds fed 10 or 30% CM. Breast yield, as a percent of live weight was significantly reduced in a linearly manner by each inclusionary level of CM, with a concomitant increase in wing weights as a percentage of live weight as CM increased 10 through 40%. The yields of leg quarters or carcass rack measured as a percentage of live weight were not significantly affected by CM rates.

When expressed as a percentage of carcass weight (Table 11), breast yield was significantly decreased by all CM inclusionary levels in a linearly fashion. While yield of leg quarters and wings was significantly increased as levels of CM were increased at all levels.

Processing results parts yield as expressed in weight are found in Table 12. Carcass weights results revealed significant contrast between the broilers consuming the control, 10% CM diets, and the remainder of the treatments (Table 12). In general, a linear decrease was exhibited with increasing amounts of CM. The largest weights recorded in leg quarters and wings were in broilers eating the 10% CM diets. The greatest contrasts were found in the breast weight category, where a decline was noted from the control through every diet.

DISCUSSION

A summary of other research studies containing CM in broiler diets is found in Table 13. Although a substantial number of broiler studies have been conducted evaluating the replacement value of CM for SBM, most have maintained diets isocalorically by increasing the level of poultry oil (PO), including our previous study, Bradley et al., (2013). Salmon et al., (1981) is one of few who have evaluated the use of canola meal in broiler diets for performance and carcass characteristics with low and high crude protein and low and high nutrient density. Salmon et al., (1981) incorporated canola meal into wheat-based broiler diets at up to 28.1% in starter diets with either 21 or 23% CP and up to 12.1% in finisher diets with either 17 or 19% CP. Salmon et al., (1981) reported that live weight gain was not affected by canola meal or nutrient densities and feed efficiency was not affected by canola meal when nutrient density was kept high by fat supplementation but declined with lower density diets. In disagreement with Salmon et al., (1981), we found BW declined significantly when birds were fed CM at greater than 20%, but BW and FCR declined linearly throughout. Substantially worse FCR was shown in birds eating

CM at 10%. Our processing results are in disagreement with Salmon et al., (1981) who reported total meat was not significantly ($P < 0.05$) impacted but a linear decline in fleshing grade was associated with increasing CM. The results from this experiment compared with performance and carcass results from our previous study, Bradley et al., (2013), where the diets where maintained, suggest that bird performance and carcass characteristic suffered from the reduced energy values. It would seem if PO isn't added at rates above 2%, CM should not replace SBM at rates above 10%.

Canola meal when compared to soybean meal experiences a considerable reduction in true metabolizable energy (TME). Rostagno et al., (2011) reported SBM has a TME level of 2590 kcal/kg while CM has a TME level of 1900 kcal/kg. Thus, diets including CM above 10% need PO to raise the TME. However, problems arise from adding higher levels of PO such as poor pellet quality and the economics of supplemental fats. The added cost of PO by itself could possibly disqualify the use of CM. The difficulties of feeding diets lower in PO and ME have been well documented. Salah et al., (2004) described increasing broiler performance for body weights and FCR in 42 day-old broilers as dietary nutrient densities increased. Jackson et al., (1982) reported reduced BW and FE with reducing dietary energy levels.

Other researchers have explored the use of CM and high nutrient density diets replacing SBM. Thomke et al., (1983) conducted extensive studies using a low-glucosinolate rapeseed meal of Swedish origin. Feeding the meal resulted in unaltered performance compared to soybean meal. Elwinger and Saterby (1986) reported that feeding diets with 12 to 20% of a low glucosinolate rapeseed meal did not adversely affect performance or health of broilers. Nassar and Arscott (1986) found satisfactory performance when canola meal was used in both broiler starter (19.2%) and finisher (16.3%) diets replacing up to 50% soybean meal. Roth-Maier and Kirchgessner

(1987) recommended the use of up to 15% canola meal in broiler diets. Leeson et al., (1987) reported that canola meal could replace 100% of the soybean meal in broiler rations without any effect on feed intake, weight gain, or feed efficiency.

Perez-Maldonado et al., (2003) concluded that up to 20% of a solvent extracted or a solvent extracted-extruded canola meal could be used during the starter phase in diets formulated on a digestible amino acid basis. Ahmad et al., (2007) reported that canola meal could be used up to 20% of diets fed 1 to 28 d without any adverse effects of broiler performance. Hickling (2001) recommended a maximum inclusion level of 15% canola meal in diets typically fed to broilers.

CONCLUSION

These data suggest CM can be moderately substituted for SBM without unwarranted quantities of supplemental fat; however, if diets are maintained by optimum nutrient density any amount >10% CM will significantly reduce bird performance and weight of leg quarters. Carcass data also suggests any inclusionary level of CM will significantly reduce breast weight, even though CM can be added at amount ≤ 30% without significantly effecting wing weights. More study is needed to determine if CM digestibility can be improved by the addition of protease enzymes to the diet.

REFERENCES

Ahmad, G., T. Mushtaq, M. Aslam Mirza, and Z. Ahmed. 2007. Comparative bio efficacy of lysine from L-lysine hydrochloride or L-lysine sulfate in basal diets containing graded levels of canola meal for female broiler chickens. Poult. Sci. 86:525–530

Ajuyah, A., K. Lee, R. Hardin, and J. Sim. 1991. Changes in the yield and in the fatty acid composition of whole carcass and selected meat portions of broiler chickens fed full-fat oil seeds. Poult. Sci. 70:2304-2314.

Bradley C.D., S. Goodgame, F. Mussini, C. Lu, and P. Waldroup. 2013. Use of canola meal in high energy diets. 1. Isocaloric diets. In press

Elwinger, K., and R. Saterby. 1986. Continued experiments with rapeseed meal of a Swedish low glucosinolate type fed to poultry. 1. Experiments with broiler chickens. Swedish J. Agric. Res. 16:27-34.

FASS, 2010. Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching. 3rd ed. Federation of Animal Science Societies, Savoy IL.

Fritts, C.A., and P.W. Waldroup, 2006. Modified phosphorus program for broilers based on commercial feeding intervals to sustain live performance and reduce total and water-soluble phosphorus in litter. J. App. Poult. Res. 15:207-218.

Hickling, D. 2001. Pages 16-21 in Canola Meal Feed Industry Guide 3rd ed. Canadian International Grains Institute, Winnipeg, Manitoba, Canada

Jackson, S., J.D. Summers, and S. Leeson, 1982. Effect of dietary protein and energy on broiler performance and production costs. Poult. Sci. 61:2232-2240.

Khan, A., A. Azim, and M. Anjum. 2006. Effect of different levels of rapeseed meal and canola meal on broiler production performance and carcass characteristics. Pakistan Vet. J. 26:9-13.

Kocher, A., M. Choct, L. Morrisroe, and J. Broz. 2001. Effects of enzyme supplementation on the replacement value of canola meal for soybean meal in broiler diets. Aust. J. Agric. Res. 52:447-452.

Leeson, S., J.O. Atteh, and J. D. Summers. 1987. The replacement value of canola meal for soybean meal in poultry diets. Can. J. Anim. Sci. 67:151-158.

McNeill, L., K. Bernard, and M. MacLeod. 2004. Food intake, growth rate, food conversion and food choice in broilers fed on diets high in rapeseed meal and pea meal, with observations on sensory evaluation of the resulting poultry meat. Br. Poult. Sci. 45:519-523.

Min, Y., Z. Wang, C. Coto, F. Yan, S. Cerrate, F. Liu, and P. Waldroup. 2011. Evaluation of Canola Meal from Biodiesel Production as a Feed Ingredient for Broilers. Int. J. Poult. Sc. 10:782-785.

Montazer-Sadegh, R., Y. Ebrahim-Nezhad, and N. Maheri-Sis. 2008. Replacement of different levels of rapeseed meal with soybean meal on broilers performance. Asian J. Anim. Vet. Ad. 3:278-285.

Naseem, M., S. Khan, and M. Yousaf. 2006. Effect of feeding various levels of canola meal on the performance of broiler chicks. J. Anim. Plant Sc. 16.

Nassar, A.R., and G. H. Arscott. 1986. Canola meal for broilers and the effect of a dietary supplement of iodinated casein on performance and thyroid status. Nutr. Rep. Int. 34:791-199.

Perez-Maldonado RA, K.M.Barram and D.N.Singh. 2003. How much canola or cottonseed meals can be used for commercial chicken meat production. Asia Pac. J. Clin. Nutr.12, suppl: S41

Rostagno, H.R., L.F. T. Albino, J. L. Donzele, P. C. Gomes, R.F. de Olveira, D. C. Lopes, A.S. Firiera, and, S. L. de T. Barreto, 2005. Brazilian Tables for Poultry and Swine. Composition of Feedstuffs and Nutritional Requirements. 2nd ed. H. S. Rostagno, ed. Universidade Federal de Vocosa, Dept. Zootecnia, Vicosa, MG, Brazil.

Rostagno, H.R., L.F. T. Albino, J. L. Donzele, P. C. Gomes, R.F. de Olveira, D. C. Lopes, A.S. Firiera, S. L. de T. Barreto, and R.F. Euclides, 2011. Brazilian Tables for Poultry and Swine. Composition of Feedstuffs and Nutritional Requirements. 2nd ed. H. S. Rostagno, ed. Universidade Federal de Vocosa, Dept. Zootecnia, Vicosa, MG, Brazil.

Roth-Maier, D. A., and M. Kirchgessner. 1987. Feeding canola meal to fattening broilers. Arch. Geflugelk. 57:241-246.

Saleh, E.A., S.E. Watkins, A.L. Waldroup, and P.W. Waldroup. 2004. Effects of dietary density on performance and carcass quality of male broilers grown for further processing[1]. Int. J. Poult. Sc. 3 (1):1-10.

Salmon, R. E., E. E. Gardiner, K. K. Klein, and E. Larmond. 1981. Effect of canola (low glucosinolate rapeseed) meal, protein and nutrient density on performance, carcass grade, and meat yield and of canola meal on sensory quality of broilers. Poult. Sci. 60:2519-2528.

SAS Institute, 1991.SAS® User’s Guide: Statistics. Version 6.03 Edition. SAS Institute, Inc., Cary, NC.

Taraz, Z., S. Jalali, and F. Rafeie. 2006. Effects of replacement of soybean meal with rapeseed meal on organs weight, some blood biochemical parameters and performance of broiler chicks. Int. J. Poult. Sci. 5:1110-1115.

Thomke, S., K. Elwinger, M. Rundgren, and B. Ahestrom. 1983. Rapeseed meal of Swedish low-glucosinolate type fed to broiler chickens, laying hens, and growing-finishing pigs. Acta Agr. Scand. 33:75-96.

Table 1. Composition (g/kg) of starter diets fed 0 to 21 d of age with soybean meal and canola meal

Ingredient	0% CM	10% CM	20% CM	30% CM	40% CM
Yellow corn	602.65	573.48	539.34	493.74	448.14
Soybean meal	350.52	270.25	194.47	129.05	63.63
Canola meal	0.00	100.00	200.00	300.00	400.00
Dicalcium phosphate	16.72	16.17	15.58	14.96	14.33
Poultry oil	10.02	20.12	30.99	43.62	56.24
Ground limestone	7.36	7.27	7.15	6.96	6.78
Sodium chloride	4.38	4.35	4.32	4.28	4.24
MHA[1]	3.04	2.63	2.19	1.64	1.10
L-Lysine HCl	1.96	2.38	2.67	2.66	2.65
L-Threonine	0.60	0.60	0.54	0.34	0.14
Broiler premix[2]	0.25	0.25	0.25	0.25	0.25
Mintrex P_Se[3]	1.00	1.00	1.00	1.00	1.00
Coban 90[4]	0.50	0.50	0.50	0.50	0.50
Choline Cl 60%	1.00	1.00	1.00	1.00	1.00
TOTAL	1000.00	1000.00	1000.00	1000.00	1000.00

[1]Methionine hydroxy analogue calcium salt. Novus International, St. Louis MO 63141.

[2] Provides per kg of diet: vitamin A (from vitamin A acetate) 7715 IU; cholecalciferol 5511 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg.

[3]Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 40 mg; Zn (as zinc methionine hydroxy analogue complex) 40 mg; Cu (as copper methionine hydroxy analogue complex) 20 mg; Se (as selenium yeast) 0.3 mg. Novus International, Inc., St. Louis MO 63141.

[4] Elanco Animal Health division of Eli Lilly & Co., Indianapolis, IN 46825.

[5] Uniscope Inc., Johnstown CO 80534.

Table 2. Composition (g/kg) of grower diets fed 22 to 35 d of age with soybean meal and canola meal

Ingredient	0% CM	10% CM	20% CM	30% CM	40% CM
Yellow corn	611.02	601.44	582.07	559.44	536.15
Soybean meal	330.69	241.35	162.47	87.36	12.33
Canola meal	0.00	100.00	200.00	300.00	400.00
Dicalcium phosphate	15.25	14.39	13.40	12.37	11.33
Poultry oil	20.07	20.00	20.09	19.98	20.04
Ground limestone	7.25	7.16	6.99	6.78	6.49
Sodium chloride	4.39	4.37	4.33	4.29	4.25
MHA[1]	2.76	2.29	1.68	1.03	0.66
L-Lysine HCl	1.67	2.13	2.26	2.25	2.25
L-Threonine	0.37	0.37	0.21	0.00	0.00
Vitamin premix[1]	5.00	5.00	5.00	5.00	5.00
Mintrex P_Se[1]	1.00	1.00	1.00	1.00	1.00
Coban 90[1]	0.50	0.50	0.50	0.50	0.50
TOTAL	1000.00	1000.00	1000.00	1000.00	1000.00

[1]As given in Table 1.

Table 3. Composition (g/kg) of finisher diets fed 36 to 42 d of age with soybean meal and canola meal

Ingredient	0% CM	10% CM	20% CM	30% CM	40% CM
Yellow corn	642.40	632.20	610.15	586.65	551.41
Soybean meal	301.96	213.10	137.18	62.62	0.00
Canola meal	0.00	100.00	200.00	300.00	400.00
Dicalcium phosphate	13.62	12.79	11.80	10.79	9.63
Poultry oil	20.06	20.07	20.04	20.08	20.37
Ground limestone	6.97	6.88	6.69	6.46	6.05
Sodium chloride	4.41	4.38	4.35	4.31	4.27
MHA[1]	2.50	2.03	1.40	0.85	0.44
L-Lysine HCl	1.74	2.21	2.25	2.24	1.83
L-Threonine	0.34	0.34	0.14	0.00	0.00
Vitamin premix[1]	5.00	5.00	5.00	5.00	5.00
Mintrex P_Se[1]	1.00	1.00	1.00	1.00	1.00
TOTAL	1000.00	1000.00	1000.00	1000.00	1000.00

[1]As in Table 1.

Table 4. Calculated nutrient content of broiler starter diets fed 0 to 21 d with soybean meal and varying levels of canola meal. Digestible amino acid values in bold italic are at minimum specified levels.

Nutrient	0 % CM	10% CM	20% CM	30% CM	40% CM
Crude protein %	21.34	21.44	21.74	22.34	22.94
Calcium %	0.90	0.88	0.86	0.85	0.83
Total P %	0.75	0.78	0.80	0.82	0.85
Nonphytate P %	0.45	0.44	0.43	0.43	0.42
Sodium %	0.20	0.20	0.20	0.20	0.20
ME kcal/lb	1372.00	1353.00	1332.50	1308.50	1285.00
ME kcal/kg	3023.87	2982.00	2936.81	2883.91	2832.14
Met %	0.63	0.61	0.57	0.55	0.52
Lys %	1.30	1.30	1.31	1.31	1.31
Thr %	0.87	0.87	0.88	0.88	0.89
TSAA %	0.97	0.97	0.98	0.98	0.99
Gly+Ser %	1.93	1.98	2.05	2.16	2.26
dMet %	0.54	0.52	0.49	0.45	***0.42***
dLys %	***1.16***	***1.14***	***1.12***	***1.10***	***1.08***
dThr %	***0.75***	***0.74***	***0.73***	***0.72***	***0.70***
dIle %	0.79	0.76	***0.73***	***0.72***	***0.70***
dHis %	0.50	0.48	0.48	0.48	0.48
dVal %	***0.87***	***0.86***	0.85	0.86	0.88
dLeu %	1.62	1.59	1.57	1.57	1.56
dArg %	1.29	1.24	1.20	1.19	1.17
dTSAA %	***0.82***	***0.81***	***0.80***	***0.78***	0.77

Table 5. Calculated nutrient content of broiler grower diets fed 22 to 35 d with soybean meal and varying levels of canola meal. Digestible amino acid values in bold italic are at minimum specified levels.

Nutrient	0 % CM	10% CM	20% CM	30% CM	40% CM
Crude protein %	19.85	19.97	20.47	21.09	21.73
Calcium %	0.82	0.80	0.79	0.78	0.76
Total P %	0.67	0.70	0.72	0.75	0.78
Nonphytate P %	0.41	0.40	0.39	0.39	0.38
Sodium %	0.20	0.20	0.20	0.20	0.20
ME kcal/lb	1392.50	1373.55	1351.00	1326.60	1302.20
ME kcal/kg	3069.06	3027.28	2977.60	2923.81	2870.04
Met %	0.58	0.56	0.53	0.50	0.49
Lys %	1.20	1.20	1.20	1.21	1.21
Thr %	0.80	0.81	0.82	0.82	0.85
TSAA %	0.91	0.92	0.92	0.92	0.95
Gly+Ser %	1.79	1.84	1.93	2.04	2.14
dMet %	0.50	0.47	0.44	0.41	***0.40***
dLys %	***1.06***	***1.05***	***1.03***	***1.01***	***0.99***
dThr %	***0.69***	***0.68***	***0.67***	0.66	0.67
dIle %	0.74	0.71	***0.69***	***0.68***	***0.67***
dHis %	0.47	0.45	0.46	0.46	0.46
dVal %	***0.82***	***0.81***	0.81	0.82	0.84
dLeu %	1.54	1.51	1.50	1.50	1.50
dArg %	1.19	1.14	1.12	1.10	1.09
dTSAA %	***0.77***	***0.76***	***0.74***	***0.73***	0.74

Table 6. Calculated nutrient content of broiler finisher diets fed 36 to 42 d with soybean meal and varying levels of canola meal. Digestible amino acid values in bold italic are at minimum specified levels.

Nutrient	0 % CM	10% CM	20% CM	30% CM	40% CM
Crude protein %	18.76	18.90	19.50	20.15	21.26
Calcium %	0.75	0.74	0.73	0.72	0.70
Total P %	0.63	0.65	0.68	0.71	0.74
Nonphytate P %	0.37	0.37	0.36	0.36	0.35
Sodium %	0.20	0.20	0.20	0.20	0.20
ME kcal/lb	1408.50	1389.50	1365.50	1341.00	1312.00
ME kcal/kg	3104.34	3062.46	3009.55	2955.56	2891.64
Met %	0.55	0.52	0.49	0.47	0.47
Lys %	1.13	1.13	1.14	1.14	1.15
Thr %	0.76	0.76	0.77	0.79	0.83
TSAA %	0.86	0.87	0.87	0.88	0.92
Gly+Ser %	1.68	1.74	1.84	1.95	2.10
dMet %	0.46	0.44	0.41	***0.38***	***0.37***
dLys %	***1.00***	***0.99***	***0.97***	***0.95***	***0.93***
dThr %	***0.65***	***0.64***	***0.63***	0.63	0.65
dIle %	0.70	0.66	***0.65***	***0.64***	0.64
dHis %	0.44	0.43	0.43	0.44	0.45
dVal %	***0.77***	***0.76***	0.77	0.79	0.82
dLeu %	1.48	1.44	1.44	1.44	1.47
dArg %	1.11	1.06	1.05	1.04	1.06
dTSAA %	***0.72***	***0.71***	***0.70***	0.70	0.71

Table 7. Effect of levels of canola meal on performance of broilers during the starter phase of 0 – 21 days (Means of six pens of 50 male broilers each)

% CM	Body weight (kg)	Feed Intake (kg)	FCR (kg/kg)	% Mortality	Calorie conversion (kcal : kg)
0	0.693^{b}	1.014^{ab}	1.476^{a}	2.000	4454.88^{a}
10	0.745^{a}	1.056^{a}	1.451^{b}	0.833	4325.77^{b}
20	0.706^{b}	1.036^{ab}	1.472^{a}	0.000	4323.70^{b}
30	0.708^{b}	1.006^{b}	1.441^{bc}	2.500	4142.30^{c}
40	0.662^{c}	0.952^{c}	1.423^{c}	3.000	4031.47^{d}
CV	2.053	3.485	1.155	1.319	1.160
SEM	0.007	0.016	0.008	1.210	20.302
P < 0.05	0.001	0.001	0.001	0.349	< 0.001

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Table 8. Effect of levels of canola meal on performance of broilers during the grower phase of 0 – 35 days (Means of six pens of 50 male broilers each)

% CM	Body weight (kg)	FCR (kg/kg)	Feed Intake (kg)	% Mortality	Calorie conversion (kcal : kg)
0	1.796^{a}	1.616^{c}	2.902^{b}	0.800	4934^{ab}
10	1.816^{a}	1.650^{bc}	2.997^{a}	0.333	4969^{ab}
20	1.735^{b}	1.695^{a}	2.940^{ab}	0.000	5021^{a}
30	1.744^{b}	1.673^{ab}	2.917^{ab}	0.666	4867^{b}
40	1.611^{c}	1.713^{a}	2.760^{c}	1.000	4849^{b}
CV	2.020	1.870	2.280	0.319	2.095
SEM	0.016	0.014	0.030	0.287	46.175
P < 0.05	< 0.001	< 0.001	< 0.001	0.110	0.046

^{a,b,c} means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Table 9. Effect of levels of canola meal on performance of broilers during the finisher phase of 0 – 42 days (Means of six pens of 50 male broilers each)

% CM	Body weight (kg)	FCR (kg/kg)	Feed Intake (kg)	% Mortality	Calorie conversion (kcal : kg)
0	2.397[a]	1.723[b]	4.031[ab]	0.800	5286
10	2.386[a]	1.767[ab]	4.169[ab]	0.333	5349
20	2.315[ab]	1.802[a]	4.135[b]	0.000	5365
30	2.295[b]	1.807[a]	4.063[ab]	0.667	5283
40	2.144[c]	1.809[a]	3.869[a]	1.000	5268
CV	2.820	2.730	3.840	0.319	1.590
SEM	0.029	0.022	0.070	0.287	37.844
P < 0.05	< 0.001	0.040	0.040	0.110	0.234

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Table 10. Effects of levels of canola meal on dressing percentage and parts yield as a percentage of live weight (Means of six pens of five birds)

% CM	Dress %	Breast % Live weight	Leg quarters % Live weight	Wings % Live weight	Rack % Live weight
0	73.08[a]	22.99[a]	22.78	7.74[c]	19.04
10	72.11[ab]	21.63[b]	23.31	7.96[b]	19.00
20	71.69[b]	21.22[b]	23.07	8.10[ab]	19.14
30	72.20[ab]	20.85[bc]	22.86	8.23[a]	19.46
40	71.36[b]	20.16[c]	23.12	8.19[a]	19.20
CV	2.712	6.931	4.486	4.542	5.738
SEM	0.370	0.275	0.192	0.068	0.204
$P < 0.05$	0.013	< 0.001	0.296	< 0.001	0.524

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Table 11. Effects of levels of canola meal on processing characteristics of broilers (Means of six pens of five birds)

% CM	Breast % Carcass	Leg quarters % Carcass	Wings % Carcass	Rack % Carcass
0	31.456[a]	31.183[b]	10.587[c]	26.063
10	29.988[b]	32.339[a]	11.039[b]	26.365
20	29.411[bc]	32.025[a]	11.241[ab]	26.552
30	28.838[cd]	31.680[ab]	11.360[a]	26.911
40	28.247[d]	32.402[a]	11.473[a]	26.906
CV	5.918	4.166	4.618	5.683
SEM	0.331	0.279	0.097	0.285
$P < 0.05$	< 0.001	0.009	< 0.001	0.151

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Table 12. Effects of canola meal on processing characteristics parts yield (means of six pens of five birds)

% CM	Carcass (kg)	Breast (g)	Leg Quarters (g)	Wings (g)
0	1.817[a]	572.07[a]	566.40[a]	192.20[a]
10	1.758[a]	527.77[b]	567.97[a]	193.83[a]
20	1.652[b]	489.07[c]	529.28[b]	185.66[ab]
30	1.649[b]	477.28[c]	522.14[bc]	187.69[a]
40	1.552[c]	439.40[d]	502.50[c]	177.80[b]
SEM	0.030	11.643	9.118	2.974
CV	9.500	12.505	9.130	8.544
$P < 0.05$	< 0.001	< 0.001	< 0.001	0.001

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Table 13. Summary of trials to evaluate the replacement value of canola meal for soybean meal on broiler performance and processing characteristics

Author	Max level of CM	length of experiment	Total or digestible amino acids	Comment
Ahmad et al., (2007)	20%	42 days	Digestible	cornstarch and cane molasses were added to diets, diets were maintained isocalorically
Ajuyah et al., (1991)	13%	6 weeks	Total	performance and processing were evaluated, diets maintained Isocaloric, CM diets included 3.5 and 7% canola oil
Elwinger and Saterby, (1986) Experiment 3	18%	42 days	Total	Wheat based diets fed Isocaloric, included varying amounts of fish meal
Elwinger and Saterby, (1986) Experiment 4	20%	42 days	Total	Wheat base diets fed Isocaloric, included increasing amounts of peas in addition to RSM
Elwinger and Saterby, (1986) Experiment 5	12%	42 days	Total	Wheat based diets fed Isocaloric, included constant amounts of fish meal
Hickling, (2001)	N/A	N/A	N/A	recommends only 15% inclusion in broiler grower diets because of possible reduction in FI due to dietary cation and anion levels
Khan et al., (2006)	15%	50 days	Total	performance and processing were evaluated, diets maintained Isocaloric
Kocher et al., (2001)	35%	37 days	Total	performance and processing were evaluated, diets maintained Isocaloric, diets compared with and without addition of enzymes
Leeson et al., (1987)	100%	21 days	Total	corn-soy-CM diets maintained Isocaloric

Continued on next page

Continued from previous page

Table 8. Summary of trials to evaluate the replacement value of canola meal for soybean meal on broiler performance and processing characteristics

McNeill et al., (2004)	20%	42 days	Total	performance, processing, and sensory were evaluated, diets maintained Isocaloric
Min et al., (2011)	25%	28 days	Digestible	compared 5 CM inclusion levels to control, diets maintained Isocaloric
Montazer-Sadegh et al., (2008)	16%	49 days	Total	performance and processing were evaluated, diets maintained Isocaloric
Naseem et al., (2006)	25%	35 days	Total	performance and processing were evaluated, diets maintained Isocaloric
Nassar and Arscott, (1986)	100%	7 weeks	Total	evaluated 0, 25, 50,75 and 100% CM in CS based isocaloric diets
Perez-Maldonado et al., (2003)	20% starter, 30% finisher	43 days	Digestible	compared one level of CM to control, diets maintained Isocaloric
Salmon et al., (1981)	28.1% starter, 12.1% finisher	8 weeks	Total	Wheat based diets compared Isocaloric and Optimum density diets.
Taraz et al., (2006)	100%	49 days	Total	performance and processing were evaluated, diets maintained Isocaloric
Thomke et al., (1983) Experiment 2	18% solvent extracted, 7% press extracted	43 days	Total	compared RSM of varying extraction processes, cereal based diets maintained Isocaloric
Thomke et al., (1983) Experiment 1	15% on solvent extracted, 20% on prepress extracted	35 days	Total	compared RSM of varying extraction processes, cereal based diets maintained Isocaloric

Effect of Protease Enzyme on Utilization of Canola Meal in Broiler Diets

C.D. Bradley, S.D. Goodgame, F.J. Mussini, S.M. Fiscus, and P.W. Waldroup
Poultry Science Department, University of Arkansas, Fayetteville AR 72701

ABSTRACT

Two similar 18 day battery experiments were conducted which examined two diet type's corn-soy (CS) and corn-soy-canola (CSC) and four amino acid (AA) levels (80, 85, 90, and 95% of suggested level). In each of the experiments, a protease enzyme was added at 3 different levels (0, 1, and 2 times suggested amount). This resulted in a 2x4x3 factorial arrangement. Six pens of five Cobb 500 chicks were randomly assigned to each of the treatment. Measurements for body weight (BW) and feed conversion ratios (FCR) were taken at day 1 and 18. The results for BW and FCR showed birds fed incrementally higher percentages of AA and the CSC diet consistently outperformed the CS. The addition of enzymes did not significantly improve BW. However, significant three-way interaction suggests FCR decreased (improved) when birds consumed diets containing ProAct at 2 times the suggested level, CM, and increased AA levels.
Key words: Broilers, canola, protease, enzyme, digestibility

INTRODUCTION

For a number of years, poultry producers relied heavily on soybean meal as the primary protein source for broiler diets. SBM is considered to have high amino acid digestibility as well as a good balance of amino acids, especially when fortified with methionine. Recent changes in the supply of feedstuffs, however, have brought changes in feed ingredients available for use by nutritionists. Driven by the demand for ethanol, and to a lesser extent by the demand for biodiesel, the shift for corn and inedible fats has made a significant change in feed formulation, bringing in to consideration ingredients such as dried distillers grains with solubles (DDGS).

Biodiesel production has received less attention than ethanol production, but demand is growing rapidly. The price of inedible fats has already responded to the demand, and interest is growing in producing more vegetable oil to supply the needs of the biodiesel industry. This has focused attention on the production of canola, which produces three times more oil per acre than soybeans. While canola has traditionally been produced in high latitudes, such as Canada, the northern tier of U.S. states, and the E.U., it can be grown in the southern U.S. as a winter cover crop followed by soybeans, rice, or cotton, thus receiving considerable attention by agronomists seeking suitable varieties. With the potential increase in canola production, a concomitant increase in canola meal available for use in poultry feeds will follow.

While canola meal is potentially a good source of crude protein, it suffers in comparison to soybean meal not only in total protein content but more importantly in amino acid digestibility. A comparison of the digestibility of some of the key amino acids for canola meal and soybean meal is shown below. (Ajinomoto Heartland Lysine)

	Lys	Met	TSAA	Thr	Val
Canola meal	78.7	88.7	80.4	77.8	81.1
Soybean meal	90.6	92.1	87.8	88.4	90.8

Thus, it would appear that diets with a significant amount of canola meal would benefit considerably from the addition of an effective protease enzyme. The following study was conducted to evaluate a commercially available protease enzyme utilized in diets with high levels of canola meal.

MATERIALS AND METHOD

A series of diets were formulated to provide 80, 85, 90, and 95% of the digestible amino acid levels suggested for starting broiler chicks by Rostagno et al., (2011). The requirement for Gly+Ser was based on total requirement as no valid data for Gly+Ser digestibility was available. Diets were formulated so that the diet with the lowest amino acid level with corn and soybean meal would contain approximately 1.0% added poultry oil with the amino acids adjusted to the dietary energy level. Additional diets were then maintained isocaloric to this level, even though requiring some very high levels of poultry oil in the canola meal diets. Diets incorporated commercially available amino acids (Met, Lys, Thr, and Val) to reduce amino acid excess and bring as many amino acids to a minimum level as possible in order to make the diets more sensitive to improvement in digestibility. One series was formulated using only CS of known composition (Table 1) while a second series was formulated using CS, and 30% CM of known composition (Table 2). These two series were fed with no protease supplementation and served as the standard response curve to assess the effectiveness of the protease enzyme.

Two parallel studies were conducted using the same experimental design. Aliquots of the diets with 80, 85, 90, and 95% suggested amino acid levels were supplemented with one of two commercial protease enzymes (Ronozyme ProAct, DSM; Cibenza DP-100, Novus). For each enzyme, one group received the suggested level of supplementation, while a second group received twice the suggested level of supplementation. The ProAct was fed at 200 and 400 g per metric ton (0.02 and 0.04%) while the Cibenza was fed at 500 and 1,000 g per metric ton (0.05 and 0.10%). Both products are based on *Bacillus licheniformis*. Each diet was fed to six replicate pens of five male broilers of a commercial strain. Birds were placed on the test diets at one day of age and fed for 18 days. Body weight and feed consumption were recorded at day 18.

Performance of birds fed the diets supplemented with enzymes was compared to the standard response curve to determine extent of response to the protease enzyme.

Male chicks of a commercial broiler strain (Cobb 500) were obtained from a local hatchery where they were vaccinated in ovo for Marek's Disease and had received vaccinations for Newcastle Disease and infectious bronchitis post hatch via a coarse spray. In each study, five chicks were assigned to each of 144 compartments in the brooders. Fluorescent lights provided 24 hours of light daily. Care and management of the birds followed recommended guidelines (FASS, 2010). All procedures were approved by The University of Arkansas Institutional Animal Care and Use Committee.

Statistical Analysis

Pen means served as the experimental unit. Data was analyzed as a 2 x 4 x 3 factorial arrangement of treatments with two diet types (corn-soy, corn-soy-canola) four amino acid levels (80, 85, 90, and 95%) and the enzymes fed at three levels (0, 1X, and 2X), using the General Linear Models procedure of the SAS Institute (1991) for ANOVA. When significant differences among treatments were found, means were separated using the Duncan's multiple range test. Mortality data were transformed to $\sqrt{n+1}$ prior to analysis; data are presented as natural numbers. All statements of statistical significance are based on $P \leq 0.05$.

RESULTS

Diets formulated with corn and soybean meal were at the minimum level for lysine, TSAA, valine, threonine, and glycine+serine at every amino acid level (Table 1). In contrast, the diets formulated with corn, soybean meal, and canola meal were at minimum levels of lysine, TSAA, threonine, and isoleucine in every diet (Table 2). Although valine was offered in the canola meal diets, it was not accepted since isoleucine was the fourth limiting amino acid.

Proact Enzyme

The ANOVA results for the ProAct enzyme study are shown in Table 3. The main effects of diet type, amino acid level, and ProAct enzyme are see in Table 4.

The diet type had a significant effect on BW and FCR at 18 d with no effect on mortality. Birds fed the diets with 30% CM were significantly superior in both measurements compared to those fed corn-soybean meal diets. As expected, birds responded to the increase in dietary amino acid levels with an increased BW and improved FCR. Addition of the enzyme at its recommended rate (1x) did not improve BW or FCR. However, when added at 2x rate the FCR was significantly reduced compared to the control or 1x level.

The statistical evaluations for the ProAct enzyme study are shown in Table 3. Treatment means are shown in Table 5 and Table 6. There was a significant interaction between amino acid level and ProAct enzyme level for FCR (Table 3) and between diet type x amino acid level x enzyme level (Table 3) that significantly improved FCR as seen in Figure 1.

Cibenza Enzyme

The ANOVA results for the Cibenza enzyme study are shown in Table 7. The main effects of diet type, amino acid level, and Cibenza enzyme level are shown in Table 8.

Birds fed the diets with 30% CM had significant better BW and improved FCR than those fed the corn-soybean meal control diet. As expected, BW and FCR improved significantly as the amino acid level increased. No significant improvement in BW or FCR was noted from the addition of enzyme, even at the 2x level of supplementation.

The statistical evaluations for the Cibenza enzyme study are shown in Table 7. Treatment means are shown in Table 9, Table 10 and Figure 2. There was a significant interaction of diet type and amino acid level for BW and significant interaction of diet type and enzyme for FCR that improved these performance parameters (Table 7). In addition, significant interaction was displayed between diet type, amino acid level, and enzyme level for BW that also improved this production parameter (Table 7).

DISCUSSION

Amino Acid levels, Canola Meal Inclusion, and Mortality

The performance outcomes for BW and FCR in this experiment indicated that birds fed diets containing incrementally higher percentages of AA, or diets containing CSC, consistently outperformed the birds fed lower amounts of AA or diets not containing CM. Our results of declining bird BW and FCR, as birds were fed reduced amounts of AA, were in agreement with the recommended amounts for AA levels reported by Rostagno et al., (2011). Our outcomes were also in agreement with those reported by (Waldroup et al., 1990; Skinner et al., 1991; Kidd et al., 2004; Corzo et al., 2005), who all reported reduced broiler performance when birds were fed diets with incrementally reduced AA levels. Our conclusion of improved performance with the inclusion of 30% CM was in disagreement with Hickling, (2001) who recommended a maximum level of 15% canola meal in in standard broiler diets; Roth-Maier et al., (1999) who reported a reduction in BW with CM inclusion greater than 15%; and Mushtaq et al., (2007) who concluded that 30% CM should not be used in broiler starter diets. Our findings of improved BW and FCR were also in disagreement with Thomke et al., (1983) who reported in two separate experiments that feeding CM from solvent extraction to broilers resulted in unaltered BW as compared to soybean meal. However, our results confirmed the results of Nassar and Arscott, (1986) research that reported CM could be utilized in broiler starter diets to replace up to 50% of SBM without adversely affecting general performance. Our findings of improved BW and FCR with birds fed diets including 30% CM were also in agreement with Nassem et al., (2006) who reported in their 35 day study that BW and FCR improved when CM was included in broiler diets up to 25%. Mortality showed no significant differences related to AA levels or the inclusion of CM throughout our research.

Protease enzymes

Effects of using protease enzymes to advance broiler performance by improving the digestibility of protein by hydrolysis of the peptide bonds and poly-peptide chains found in oilseed meals have been investigated and a variety of different outcomes has been established. Our research results showed the addition of the protease enzymes ProAct or Cibenza did not significantly improve BW. Our findings of unimproved BW for broilers fed diets containing protease enzymes were in agreement with the following scientists and their reported findings; Kocher et al., (2003) reported that none of the multiple enzyme combinations used in their experiment proved beneficial in improving the performance of 3 to 4 week old broiler chickens; Kocher et al., (2000) investigated the addition of enzymes to oilseed diets including three treatments with 35% CM and they reported no significant effects on growth; Marsman et al., (1997) used a combination of protease and carbohydrase enzymes and reported results of unimproved growth performance in their study; Kalmendal and Tauson, (2012) investigated the addition of ProAct to broiler diets and reported no effect on BW; However, in disagreement with the findings for BW of our experiment; Fru-nji et al., (2011) reported male broilers consuming diets that included the addition of the protease enzyme ProAct had significantly improved BW, but they used ProAct in combination with other enzymes. In our experiment, the performance parameter of FCR proved unaffected by the addition of Cibenza at any level, however significant improvement occurred when ProAct was fed to broilers at 2 times the recommended level. Our results in agreement with Kocher et al., (2000), reported no improvement in FCR for chickens fed diets containing 35% CM and enzymes at supplier's recommended level; Marsman et al., (1997) also reported no difference in FCR for broilers fed diets containing a protease enzyme or a combination of a protease enzyme and a cell wall degrading enzyme, but neither of these experiments add the protease enzyme ProAct at 2 times the recommended level.

CONCLUSION

These data suggest that birds performed better as AA percentages increased or when consuming diets with CSC. The addition of protease enzymes did not improve the bird's BW; however, when birds consumed diets containing ProAct at 2 times the suggested level, FCR displayed significant improvement when compared to the control or when added at suggested level.

REFERENCES

Corzo, A., M. T. Kidd, D. J. Burnham, E. R. Miller, S. L. Branton, and R. Gonzalez-Esquerra. 2005. Dietary amino acid density effects on growth and carcass of broilers differing in strain cross and sex. J. Appl. Poult. Res. 14:1-9.

FASS, 2010. Guide for the Care and Use of Agricultural Animals in Research and Teaching. 3rd ed. Federation of Animal Science Societies, Savoy IL.

Fru-Nji, F., A. M. Kluenter, M. Fischer, and K. Pontoppidan. (2011). A feed serine protease improves broiler performance and increases protein and energy digestibility. J. Poult. Sci. 48:239-246.

Hickling, D., 2001. Canola Meal: Feed Industry Guide. Canola Council of Canada.

Kalmendal, R. and R. Tauson. (2012). Effects of xylanase and protease, individually or in combination, and an ionophore coccidiostat on performance, nutrient utilization, and intestinal morphology in broiler chickens fed a wheat-soybean meal-based diet. Poult. Sci. 91:1387-1393.

Kidd, M. T., C. D. McDaniel, S. L. Branton, E. R. Miller, B. B. Boren, and B. I. Fancher. 2004. Increasing amino acid density improves live performance and carcass yields of commercial broilers. J. Appl. Poult. Res. 13:593-604.

Kocher, A., M. Choct, M. D. Porter, and J. Broze. (2000). The effect of enzyme addition to broiler diets containing high concentrations of canola or sunflower meal. Poult. Sci. 79:1767-1774.

Kocher, A., M. Choct, G. Ross, J. Broz, and T. K. Chung. (2003). Effects of enzyme combinations on apparent metabolizable energy of corn-soybean meal-based diets in broilers. J. Appl. Poult. Res. 12:275-283.

Marsman, G. J. P., H. Gruppen, A. F. B. Van Der Poel, R. P. Kwakkel, M. W. A. Verstegan, and A. G. J. Vorgan. (1997). The effect of thermal processing and enzyme treatments of soybean and chyme characteristics in broiler chicks. Poult. Sci. 76:884-872.

Mushtaq, T., M. Sarwar, G. Ahmad, M. A. Mirza, H. Nawaz, M. M. Haroon Mushtaq, and U. Noreen. 2007. Influence of canola meal-based diets supplemented with exogenous enzyme and digestible lysine on performance, digestibility, carcass, and immunity responses of broiler chickens. Poult. Sci. 86:2144-2151.

Naseem, M., S. Khan, and M. Yousaf. 2006. Effect of feeding various levels of canola meal on the performance of broiler chicks. J. Anim. Plant Sc. 16.

Nassar, A., and G. Arscott. 1986. Canola meal for broilers and the effect of a dietary supplement of iodinated casein on performance and thyroid status. Nutr. Rep. Int. 34.

Rostagno, H. R., L. F. T. Albino, J. L. Donzele, P. C. Gomes, R. F de Olveira, D. C. Lopes, A. S. Ferreira, S. L. deT. Barreto, and R. F. Euclides. 2011. Brazilian Tables for Poultry and Swine. Composition of Feedstuffs and Nutritional Requirements. 3rd ed. H. S. Rostagno, ed. Universidade Federal de Vocosa, Dept. Zootecnia, Vicosa, MG, Brazil.

Roth-Maier, D. 1999. Investigation on feeding full-fat canola seed and canola meal to poultry. 10th International Rapeseed Congress. Canberra, Australia. 1999.

SAS Institute, 1991. SAS® User's Guide: Statistics. Version 6.03 edition. SAS Institute Inc., Cary, NC.

Skinner, J., A. Izat, and P. W. Waldroup. 1991. Effects of dietary amino acid levels on performance and carcass composition of broilers 42 and 49 days of age. Poult. Sci. 70:1223-1230.

Thomke, S., K. Elwinger, M. Rundgren, and B. Ahlström. 1983. Rapeseed meal of Swedish low-glucosinolate type fed to broiler chickens, laying hens and growing-finishing pigs. Acta Agric. Scand. 33:75-96.

Waldroup, P. W., N. M. Tidwell, and A. L. Izat. 1990. The effects of energy and amino acid levels on performance and carcass quality of male and female broilers grown separately. Poult. Sci. 69:1513-1521.

Table 1. Composition (%) and calculated nutrient content of diets with corn and soybean meal formulated to meet various percentages of 2011 Brazil recommendations. All diets contain 1400 ME kcal/l, 0.84% calcium, 0.40% nonphytate P, and 0.25% sodium. Nutrient values in bold are at minimum specified level.

Ingredient	Percent of suggested amino acid levels						
	80	85	90	95	100	105	110
Yellow corn	67.534	64.419	61.063	58.012	53.936	51.300	48.131
Soybean meal	27.803	30.460	33.340	35.932	39.157	41.690	44.401
Poultry oil	1.047	1.517	2.032	2.488	3.354	3.504	3.987
Limestone	0.870	0.837	0.799	0.766	0.733	0.697	0.661
Dical phosphate	1.528	1.513	1.497	1.482	1.475	1.449	1.434
Sodium chloride	0.568	0.567	0.566	0.565	0.564	0.563	0.562
MHA-[1]	0.244	0.270	0.300	0.330	0.350	0.370	0.400
L-Lysine HCl	0.189	0.183	0.179	0.182	0.181	0.173	0.170
L-Threonine	0.039	0.046	0.040	0.048	0.055	0.056	0.058
L-Valine	0.003	0.013	0.009	0.020	0.020	0.023	0.021
Broiler premix[2]	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Mintrex P_Se[3]	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Choline Cl 60%	0.100	0.100	0.100	0.100	0.100	0.100	0.100
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Crude protein	17.96	18.96	20.03	21.01	22.20	23.17	24.18
Methionine	0.50	0.54	0.58	0.61	0.64	0.67	0.71
Lysine	1.09	1.15	1.22	1.29	1.37	1.43	1.49
Tryptophan	0.22	0.23	0.25	0.26	0.28	0.29	0.31
Threonine	0.73	0.78	0.81	0.86	0.91	0.95	1.00
Valine	0.84	0.90	0.94	1.00	1.06	1.11	1.15
TSAA	0.81	0.86	0.91	0.96	1.00	1.04	1.09
Gly+Ser	**1.60**	**1.70**	**1.80**	**1.89**	**2.01**	**2.10**	**2.19**
dLysine	**0.96**	**1.02**	**1.08**	**1.14**	**1.21**	**1.27**	**1.32**
dMethionine	0.45	0.48	0.52	0.55	0.58	0.61	0.65
dTSAA	**0.70**	**0.74**	**0.79**	**0.84**	**0.88**	**0.91**	**0.96**
dTryptophan	0.18	0.19	0.21	0.22	0.24	0.25	0.26
dThreonine	**0.63**	**0.67**	**0.70**	**0.74**	0.79	**0.82**	**0.86**
dArginine	**1.05**	1.12	1.20	1.27	1.36	1.42	1.50
dValine	**0.74**	**0.79**	**0.83**	**0.88**	**0.93**	**0.98**	**1.02**
dIsoleucine	0.66	0.71	0.75	0.79	0.84	0.88	0.93
dLeucine	1.43	1.49	1.55	1.61	1.67	1.73	1.79
dHistidine	0.43	0.45	0.47	0.50	0.52	0.54	0.57
dPhenylalanine	0.79	0.83	0.88	0.92	0.98	1.02	1.07

Notes from Table 1 continued on following page

Notes from Table 1 continued from previous page

[1]Methionine hydroxy analogue calcium salt. Novus International, St. Louis MO.
[2] Provides per kg of diet: vitamin A 7715 IU; cholecalciferol 5511 IU; vitamin E 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione 1.5 mg; folic acid 0.9 mg; thiamin 1.54 mg; pyridoxine 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg.
[3] Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 20 mg; Zn (as zinc methionine hydroxy analogue complex) 20 mg; Cu (as copper methionine hydroxy analogue complex) 10 mg; Se (as selenium yeast) 0.15 mg.

Table 2. Composition (%) and calculated nutrient content of diets with corn, soybean meal, and canola meal formulated to meet various percentages of 2011 Brazil recommendations. All diets contain 1400 ME kcal/lb, 0.84% calcium, 0.40% nonphytate P, and 0.25% sodium. Nutrient values in bold are at minimum specified level.

Ingredient	Percent of suggested amino acid levels						
	80	85	90	95	100	105	110
Yellow corn	51.242	48.349	45.298	42.251	39.419	36.159	33.190
Soybean meal	10.370	12.840	15.439	18.030	20.439	23.229	25.760
Canola meal	30.000	30.000	30.000	30.000	30.000	30.000	30.000
Poultry oil	5.270	5.708	6.173	6.633	7.056	7.553	8.005
Limestone	0.775	0.744	0.705	0.676	0.643	0.610	0.575
Dical phosphate	1.320	1.305	1.291	1.276	1.262	1.245	1.230
Sodium chloride	0.528	0.527	0.526	0.525	0.524	0.523	0.522
MHA[1]	0.117	0.140	0.180	0.210	0.230	0.260	0.290
L-Lysine HCl	0.202	0.201	0.205	0.208	0.223	0.215	0.217
L-Threonine	0.001	0.011	0.008	0.016	0.029	0.031	0.036
L-Valine	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Broiler premix[1]	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Mintrex P_Se[1]	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Choline Cl- 60%	0.100	0.100	0.100	0.100	0.100	0.100	0.100
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Crude protein	19.93	20.86	21.83	22.81	23.73	24.77	25.72
Methionine	0.46	0.49	0.53	0.57	0.60	0.64	0.67
Lysine	1.14	1.21	1.27	1.34	1.42	1.48	1.55
Tryptophan	0.22	0.23	0.24	0.26	0.27	0.29	0.30
Threonine	0.78	0.82	0.86	0.91	0.96	1.00	1.04
Valine	0.93	0.97	1.02	1.07	1.11	1.16	1.20
TSAA	0.85	0.90	0.95	1.00	1.04	1.09	1.14
Gly+Ser	1.92	2.00	2.10	2.19	2.27	2.37	2.46
dLysine	**0.96**	**1.02**	**1.08**	**1.14**	**1.21**	**1.27**	**1.32**
dMethionine	0.40	0.43	0.47	0.51	0.53	0.57	0.60
dTSAA	**0.70**	**0.74**	**0.79**	**0.84**	**0.87**	**0.92**	**0.96**
dTryptophan	0.18	0.19	0.20	0.22	0.23	0.24	0.25
dThreonine	**0.63**	**0.67**	**0.70**	**0.74**	0.78	**0.82**	**0.86**
dArginine	1.06	1.13	1.20	1.27	1.33	1.41	1.47
dValine	0.78	0.82	0.86	0.90	0.94	0.98	1.02
dIsoleucine	**0.65**	**0.69**	**0.73**	**0.77**	**0.81**	**0.85**	**0.89**
dLeucine	1.42	1.47	1.53	1.58	1.63	1.69	1.75
dHistidine	0.43	0.46	0.48	0.50	0.52	0.54	0.57
dPhenylalanine	0.75	0.79	0.83	0.88	0.92	0.97	1.01

[1]As given in Table 1.

Table 3. Statistical analysis for ProAct enzyme

Source of variation	Probability > F		
	BW	FCR	Mort
Diet x Amino x Enz.Level	0.087	0.030	0.214
SEM	0.004	0.006	0.002
CV	6.758	5.083	1.829
Diet type (CS vs. CSC)	< 0.001	< 0.001	0.617
Amino acid	< 0.001	< 0.001	0.182
Enzyme level (level)	0.277	0.003	0.289
Diet x Amino	0.541	0.497	0.277
Diet x Enz. level	0.516	0.072	0.247
Amino x Enz. Level	0.14	0.035	0.767

Table 4. The main effects of diet type, amino acid level, and level of ProAct enzyme on live performance of 18 d broilers

Treatment	BW (kg)	FCR (kg/kg)	% Mort
Diet type			
Corn-soy (CS)	0.633[b]	1.406[a]	0.556
Canola (CSC)	0.660[a]	1.365[b]	0.889
Amino acid %			
80	0.610[c]	1.443[a]	0.000
85	0.641[b]	1.393[b]	1.667
90	0.657[b]	1.363[c]	0.000
95	0.676[a]	1.342[c]	1.222
Enzyme Level			
0	0.640	1.396[a]	0.000
1X	0.647	1.397[a]	0.917
2X	0.652	1.364[b]	1.250

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Table 5. Treatment means of ProAct enzyme trial on live performance of 18 d broilers.

Diet x AA		BW (kg)	FCR (kg/kg)	% Mort
CS	80	0.602	1.461	0.000
	85	0.624	1.405	2.222
	90	0.638	1.394	0.000
	95	0.665	1.364	0.000
CSC	80	0.618	1.426	0.000
	85	0.658	1.381	1.111
	90	0.676	1.332	0.000
	95	0.687	1.321	2.444
Diet x enzyme level		BW (kg)	FCR (kg/kg)	%Mort
CS	0	0.622	1.432	0.000
	1X	0.636	1.409	0.000
	2X	0.640	1.378	1.667
CSC	0	0.659	1.361	0.000
	1X	0.657	1.385	1.833
	2X	0.663	1.349	0.833
Amino x enzyme level		BW (kg)	FCR (kg/kg)	%Mort
80	0	0.596	1.432	0.000
	1X	0.614	1.458	0.000
	2X	0.621	1.439	0.000
85	0	0.634	1.426	0.000
	1X	0.645	1.415	1.667
	2X	0.644	1.339	3.333
90	0	0.648	1.386	0.000
	1X	0.670	1.352	0.000
	2X	0.654	1.351	0.000
95	0	0.684	1.340	0.000
	1X	0.656	1.362	2.000
	2X	0.689	1.325	1.667

Figure 1. Treatment means in ProAct enzyme trial on feed conversion ratio on 18 d broilers

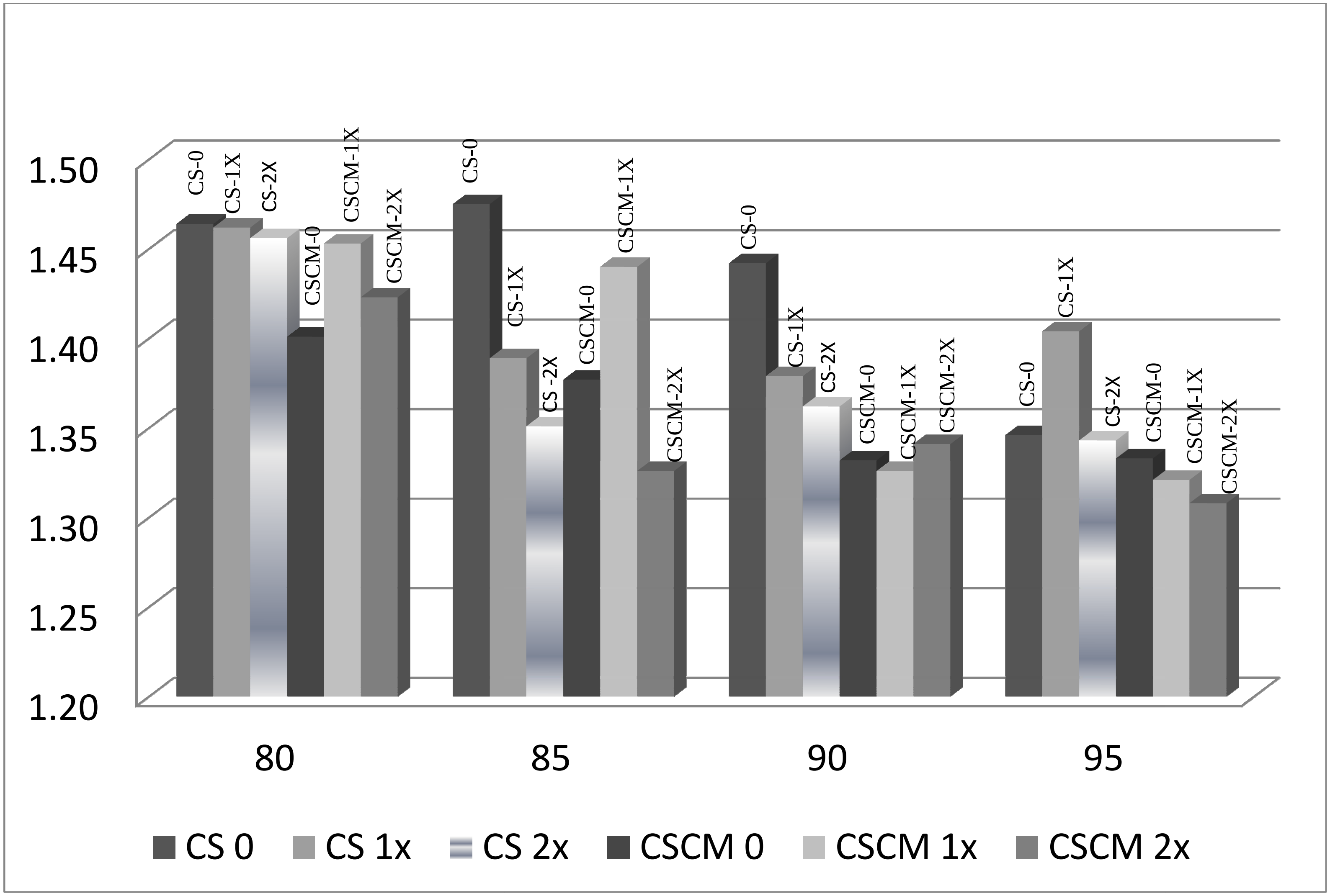


Table 6. Treatment means in ProAct enzyme trial on live performance of 18 d broilers.

Diet x AA x enzyme level			BW (kg)	FCR (kg/kg)	% Mort
CS	80	0	0.569	1.464	0.000
	80	1x	0.622	1.462	0.000
	80	2x	0.616	1.456	0.000
	85	0	0.604	1.475	0.000
	85	1x	0.644	1.389	0.000
	85	2x	0.626	1.351	6.667
	90	0	0.638	1.442	0.000
	90	1x	0.638	1.379	0.000
	90	2x	0.639	1.362	0.000
	95	0	0.677	1.346	0.000
	95	1x	0.640	1.404	0.000
	95	2x	0.679	1.343	0.000
CSC	80	0	0.623	1.401	0.000
	80	1x	0.607	1.453	0.000
	80	2x	0.625	1.423	0.000
	85	0	0.664	1.377	0.000
	85	1x	0.647	1.440	3.333
	85	2x	0.663	1.326	0.000
	90	0	0.658	1.332	0.000
	90	1x	0.701	1.326	0.000
	90	2x	0.668	1.341	0.000
	95	0	0.690	1.333	0.000
	95	1x	0.673	1.321	4.000
	95	2x	0.699	1.308	3.333

Table 7. Statistical analysis for Cibenza enzyme.

Source of variation	Probability > F		
	BW	FCR	Mort
Diet x Amino x Enz. Level	0.049	0.170	0.712
SEM	0.021	0.007	0.001
CV	7.129	5.414	1.475
Diet type (CS vs. CSC)	< 0.001	< 0.001	0.563
Amino acid	< 0.001	< 0.001	0.395
Enzyme level (level)	0.541	0.398	0.435
Diet x Amino	0.011	0.111	0.174
Diet x Enz. level	0.122	0.022	0.820
Amino x Enz. Level	0.306	0.583	0.873

Table 8. The main effects of diet type, amino acid level, and level of Cibenza enzyme on live performance of 18 d broilers

Treatment	BW (kg)	FCR (kg/kg)	% Mort
Diet type			
Corn-soy (CS)	0.634[b]	1.415[a]	0.611
Canola (CSC)	0.657[a]	1.373[b]	0.278
Amino acid %			
80	0.610[c]	1.444[a]	1.222
85	0.640[b]	1.407[b]	0.000
90	0.650[b]	1.382[b]	0.556
95	0.681[a]	1.342[c]	0.000
Enzyme Level			
0	0.642	1.403	0.000
1X	0.649	1.393	0.917
2X	0.645	1.385	0.417

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

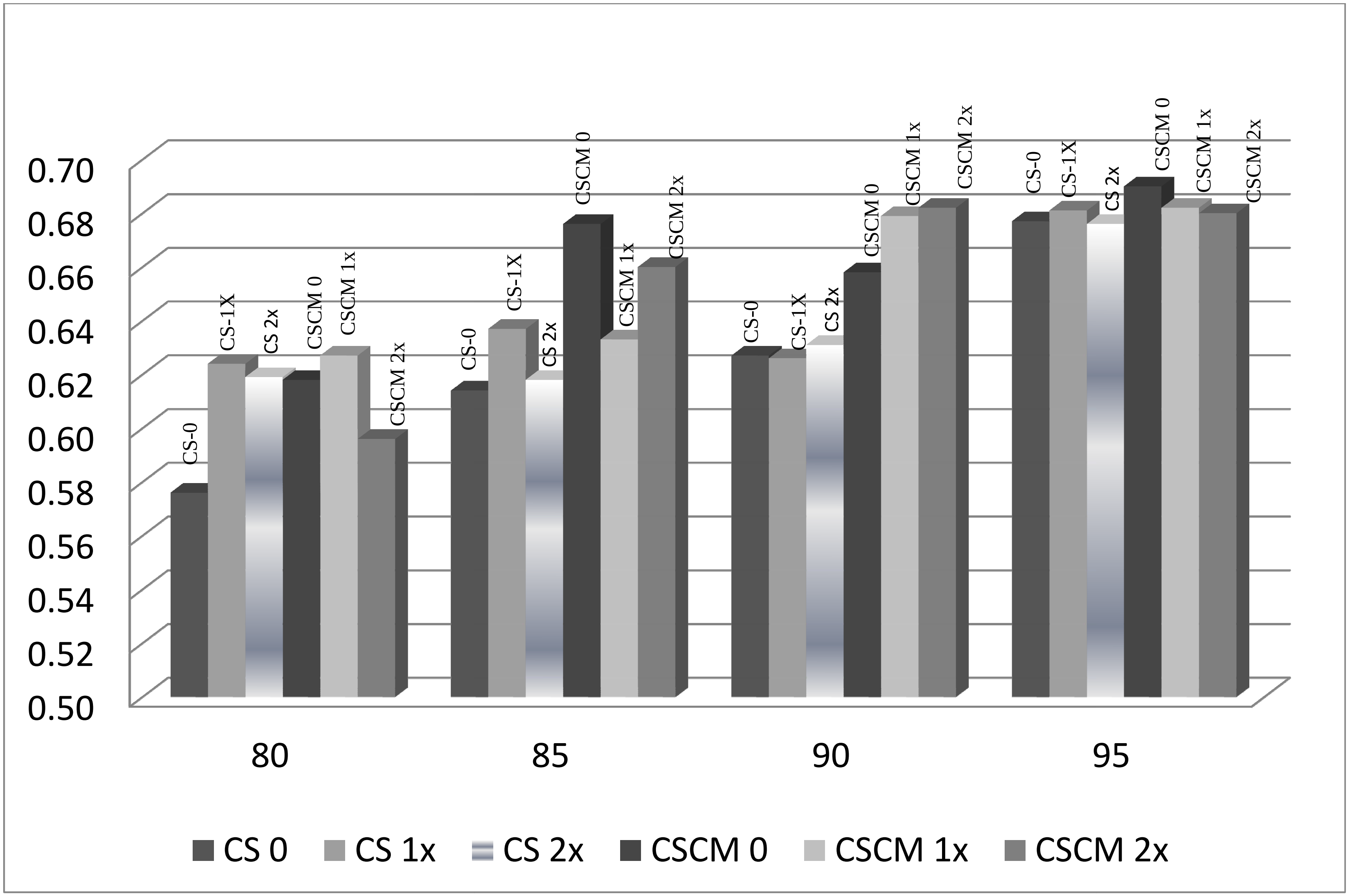
Table 9. Treatment means in Cibenza enzyme trial on live performance of 18 d broilers.

Diet x AA		BW (kg)	FCR (kg/kg)	% Mort
CS	80	0.606	1.480	2.444
	85	0.623	1.411	0.000
	90	0.628	1.414	0.000
	95	0.678	1.355	0.000
CSC	80	0.613	1.408	0.000
	85	0.656	1.404	0.000
	90	0.673	1.350	1.111
	95	0.684	1.329	0.000
Diet x enzyme level		**BW (kg)**	**FCR (kg/kg)**	**% Mort**
CS	0	0.623	1.444	0.000
	1X	0.642	1.400	1.000
	2X	0.636	1.405	0.833
CSC	0	0.660	1.362	0.000
	1X	0.655	1.389	0.833
	2X	0.655	1.366	1.000
Amino x enzyme level		**BW (kg)**	**FCR (kg/kg)**	**% Mort**
80	0	0.597	1.444	0.000
	1X	0.626	1.447	2.000
	2X	0.607	1.441	1.667
85	0	0.645	1.426	0.000
	1X	0.635	1.386	0.000
	2X	0.639	1.410	0.000
90	0	0.642	1.404	0.000
	1X	0.652	1.388	1.667
	2X	0.656	1.353	0.000
95	0	0.684	1.339	0.000
	1X	0.682	1.350	0.000
	2X	0.678	1.338	0.000

Table 10. Treatment means in Cibenza enzyme trial on live performance of 18 d broilers.

Diet x AA x enzyme level			BW (kg)	FCR (kg/kg)	% Mort
CS	80	0	0.576	1.488	0.000
	80	1x	0.624	1.478	4.000
	80	2x	0.619	1.475	0.000
	85	0	0.614	1.466	0.000
	85	1x	0.637	1.346	0.000
	85	2x	0.618	1.422	0.000
	90	0	0.627	1.477	0.000
	90	1x	0.626	1.401	0.000
	90	2x	0.631	1.365	0.000
	95	0	0.677	1.346	0.000
	95	1x	0.681	1.361	0.000
	95	2x	0.676	1.359	0.000
CSC	80	0	0.618	1.400	0.000
	80	1x	0.627	1.417	0.000
	80	2x	0.596	1.407	3.333
	85	0	0.676	1.385	0.000
	85	1x	0.633	1.427	0.000
	85	2x	0.660	1.399	0.000
	90	0	0.658	1.331	0.000
	90	1x	0.679	1.375	3.333
	90	2x	0.682	1.341	0.000
	95	0	0.690	1.333	0.000
	95	1x	0.682	1.338	0.000
	95	2x	0.680	1.316	0.000

Figure 2. Treatment means in Cibenza enzyme trial on 18 d broiler body weight



Effect of Combinations of Distillers Dried Grains with Solubles (DDGS) and Canola Meal in Broiler Diets

C.D. Bradley, S. M. Fiscus, S. D. Goodgame, F.J. Mussini, C. Lu, and P.W. Waldroup
Poultry Science Department, University of Arkansas, Fayetteville AR 72701

ABSTRACT

The objective of this research was to evaluate pellet quality, broiler performance, and carcass characteristics of birds fed diet combinations of distillers dried grains with solubles (DDGS), soybean meal (SBM), and canola meal (CM). This 42 day experiment examined 25 chicks (Cobb 500) in 24 floor pens that were fed four different diets. The diets included a 2 x 2 factorial arrangement with DDGS levels of 0 and 15% and CM levels of 0 and 20%. Samples of each diet were assessed for pellet quality by evaluating percentages of intact pellets. Bird performance was evaluated at three stages of development for body weight (BW), feed conversion ratio (FCR), feed intake (FI), mortality (MORT), calories consumed (CC), and caloric efficiency (CE). Five birds from each pen were processed for dressing percentage and parts yield. At 42 days, FCR and CE significantly decreased as CM was added. However, BW showed no significant differences with any group. Processing results revealed, dressing percentage (DP), breast percentages and breast weights in grams declined significantly with the addition of CM. These data suggest that 15 % DDGS and 20% CM can be used in combination without significantly affecting pellet quality. However, performance and parts yield displayed undesirable characteristics in BW and FCR as the CM was added and it is not recommended to use 20% CM in combination with 15% DDGS.

Key words: Broiler, canola, DDGS, distillers, grain, optimum density

INTRODUCTION

In the last decade, our world has begun looking for ways to replace a percentage of fossil fuels and become more environmental friendly. This search for “green” fuels has contributed to an increase in ethanol and biodiesel production, which in turn has produced a greater demand for grains like corn, soybeans, and canola. As production of biofuels from grains has increased, so have the byproducts of this process. The byproducts produced from biofuel production include dried distillers grains with soluble (DDGS) from corn, soybean meal (SBM) from soybeans, and canola meal (CM) from the oilseed canola. The increase in DDGS, SBM, and CM availability has initiated nutritionists to look closer at this combination of byproducts as a way to feed broiler chickens.

Increases in production of biofuels, both ethanol and biodiesel, have had a significant impact upon the poultry industry due to diversion of grains and inedible fats and oils. This has caused a major increase in the price of corn, soybean meal, and feed grade fat meals that have served as the primary feed ingredient for many years. This has caused nutritionist to focus their attention to alternative feedstuffs that might substitute for a portion of the broiler diet. Many studies have demonstrated that both DDGS and canola meal can be effectively used in broiler diets when substituted on the basis of their digestible nutrient content; however few have investigated the combined use of these two ingredients. Min et al., (2009) demonstrated that when DDGS and canola meal are used in combination, the total level of the two ingredients in the formulation should be considered. One of the adverse effects of addition of combinations of DDGS and canola meal in the cited study was the reduction in pellet quality as the level of the ingredients increased and the need to increase supplemental fats to maintain the diets isocaloric. The objective of the present study is to evaluate the individual and combined usage of canola meal and DDGS in diets for broiler chickens when formulated to optimum nutrient density on broiler performance, processing part yields, and pellet quality.

MATERIALS AND METHODS

Corn, soybean meal, canola meal, and DDGS of known composition were used in the study. The diets were formulated to meet the digestible amino acid needs for high performing broilers suggested by Rostagno et al., (2011). Four diets were prepared within each age group. These consisted of a positive control diet using only corn and soybean meal as intact sources of energy and protein, a diet with 15% DDGS, a diet with 20% canola, and a diet with 15% DDGS plus 20% canola meal. Supplemental methionine, lysine, threonine, and valine were provided to enable meeting as many amino acids at minimum specifications. Diets were formulated to have the optimum nutrient density (metabolizable energy and related nutrients) commensurate with approximately 1% supplemental poultry oil, added prior to pelleting. Diets were fortified with complete vitamin and trace mineral premixes obtained from commercial sources. Composition of diets for starter, grower, and finisher periods is shown in Tables 1, 2, and 3 Calculated nutrients for diets is shown in tables 4, 5, and 6. Diets were pelleted with steam with starter diets fed as crumbles. Each of the four dietary treatments was assigned to six replicate pens of 25 chicks in a randomized block design.

Male chicks of a commercial broiler strain (Cobb 500) were obtained from a local hatchery where they had been vaccinated in ovo for Marek's disease and had received vaccinations for Newcastle Disease and Infectious Bronchitis post hatch via a coarse spray. New softwood shavings served as litter over concrete floors. Twenty five chicks were assigned to each of 24 pens in a broiler house of commercial design. Each pen was equipped with two tube feeders and an automatic water font. Supplemental feeders and waters were used during the first seven days. Temperature and airflow were controlled by automatic heaters and ventilation fans. Incandescent lights supplemented natural daylight to provide 23 hours of light daily. Care and management of the birds followed recommended guidelines (FASS, 2010). All procedures were approved by the University of Arkansas Institutional Animal Care and Use Committee.

Body weights by pen were obtained at 1, 21, 35, and 42 d of age with feed consumption determined during the same period. Birds were checked twice daily for mortality; any bird that died or was removed to alleviate suffering was weighed with the weight used to adjust feed conversion. At the conclusion of the study, five birds per pen were randomly selected for processing after a 12 hour fast in a pilot processing plant using mechanical evisceration to determine dressing percentage and parts yield.

Grower and finisher diets were evaluated for pellet quality. For one evaluation, pellet quality was determined using quadruplicate samples taken at intervals during the pelleting process. A weighed amount of feed (approx. 500 g) was placed on a stack of sieves on a Tyler Sieve Shaker (W.S. Tyler Co., Mentor OH 44060) for 30 sec at a rate of 278 oscillations per min. Feed that passed through a 2 mm screen was considered as fines. In the second evaluation, a 500 g sample of screened pellets was placed in a rotating tumbling device for ten minutes; at the end of ten minutes the percentage of intact pellets was determined.

Pen means served as the experimental unit. Data was analyzed as a 2 x 2 factorial arrangement of treatments with two DDGS levels (0, 15%) and two CM levels (0, 20%), using the General Linear Models procedure of the SAS Institute (1991) for ANOVA. When significant differences among treatments were found, means were separated using the Duncan's multiple range test. Mortality data were transformed to $\sqrt{n+1}$ prior to analysis; data are presented as natural numbers. All statements of statistical significance are based on $P \leq 0.05$.

RESULTS

Performance

The statistical evaluations for 21 d are presented in Table 7. The effects for 21 d performance are presented in Table 8.

At 21 d (Table 8), there was no significant difference in BW between birds fed corn-soybean meal control diet or the diet with 15% DDGS. However, the inclusion of 20% CM significantly reduced the BW. Similar results were observed for feed conversion. There was no significant difference in FCR between birds fed the corn-soybean meal control and those fed the diet with 15% DDGS. However, birds fed the diet with 20% CM had significantly higher FCR than those fed the control diet. As these diets were not isocaloric this increase should be expected. No significant difference was observed among any of the treatments for Calorie Conversion Ratio (CCR) or mortality in the first stage of development. Feed intake was significantly increased when birds consumed the diet containing 15% DDGS when compared to the CS control diet. The calories consumed per bird showed significant reduction as birds were fed diets containing CM. There was no significant interactions displayed for DDGS X CM in the 0-21d data (Table 7).

The statistical evaluations for 35 d are presented in Table 9. The effects for 35 d performance are presented in Table 10.

At 35 d (Table 10), no significant difference was shown in FI or percent mortality. No significant difference was displayed in BW between birds fed the corn-soybean meal diet and the diet with 15% DDGS. However, the BW of birds fed the diet with 20% CM was significantly reduced. Feed conversion followed the same pattern of response. Birds fed diets containing amounts of DDGS or CM displayed the best CCR. The calories consumed per bird revealed significant reduction as birds were fed diets containing CM when compared to birds fed the control diet. An interaction between DDGS x CM was significant, increasing FI (Table 9).

The statistical evaluations for 42 d are presented in Table 11. The effects for 42 d performance are presented in Table 12.

At 42 d (Table 12), No significant difference was observed among any of the treatments in this experiment for CCR or mortality. Body weights were significantly decreased as birds were fed the diets containing CM when compared to the control. Feed conversion of the birds fed the diet with 20% CM or 15 % DDGS was significantly higher than that of birds fed the corn-soybean meal control. Calories consumed per bird when all stages of development were combined showed a significant decrease when birds were fed CM compared to the control. Birds consuming the diet containing 15% DDGS or 20% CM exhibited significantly higher FI than those of the control groups. There were no significant interactions displayed for DDGS X CM in the 0-42d data (Table 7).

Processing

The statistical evaluations for processing measured as a percentage of LW and CW are presented in Table 13. The effects of parts yield as a percentage of CW or LW are presented in Table 14. The statistical evaluations for processing measured in actual weight are presented in Table 15. The effects on actual carcass weights are presented in Table 16.

Dress percentage was significantly reduced in birds fed 20% CM as compared to the birds fed the corn-soybean meal control (Table 14). Breast meat yield, expressed either as a percent of live or a percent of carcass weight, was also significantly reduced in birds fed the CM treatments. Leg quarters expressed as a % of CW showed a significant decrease as CM was included in the diet. This resulted in proportional increases in the percentage of wings. There were no significant interactions displayed for DDGS X CM in the processing data measured as a percentage of LW or CW (Table 13).

It appears that the primary effect of the dietary treatment or parts yield was the reduction in breast weight of birds fed diets with 20% CM (Table 16). There was no significant difference in weight of leg quarters, weight of wings or no significant interactions displayed for DDGS X CM in actual parts weights (Table 15).

There was no significant difference in pellet quality of the diets, measured either by the Tyler Sieve Shaker or the by the rotating tumble mixer (Table 17). As these diets contained a similar amount of supplemental poultry oil, differences in pellet quality were not expected, therefore the adverse response to diets with 20% CM or the combination of 15% DDGS and 20% CM was not related to pellet quality.

DISCUSSION

Performance

Although many experiments have been conducted evaluating bird performance when fed diets containing CM or DDGS, few have explored the combination of the two in broiler diets. Most of the experiments containing DDGS, CM, or a combination of the two, have maintained diets on an isocaloric basis with the addition of PO. This study maintained diets with optimum nutrient density and a constant 1% PO. The findings for BW when DDGS was added to the diets generally agreed with the findings of Min et al., (2009) who reported in an 18d battery trial that chicks BW showed little differences when DDGS was added to diets. However, our findings disagreed with those of Min et al., (2009) when CM was added. Min reported little adverse effect on BW within CM levels of 10 to 20% this difference was probably due to the lower caloric value of the diets when CM was added. Our findings for FI and FCR were also in disagreement with those of Min et al., (2009) who reported FI was significantly impacted by both DDGS and CM inclusion levels and no significant differences for FCR in any treatment containing CM or DDGS. Again, the differences between our findings and Min et al., (2009) findings can be explained by the lower caloric value of the diets containing CM in our study. This theory is confirmed by the results from our previous CM experiments Bradley et al., (2013a) and Bradley et al., (2013b) when broiler performance and carcass results displayed a significant decline from a reduction in energy values when diets were not kept isocaloric. Also in agreement with Bradley et al., (2013b), the calorie conversion ratio in this study was not significantly affected by the level of CM and that indicates that although the diet was lower in energy, the birds utilized the dietary energy effectively.

Processing

Our processing results were in agreement with those of Wang et al., (2007) who found that birds fed 15% DDGS did not differ in carcass characteristics from those fed diets with no DDGS. The processing outcomes also agreed with those of our previous experiment Bradley et al., (2013b) that found birds fed diets containing 20% CM suffered from a significant decline in carcass part yields.

CONCLUSION

These data suggest that pellet quality was not detrimentally affected with combinations up to 15% DDGS and 20% CM, but performance and processing parts yield weights showed a decline when CM was added to the broiler diets. More work is needed to define proper usage levels of the DDGS and CM in broiler diets if they are maintained isocalorically compared to optimum nutrient densities.

REFERENCES

Bradley C.D., S. Goodgame, F. Mussini, N. Comert, C. Lu, and P. Waldroup. (2013a). Use of canola meal in high energy diets. 1. Isocaloric diets. In preparation.

Bradley C.D., S. Goodgame, F. Mussini, C. Lu, and P. Waldroup. (2013b). Use of canola meal in high energy diets. 1. Optimum density diets. In preparation.

FASS, 2010. Guide for the care and use of agricultural animals in research and teaching. 3rd ed. Federation of Animal Science Societies, Savoy IL.

Min, Y., A. Hancock, F. Yan, C. Lu, C. Coto, A. Karimi, J. Park, F. liu, and P. Waldroup. 2009. Use of combinations of canola meal and distillers dried grains with soluble in broiler starter diets[1]. J. Appl. Poult. Res. 18:725-733.

Rostagno, H.R., L.F.T. Albino, J. L. Donzele, P.C. Gomes, R.F de Olveira, D.C. Lopes, A.S. Ferreira, S.L. deT. Barreto, and R.F. Euclides. 2011. Brazilian Tables for Poultry and Swine. Composition of Feedstuffs and Nutritional Requirements. 3rd ed. H. S. Rostagno, Ed. Universidade Federal de Vocosa, Dept. Zootecnia, Vicosa, MG, Brazil.

SAS Institute, 1991. SAS® User's Guide: Statistics. Version 6.03 edition. SAS Institute Inc., Cary, NC.

Wang, Z., S. Cerrate, C. Coto, F. Yan and P.W. Waldroup. (2007). Effect of rapid and multiple changes in level of Distillers Dried Grain with Soluble (DDGS) in broiler diets on performance and carcass characteristics. Int. J. Poult. Sci. 6:725-731.

Table 1. Composition (g/kg) of starter diets with different combinations of distillers dried grains with solubles (DDGS) and canola meal

INGREDIENT	A	B	C	D
Yellow corn	60.510	52.203	55.608	45.300
Soybean meal 47.5%	34.920	28.290	20.190	15.740
DDGS	0.000	15.000	0.000	15.000
Canola meal 36.5%	0.000	0.000	20.000	20.000
Poultry oil	0.998	1.001	1.000	1.004
Ground limestone	0.782	1.042	0.732	0.976
Dicalcium phosphate	1.470	1.144	1.259	0.905
Sodium chloride	0.564	0.465	0.539	0.439
MHA[1]	0.320	0.270	0.190	0.120
L-Lysine HCl	0.149	0.281	0.199	0.252
L-Threonine	0.062	0.079	0.058	0.039
Vitamin premix[2]	0.025	0.025	0.025	0.025
Coban 90[3]	0.050	0.050	0.050	0.050
Choline Cl 60%	0.100	0.100	0.100	0.100
Mintrex P_Se[4]	0.050	0.050	0.050	0.050
TOTAL	100.000	100.000	100.00	100.000

[1]Calcium salt of methionine hydroxy analogue. Novus International, St. Charles MO.
[2] Provides per kg of diet: vitamin A (from vitamin A acetate) 7715 IU; cholecalciferol 5511 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg.
[3] Elanco Animal Health division of Eli Lilly & Co., Indianapolis, IN 46825.
[4] Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 20 mg; Zn (as zinc methionine hydroxy analogue complex) 20 mg; Cu (as copper methionine hydroxy analogue complex) 10 mg; Se (as selenium yeast) 0.15 mg. Novus International, St. Charles MO.

Table 2. Composition (g/kg) of grower diets with different combinations of distillers dried grains with solubles (DDGS) and canola meal

INGREDIENT	A	B	C	D
Yellow corn	66.585	50.872	59.352	43.664
Soybean meal 47.5%	28.990	30.006	16.809	17.818
DDGS	0	15	0	15
Canola meal 36.5%	0	0	20	20
Poultry oil	1.010	1.008	1.008	1.000
Ground limestone	0.759	0.899	0.694	0.832
Dicalcium phosphate	1.232	0.855	1.003	0.626
Sodium chloride	0.567	0.499	0.541	0.473
MHA[1]	0.306	0.324	0.155	0.173
L-Lysine HCl	0.212	0.184	0.176	0.148
L-Threonine	0.080	0.083	0.037	0.041
L-Valine	0.034	0.045	0.000	0.000
2 X Vitamin premix[2]	0.025	0.025	0.025	0.025
Coban 90[3]	0.050	0.050	0.050	0.050
Choline Cl 60%	0.100	0.100	0.100	0.100
Mintrex P_Se[4]	0.050	0.050	0.050	0.050
TOTAL	100.00	100.00	100.00	100.00

[1]Calcium salt of methionine hydroxy analogue. Novus International, St. Charles MO.

[2] Provides per kg of diet: vitamin A (from vitamin A acetate) 7715 IU; cholecalciferol 5511 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg.

[3] Elanco Animal Health division of Eli Lilly & Co., Indianapolis, IN 46825.

[4] Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 20 mg; Zn (as zinc methionine hydroxy analogue complex) 20 mg; Cu (as copper methionine hydroxy analogue complex) 10 mg; Se (as selenium yeast) 0.15 mg. Novus International, St. Charles MO.

Table 3. Composition (g/kg) of Finisher diets with different combinations of distillers dried rains with solubles (DDGS) and canola meal.

INGREDIENT	A	B	C	D
Yellow corn	69.275	58.702	61.896	51.566
Soybean meal 47.5%	26.629	22.493	14.571	10.128
DDGS	0	15	0	15
Canola meal 36.5%	0	0	20	20
Poultry oil	1.002	1.002	1.002	1.000
Ground limestone	0.691	0.934	0.628	0.870
Dicalcium phosphate	1.022	0.670	0.803	0.456
Sodium chloride	0.569	0.468	0.543	0.443
MHA[1]	0.277	0.201	0.127	0.069
L-Lysine HCl	0.210	0.254	0.174	0.230
L-Threonine	0.073	0.051	0.031	0.013
L-Valine	0.027	0.000	0.000	0.000
Vitamin premix[2]	0.025	0.025	0.025	0.025
Coban 90[3]	0.050	0.050	0.050	0.050
Choline Cl 60%	0.100	0.100	0.100	0.100
Mintrex P_Se[4]	0.050	0.050	0.050	0.050
TOTAL	100.00	100.00	100.00	100.00

[1]Calcium salt of methionine hydroxy analogue. Novus International, St. Charles MO.
[2] Provides per kg of diet: vitamin A (from vitamin A acetate) 7715 IU; cholecalciferol 5511 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg.
[3] Elanco Animal Health division of Eli Lilly & Co., Indianapolis, IN 46825.
[4] Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 20 mg; Zn (as zinc methionine hydroxy analogue complex) 20 mg; Cu (as copper methionine hydroxy analogue complex) 10 mg; Se (as selenium yeast) 0.15 mg. Novus International, St. Charles MO.

Table 4. Calculated nutrient content of starter diets with different combinations of distillers dried grains with solubles (DDGS) and canola meal

Nutrient	Unit	A	B	C	D
Crude protein	%	21.86	22.43	21.79	23.13
Calcium	%	0.84	0.84	0.80	0.80
Total P	%	0.68	0.68	0.72	0.73
Nonphytate P	%	0.40	0.40	0.38	0.38
ME	Kcal/lb	1388.32	1379.35	1327.03	1309.90
ME	Kcal/kg	3059.85	3040.09	2924.78	2887.03
Met	%	0.63	0.61	0.56	0.54
Lys	%	1.31	1.34	1.31	1.33
Thr	%	0.91	0.92	0.92	0.93
Val	%	1.04	1.07	1.05	1.12
TSAA	%	0.98	1.00	0.97	0.99
dMet	%	0.58	0.56	0.49	0.46
dLys	%	1.22	1.21	1.17	1.15
dThr	%	0.79	0.79	0.75	0.75
dVal	%	0.94	0.95	0.91	0.95
dTSAA	%	0.88	0.87	0.84	0.83

Table 5. Calculated nutrient content of broiler grower diets fed 22 to 35 d with soybean meal and varying levels of canola meal.

Nutrient	A	B	C	D
Crude protein %	19.1	22.3	20.1	23.3
Calcium %	0.63	0.62	0.67	0.65
Total P %	0.59	0.60	0.68	0.69
Nonphytate P %	0.35	0.34	0.34	0.33
ME kcal/lb	1375.91	1341.82	1321.82	1288.18
ME kcal/kg	3027.00	2952.00	2908.00	2834.00
Met %	0.57	0.64	0.48	0.55
Lys %	1.17	1.25	1.21	1.29
Thr %	0.91	0.97	0.89	1.01
Val %	1.09	1.36	1.09	1.25
TSAA %	0.89	1.01	0.90	1.03
dMet %	0.56	0.63	0.47	0.53
dLys %	1.79	1.15	1.08	1.14
dThr %	0.71	0.85	0.74	0.84
dVal %	1.01	1.15	0.97	1.09
dTSAA %	0.83	0.94	0.72	0.84

Table 6. Calculated nutrient content of broiler Finisher diets fed 36 to 42 d with soybean meal and varying levels of canola meal.

Nutrient	A	B	C	D
Crude protein %	18.3	19.4	19.2	20.2
Calcium %	0.56	0.57	0.60	0.61
Total P %	0.54	0.54	0.64	0.63
Nonphytate P %	0.31	0.30	0.30	0.29
ME kcal/lb	1039.45	1377.27	1335.45	1322.73
ME kcal/kg	3059.00	3030.00	2938.00	2910.00
Met %	0.54	0.50	0.45	0.43
Lys %	1.11	1.10	1.15	1.15
Thr %	0.81	0.81	0.84	0.85
Val %	1.04	1.05	1.04	1.07
TSAA %	0.84	0.84	0.85	0.86
dMet %	0.53	0.48	0.43	0.40
dLys %	1.03	1.01	1.02	1.004
dThr %	0.71	0.70	0.70	0.70
dVal %	0.95	0.95	0.92	0.94
dTSAA %	0.79	0.77	0.68	0.68

Table 7. Statistical analysis for live performance of broilers during starter phase days 0 – 21.

Source of variation	Probability > F					
	BW 21d (kg)	FCR 21d (kg/Kg)	% Mort 21d	Calorie conversion 21d (cal / kg)	Feed Intake (kg)	Calories consumed per bird 21d
DDGS (0 vs 15)	0.3724	0.0946	0.7555	0.9014	0.0311	0.1934
CM (0 vs 20)	0.0015	0.0011	0.7555	0.1854	0.2577	0.0001
DDGS x CM	0.8548	0.1658	0.7555	0.3117	0.2577	0.3774
SEM DDGS	0.0062	0.0064	0.7025	24.3859	0.0068	20.2109
SEM CM	0.0062	0.0064	0.7025	24.3859	0.0068	20.2109
SEM DDGS x CM	0.0088	0.009	0.9935	34.4868	0.0096	28.825
CV	1.734	1.201	1.7469	1.5187	1.4245	1.4285

Table 8. Effects of combinations of DDGS and canola meal on performance of broilers during the starter period of 0 -21 d (Means of six pens of 25 birds)

Performance 0 - 21 day							
Treatment		BW (kg)	FCR (kg/kg)	% Mort	Caloric conversion (cal / kg)	Feed Intake (kg/kg)	Calories Consumed / Bird
DDGS		Main Effect DDGS					
0		0.877	1.303	1.654	3931.08	1.152[b]	3445.25
15		0.885	1.321	1.333	3935.49	1.177[a]	3485.83
CM		Main Effect CM					
	0	0.902[a]	1.289[b]	1.654	3958.27	1.170	3566.34[a]
	20	0.860[b]	1.335[a]	1.333	3908.30	1.158	3364.73[b]
DDGS x CM		Treatment Means					
0	0	0.897	1.288	1.974	3974.69	1.163	3559.40
15	0	0.907	1.291	1.333	3941.85	1.177	3573.27
0	20	0.857	1.319	1.333	3887.48	1.140	3331.09
15	20	0.863	1.350	1.333	3929.13	1.177	3398.38

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Table 9. Statistical analysis for live performance of broilers during days 0 – 35.

Source of variation	Probability > F					
	BW 35d (kg)	FCR 35d (kg/Kg)	% Mort 35d	Calorie conversion 35d (cal / kg)	Feed Intake 35d (kg)	Calories consumed per bird 35d
DDGS (0 vs 15)	0.2462	0.4099	0.5991	0.0048	0.331	0.2739
CM (0 vs 20)	0.0004	<.0001	0.613	0.0133	0.6691	<.0001
DDGS x CM	0.2462	0.0672	0.9919	0.1194	0.0456	0.0637
SEM DDGS	0.0113	0.005	0.8783	15.4469	0.0159	57.796
SEM CM	0.0113	0.005	0.8783	15.4469	0.0159	57.796
SEM DDGS x CM	0.01598	0.0071	1.242	21.8452	0.0225	81.74
CV	1.2216	0.8212	2.195	0.8412	1.733	1.3841

Table 10. Effects of combinations of DDGS and canola meal on performance of broilers during the period of 0 -35 d
(Means of six pens of 25 birds)

Performance 0 - 35 day							
Treatment		BW (kg)	FCR (kg/kg)	% Mort	Caloric conversion (cal / kg)	Feed Intake (kg/kg)	Calories Consumed / Bird
DDGS		Main Effect DDGS					
0		2.257	1.500	1.654	4540.36[a]	2.242	10276.9
15		2.277	1.507	2.333	4455.92[b]	2.265	10180.9
CM		Main Effect CM					
	0	2.313[a]	1.476[b]	2.320	4532.72[a]	2.258	10520.4[a]
	20	2.220[b]	1.530[a]	1.667	4463.56[b]	2.248	9937.4[b]
DDGS x CM		Treatment Means					
0	0	2.313	1.481	1.974	4593.99	2.273	10656.3
15	0	2.313	1.472	2.667	4471.46	2.243	10384.5
0	20	2.200	1.520	1.333	4486.73	2.210	9897.5
15	20	2.240	1.541	2.000	4440.38	2.287	9977.3

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Table 11. Statistical analysis for live performance of broilers during days 0 – 42.

Source of variation	Probability > F					
	BW 42d (kg)	FCR 42d (kg/Kg)	% Mort 42d	Calorie conversion 42d (cal / kg)	Feed Intake 42d (kg)	Calories consumed per bird 42d
DDGS (0 vs 15)	0.6298	0.0089	0.0849	0.4895	0.0455	0.6922
CM (0 vs 20)	0.0318	<.0001	0.0972	0.925	0.0322	0.0108
DDGS x CM	0.461	0.0961	0.5129	0.1452	0.5616	0.2701
SEM DDGS	0.0259	0.0056	0.7358	16.5352	0.0214	120.1887
SEM CM	0.0259	0.0056	0.7358	16.5352	0.0214	120.1887
SEM DDGS x CM	0.03659	0.0079	1.0405	23.3843	0.0302	169.9725
CV	2.1798	0.846	2.071	0.8267	3.821	2.042

Table 12. Effects of combinations of DDGS and canola meal on performance of broilers during the period of 0 - 42 d
(Means of six pens of 25 birds)

Performance 0 - 42 day							
Treatment		BW (kg)	FCR (kg/kg)	% Mort	Caloric conversion (cal / kg)	Feed Intake (kg/kg)	Calories Consumed / Bird
DDGS		Main Effect DDGS					
0		2.898	1.615^{b}	11.954	4908.01	1.336^{b}	14382.9
15		2.917	1.643^{a}	14.000	4891.07	1.408^{a}	14452.7
CM		Main Effect CM					
	0	2.955^{a}	1.588^{b}	13.954	4900.67	1.333^{b}	14698.4^{a}
	20	2.860^{b}	1.670^{a}	12.000	4988.40	1.412^{a}	14137.2^{b}
DDGS x CM		Treatment Means					
0	0	2.960	1.582	12.575	4928.01	1.307	14780.2
15	0	2.950	1.594	15.333	4873.33	1.360	14616.6
0	20	2.837	1.649	11.333	4888.00	1.367	13985.7
15	20	2.883	1.691	12.667	4908.80	1.457	14288.8

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Table 13. Statistical analysis for carcass performance of broilers measured as a % of live weight or carcass weight.

Source of variation	Probability > F						
	Dress %	Breast % LW	Leg quarters % LW	Wings % LW	Breast % Cw	Leg quarters % CW	Wings % CW
DDGS (0 vs 15)	0.2624	0.3623	0.8341	0.6515	0.4711	0.5456	0.9663
CM (0 vs 20)	<.0001	<.0001	0.3468	0.6313	<.0001	0.0063	0.0052
DDGS x CM	0.479	0.6851	0.0913	0.0251	0.8471	0.1456	0.0529
SEM DDGS 0	0.177	0.208	0.1635	0.0416	0.244	0.2228	0.0579
SEM DDGS 15	0.1788	0.2099	0.1649	0.04197	0.244	0.2228	0.0579
SEM CM 0	0.177	0.208	0.1635	0.0416	0.244	0.2228	0.0579
SEM CM 20	0.1788	0.2099	0.1649	0.04197	0.244	0.2228	0.0579
SEM DDGS x CM	0.479	0.6851	0.0913	0.0251	0.8471	0.1456	0.0529
CV	1.85	6.7578	5.7078	4.31046	5.8926	5.7687	4.4528

Table 14. Effects of combinations of DDGS and canola meal on processing percentage and parts yield.

Carcass									
Treatment		Dress %	Breast % LW	Leg Quarters % LW	Wings % LW	Breast % CW	Leg Quarters % CW	Wings % CW
DDGS		Main Effect DDGS						
0		74.35	23.99	22.17	7.49	32.25	29.83	10.08
15		74.07	23.72	22.22	7.47	32.00	30.02	10.08
CM		Main Effect CM						
	0	74.93[a]	24.75[a]	22.08	7.47	33.02[a]	30.36[a]	9.96[b]
	20	73.48[b]	22.95[b]	22.30	7.49	31.23[b]	29.48[b]	10.20[a]
DDGS x CM		Treatment Means						
0	0	74.99	24.836	21.86	7.41	33.11	29.16	9.88
15	0	74.87	24.670	22.31	7.52	32.93	29.81	10.04
0	20	73.72	23.145	22.47	7.57	31.39	30.49	10.28
15	20	73.24	22.738	22.13	7.41	31.07	30.22	10.11

[a,b,c] means in a column with a common superscript do not differ significantly (P ≤ 0.05)

Table 15. Statistical analysis for carcass performance of broilers measured in actual weight (g).

Source of variation	Probability > F		
	Breast (g)	Leg quarters (g)	Wings (g)
DDGS (0 vs 15)	0.8626	0.4707	0.6934
CM (0 vs 20)	<.0001	0.2912	0.0683
DDGS x CM	0.2778	0.7181	0.7581
SEM DDGS 0	8.224	6.5793	1.908
SEM DDGS15	8.224	6.5793	1.908
SEM CM 0	8.224	6.5793	1.908
SEM CM 20	8.224	6.5793	1.908
SEM DDGS x CM	11.631	9.3045	2.699
CV	9.3588	8.0555	6.9317

Table 16. Effects of combinations of DDGS and canola meal on actual parts weight of birds

Carcass				
Treatment		Breast (g)	Leg Quarters (g)	Wings (g)
DDGS		Main Effect DDGS		
0		681.70	629.28	212.27
15		679.68	636.02	213.63
CM		Main Effect CM		
	0	715.48[a]	637.58	215.58
	20	645.90[b]	627.72	210.62
DDGS x CM		Treatment Means		
0	0	722.83	635.90	215.47
15	0	708.13	639.27	215.70
0	20	640.57	622.67	209.67
15	20	651.23	632.77	211.57

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Table 17. Percent intact pellets as determined by Tyler Sieve Shaker or a Tumble Mixer

% DDGS / CM	Tyler Sieve Shaker (%)		Tumble Mixer (%)	
	Grower	Finisher	Grower	Finisher
0 / 0	79.97	85.27	99.62	99.71
15 / 0	66.19	87.51	99.60	99.39
0 / 20	69.39	83.47	99.45	99.21
15 / 20	84.18	78.59	99.30	98.95
SEM	5.912	3.992		
CV	17.643	9.537		
P < 0.05	0.143	0.469		

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Evaluation of combinations of canola meal and DDGS in diets with constant energy or with constant level of supplemental poultry oil

C.D. Bradley, S.D. Goodgame, C. Lu, S. M. Fiscus, F. J. Mussini, and P.W. Waldroup
Poultry Science Department, University of Arkansas, Fayetteville AR 72701

ABSTRACT

This 35 day experiment used a 2x2x6 factorial arrangement. Treatments were prepared using two diet types; isocaloric (ISO) with varying levels of PO; and optimum nutrient density (OPT) with a constant 1% PO, two varying amounts of DDGS (0 and 15%) and six levels of canola meal (CM) (0, 5, 10, 15, 20, and 25%). A starter diet was provided days 0-21, and grower diet days 22-35. Five male chicks were randomly selected and placed on one of the 24 different diets with 6 replicates for 14 days in brooder batteries. On day 14 the chicks were moved to grow out batteries until day 35. Performance measurements for body weight (BW), feed conversion ratio (FCR), calorie conversion ratio (CCR) and mortality (MORT) where calculated on days 14, 21, and 35. Throughout this experiment bird performance was better with the addition of the higher energy levels that the PO provided. The broilers fed ISO diets with any combination of DDGS or CM exhibited a general trend of outperforming their counterparts on the OPT diets in BW, FCR, or CCR. Birds fed diets including DDGS also showed a general inclination of improved performance, regardless of additional combinations. The birds fed CM suffered depressed FCR at levels ≥ 20% but BW was not significantly impacted. These data suggest if diets are maintained isocalorically any combinations of ≤ 15% DDGS and ≤ 25% CM can be used together without significantly decreasing the performance of the birds. If diets are maintained at optimum nutrient density and 15% DDGS are added, CM can be added at 10, 15 and 20% levels without depressing BW or FCR. However if diets are maintained at optimum

nutrient density and 0% DDGS are added, CM cannot be added without depressing BW for the first 18 days of development.

Key words: Broiler, canola, DDGS, distillers, grain, optimum density, isocaloric

INTRODUCTION

The use of corn distillers dried grains with soluble (DDGS) in broiler diets has become quite common because of the high usage of corn as a substrate for the production of fuel ethanol. As the demand for biofuels grows, more canola meal is expected to become available as canola produces approximately three times the amount of oil per acre as compared to soybeans. Although both DDGS and canola meal have been used in poultry diets, studies in which both ingredients have been used have been limited.

When formulating diets with either of these ingredients, the nutritionist must make adjustments in nutrient specifications, especially in relation to the metabolizable energy level in the diet. Both are higher in fiber and lower in energy content than the corn and soybean meal that they replace. Therefore, the nutritionist must either add more supplemental fat, which has a high cost per calorie compared to corn, or must reduce the overall nutrient density and maintain a lower level of supplemental poultry oil. This study is designed to evaluate the use of DDGS and canola meal, alone or in combination, in diets using these two different formulation strategies.

In a previous study, Bradley et al., (2013c) birds were fed diets maintaining optimum nutrient density (OPT) and a constant 1% poultry oil (PO) level with 20% canola meal (CM) or 20% CM and 15% distillers dried grains with soluables (DDGS) in combination. At the conclusion of the 42 day experiment, these birds suffered statistical difference in the performance categories of feed conversion ratio (FCR), feed intake (FI), and mortality (MORT), and even though body weights (BW) were not statistically significantly different at day 42, a decline was noted as DDGS or CM was added. The data suggested the reduction in BW was primarily exposed in the processing results, specifically, breast meat yield. The objective of the present study is to evaluate the individual and combined usage of canola meal and DDGS in diets when formulated to optimum nutrient density or isocalorically on broiler performance.

MATERIALS AND METHODS

Birds and Management

The trial was designed as a 2 x 2 x 6 factorial arrangement of treatments using two formulation strategies (Isocaloric (ISO) versus optimum density (OPT) with a constant level of supplemental poultry oil), two levels of DDGS (0 and 15%) and six levels of canola meal (0, 5, 10, 15, 20, and 25%). Using corn, soybean meal, canola meal, and DDGS of known moisture and crude protein content, base diets were formulated following recommendations of Rostagno et al., (2011) with starter diets fed 0-21 d and grower diets from 22-35 d. One series of diets was formulated to be isocaloric with the base diet (no DDGS or canola) using 1% supplemental poultry oil. Within this series of diets there were base diets formulated with 0% DDGS-0% canola, 15% DDGS-0% canola, 0% DDGS-30% canola, and 15% DDGS-30% canola. The diet with the combination of 15% DDGS and 30% canola required the addition of 6.43% supplemental oil in the starter diet and 6.51% in the grower diet. A second series of diets was formulated using the same ingredient combinations, but maintaining the level of supplemental poultry oil at 1%, resulting in different levels of dietary energy. In this series, all nutrients were maintained in relationship to the dietary energy. Diets were fortified with complete vitamin and trace mineral mixes from commercial sources.

After mixing the base diets, the experimental diets were prepared by blending appropriate aliquots of the base diets to provide for the following dietary treatments:

1. Isocaloric, 0% DDGS-0% Canola
2. Isocaloric, 0% DDGS-5% Canola
3. Isocaloric, 0% DDGS-10% Canola
4. Isocaloric, 0% DDGS-15% Canola
5. Isocaloric, 0% DDGS-20% Canola
6. Isocaloric, 0% DDGS-25% Canola
7. Isocaloric, 15% DDGS-0% Canola
8. Isocaloric, 15% DDGS-5% Canola
9. Isocaloric, 15% DDGS-10% Canola
10. Isocaloric, 15% DDGS-15% Canola
11. Isocaloric, 15% DDGS-20% Canola
12. Isocaloric, 15% DDGS-25% Canola
13. Constant 1% poultry oil 0% DDGS-0% canola
14. Constant 1%, 0 % DDGS – 5% canola
15. Constant 1%, 0% DDGS-10% Canola
16. Constant 1%, 0% DDGS-15% Canola
17. Constant 1%, 0% DDGS-20% Canola
18. Constant 1%, 0% DDGS-25% Canola
19. Constant 1%, 15% DDGS-0% Canola
20. Constant 1%, 15% DDGS-5% Canola
21. Constant 1%, 15% DDGS-10% Canola
22. Constant 1%, 15% DDGS-15% Canola
23. Constant 1%, 15% DDGS-20% Canola

24. Constant 1%, 15% DDGS-25% Canola

Each of these 24 experimental diets was fed to six replicate pens of five male broilers each. For the first 14 d they were maintained in electrically heated battery brooders with wire floors. From 14 to 35 d they were maintained in unheated finishing battery pens with wire floors maintained in a temperature controlled room. The experimental diets in mash form and tap water were provided for ad libitum consumption.

Male chicks of a commercial broiler strain (Cobb 500) were obtained from a local hatchery where they had been vaccinated in ovo for Marek's disease and had received vaccinations for Newcastle Disease and Infectious Bronchitis post hatch via a coarse spray. Five chicks were assigned to each of 144 compartments in electrically heated battery brooders with wire floors. Fluorescent lights provided 24 hour of light daily. Care and management of the birds followed recommended guidelines (FASS, 2010). All procedures were approved by the University of Arkansas Institutional Animal Care and Use Committee.

Measurements

Chicks were weighed at day of hatch and at 14, 21, and 35 d of age. Feed consumed and calories consumed during the same periods were recorded and calculations made of feed conversion ratio (total feed consumed divided by weight of live and dead or culled birds) and calorie conversion ratio (total calories consumed divided by weight of live and dead or culled birds). Mortality was checked twice daily and weight of dead or culled birds recorded to adjust for conversion calculations.

Statistical Analysis

Pen means served as the experimental unit for statistical analysis. Data was analyzed using 2 x 2 x 6 factorial arrangements. Main effects of formulation strategy (isocaloric vs. optimum density), DDGS supplementation (0 vs. 15%), canola meal (0 to 25%) were examined with all interactions using the General Linear Models procedure of the SAS Institute (1991) for ANOVA. Mortality data were transformed to $\sqrt{n+1}$ prior to analysis; data are presented as natural numbers. When significant differences among treatments were found, means were separated using repeated t-tests using the LSMEANS option of the GLM procedure.

RESULTS AND DISCUSSION

The statistical evaluations are shown in Table 5. Birds fed the diets calculated to be isocaloric (ISO) had significantly higher BW and lower FCR at 14, 21, and 35 d than birds fed diets formulated to be optimum density with 1% poultry oil (Table 6). However, calorie conversion did not differ significantly between the two diet types, indicating they used the diets with equal effectiveness.

These findings were in agreement with those of our previous research conducted to explore the effects of broilers fed diets containing CM from bio-fuel production with constant Bradley et al., (2013a) or lowering amounts of true metabolizable energy (TME) Bradley et al., (2013b). Bradley et al., (2013a) reported that birds can be fed diets containing up to 40% CM without suffering significant reduction in performance if diets were maintained isocalorically. However, Bradley et al., (2013b) reported that broiler performance declined linearly throughout, when birds were fed diets containing CM with declining TME. Thus, birds fed ISO diets with high TME performed better than those fed diets formulated on optimum density and lowering TME.

Birds fed the diets with 15% DDGS had significantly better BW at 14, 21, and 35 d than those fed the diets with no DDGS (Table 6). The level of CM had no significant effect on BW at any age (Table 6). These results are in disagreement with those of our preceding study. Bradley et al., (2013c) who reported birds fed diets with combinations of CM or DDGS had no significant BW improvement particularly with the addition of 15% DDGS. This difference was most likely due to some of the diets in the current study being maintained ISO versus optimum density. The current BW results are also in disagreement with those of Min et al., (2009), and Lumpkins et al., (2004), who reported no significant differences for broilers consuming diets that contained 15% DDGS. Noll et al., (2001) also reported no significant differences in BW for turkeys consuming diets that contained up to 12% DDGS.

FCR for these birds consuming DDGS was also significantly better at 14 and 21 d, but at 35 d no significant difference was noted (Table 6). These results are in disagreement with those of Lumpkins et al., (2004) who reported no differences in feed efficiency among any treatments that included 0, 6, 12, or 18% DDGS in their 42 day experiment. Amino acid digestibility or metabolizable energy values assigned to the DDGS were from a literature composition Waldroup, et al., (2007) and their supply of DDGS may have been superior in quality.

FCR was not significantly affected by birds fed CM levels at 14 and 21 d, but at 35 d, the FCR by birds fed diets with 20 or 25% CM were significantly higher than that of chicks fed diets with lower levels of CM. The calorie conversion ratio was not significantly different among treatments at 14 and 35 d indicating the birds utilized the diets energy with equal effectiveness across all levels of CM.

There was a significant interaction between formulation strategy and level of DDGS for FCR at 14 and 35 d (Table 5). This interaction suggests that the inclusion of DDGS offset the negative effect of the OPT diet. There was also a significant interaction for caloric conversion, but it followed no courses that patterned.

There was a significant interaction between formulation strategy and level of CM for 35d FCR (Table 5). As seen in Figure 1, the FCR of birds fed the ISO diets tended to remain constant as the levels of CM increased. However, increasing the CM level in diets formulated to be isocaloric with 1% poultry oil increased. Since these diets were increasing low in energy content, their response was not unexpected. Since the calorie conversion was not significantly affected by this interaction indicates the birds made affected use of the diets calories.

There was a significant three-way interaction between formulation strategy, level of DDGS, and level of CM for 35 d BW (Table 5). As seen in Figure 2, this appeared to be primarily because of high weight for birds fed the OPT diet with 15% DDGS and 0% CM. At other CM levels, a constant response appeared.

CONCLUSION

These data suggest if diets are maintained isocalorically any combinations of ≤ 15% DDGS and ≤ 25% CM can be used together without significantly decreasing the performance of the birds. If diets are maintained at optimum nutrient density and 15% DDGS are added, CM can be added at 10, 15 and 20% levels without depressing BW or FCR. However if diets are maintained at optimum nutrient density and 0% DDGS are added, CM cannot be added without depressing BW for the first 18 days of development.

REFERENCES

Bradley C.D., S. Goodgame, F. Mussini, N. Comert, C. Lu, and P. Waldroup. (2013a). Use of canola meal in high energy diets. 1. Isocaloric diets. In preparation.

Bradley C.D., S. Goodgame, F. Mussini, C. Lu, and P. Waldroup. (2013b). Use of canola meal in high energy diets. 1. Optimum density diets. In preparation.

Bradley, C.D., S. M. Fiscus, S. D. Goodgame, F.J. Mussini, C. Lu, and P.W. Waldroup. (2013c). Effect of combinations of distillers dried grains with solubles (DDGS) and canola meal in Broiler Diets. In preparation.

FASS, 2010. Guide for the Care and Use of Agricultural Animals in Research and Teaching. 3rd ed. Federation of Animal Science Societies, Savoy IL.

Lumpkins, B.S., A.B. Batal, and N.M. Dale. 2004. Evaluation of distillers dried grains with solubles as a feed ingredient for broilers. Poult. Sci. 83:1891-1896.

Min, Y., A. Hancock, F. Yan, C. Lu, C. Coto, A. Karimi, J. Park, F. liu, and P. Waldroup. 2009. Use of combinations of canola meal and distillers dried grains with soluble in broiler starter diets[1]. J. Appl. Poult. Res. 18:725-733.

Noll, S., V. Stangeland, G. Speers, and J. Brannon. 2001. Distillers grains in poultry diets. Pages 53–61 in 62nd Minnesota Nutrition Conference and Corn Growers Assoc. Tech. Symposium. Bloomington, MN.

Rostagno, H.R., L.F.T. Albino, J. L. Donzele, P.C. Gomes, R.F de Olveira, D.C. Lopes, A.S. Ferreira, S.L. deT. Barreto, and R.F. Euclides. 2011. Brazilian Tables for Poultry and Swine. Composition of Feedstuffs and Nutritional Requirements. 3rd ed. H. S. Rostagno, ed. Universidade Federal de Vocosa, Dept. Zootecnia, Vicosa, MG, Brazil.

SAS Institute, 1991. SAS® User's Guide: Statistics. Version 6.03 edition. SAS Institute Inc., Cary, NC.

Waldroup, P.W., 2007. Biofuels and broilers-Competitors or cooperators? Pages 25-34 in: Proc. 5th Mid-Atlantic Nutrition Conference

Table 1. Composition (%) of base diets for starter period (0-21 d) with different levels of DDGS and canola meal

Ingredients	Isocaloric				Optimum Density		
	A 0-0[1]	B 15-0	C 0-30	D 15-30	E 15-0	F 0-30	G 15-30
Yellow corn	59.806	51.158	44.200	30.338	51.835	51.994	40.220
Soybean meal	35.813	29.137	17.641	15.649	28.822	14.311	11.420
DDGS	0.000	15.000	0.000	15.000	15.000	0.000	15.000
Canola meal	0.000	0.000	30.000	30.000	0.000	30.000	30.000
Poultry oil	1.003	1.352	5.278	6.428	1.003	1.006	1.009
Limestone	0.767	1.031	0.690	0.924	1.031	0.691	0.918
Dicalcium phosphate	1.453	1.142	1.252	0.914	1.133	1.128	0.756
Salt	0.460	0.361	0.449	0.348	0.358	0.418	0.309
MHA[2]	0.320	0.281	0.163	0.078	0.278	0.122	0.044
L-Lysine HCl	0.141	0.280	0.152	0.146	0.282	0.155	0.149
L-Threonine	0.062	0.083	0.000	0.000	0.083	0.000	0.000
2X Premix[3]	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Choline Cl 60%	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Mintrex P_Se[4]	0.050	0.050	0.050	0.050	0.050	0.050	0.050
	100.000	100.000	100.000	100.000	100.000	100.000	100.000

[1]Indicates percentage of DDGS-canola meal in diet.

[2]Calcium salt of methionine hydroxy analogue. Novus International, Inc., St. Louis MO.

[3]Provides per kg of diet: vitamin A (from vitamin A acetate) 7715 IU; cholecalciferol 5511 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg.

[4]Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 20 mg; Zn (as zinc methionine hydroxy analogue complex) 20 mg; Cu (as copper methionine hydroxy analogue complex) 10 mg; Se (as selenium yeast) 0.15 mg.

Table 2. Composition (%) of base diets for grower period (22-35 d) with different levels of DDGS and canola meal

Ingredients	Isocaloric				Optimum density		
	A 0-0[1]	B 15-0	C 0-30	D 15-30	E 15-0	F 0-30	G 15-30
Yellow corn	64.296	55.254	48.227	34.345	55.938	55.905	44.070
Soybean meal	31.694	25.375	13.925	11.935	25.125	10.762	7.920
DDGS	0.000	15.000	0.000	15.000	15.000	0.000	15.000
Canola meal	0.000	0.000	30.000	30.000	0.000	30.000	30.000
Poultry oil	1.004	1.414	5.349	6.507	1.003	1.008	1.003
Limestone	0.732	0.993	0.652	0.881	0.993	0.655	0.878
Dicalcium phosphate	1.195	0.882	0.992	0.653	0.871	0.881	0.512
Salt	0.429	0.330	0.418	0.317	0.327	0.388	0.279
MHA[1]	0.286	0.244	0.126	0.057	0.239	0.086	0.028
L-Lysine HCl	0.138	0.266	0.136	0.130	0.264	0.140	0.135
L-Threonine	0.051	0.067	0.000	0.000	0.065	0.000	0.000
2X Premix[1]	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Choline Cl 60%	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Mintrex P_Se[1]	0.050	0.050	0.050	0.050	0.050	0.050	0.050
	100.000	100.000	100.000	100.000	100.000	100.000	100.000

[1]As given in Table

Table 3. Calculated nutrient content of starter diets with different combinations of distillers dried grains with solubles (DDGS) and canola meal

Nutrient	Unit	A	B	C	D	E	F	G
Crude Protein	%	21.8	21.9	22.8	24.7	21.8	21.9	23.5
Calcium	%	0.71	0.73	0.79	0.81	0.73	0.76	0.77
Total P	%	0.66	0.65	0.81	0.82	0.68	0.79	0.79
Non-Phytate P	%	0.41	0.40	0.40	0.40	0.39	0.38	0.37
ME	Kcal/lb	1348.18	1350.00	1362.73	1368.18	1343.18	1277.27	1260.45
ME	Kcal/kg	2966.00	2970.00	2998.00	3010.00	2955.00	2810.00	2773.00
Met	%	0.62	0.60	0.54	0.50	0.59	0.49	0.43
Lys	%	1.30	1.30	1.40	1.41	1.29	1.32	1.32
Thr	%	0.95	0.96	0.99	1.06	0.95	0.95	1.00
Val	%	1.22	1.20	1.24	1.33	1.19	1.19	1.25
TSAA	%	0.97	0.96	1.02	1.03	0.97	0.97	0.98
dMet	%	0.61	0.59	0.52	0.48	0.58	0.47	0.43
dLys	%	1.21	1.19	1.24	1.23	1.19	1.17	1.14
dThr	%	0.84	0.83	0.82	0.86	0.83	0.78	0.81
dVal	%	1.11	1.08	1.08	1.15	1.08	1.03	1.08
dTSAA	%	0.91	0.89	0.79	0.78	0.89	0.74	0.74

Table 4. Calculated nutrient content of grower diets with different combinations of distillers dried grains with solubles (DDGS) and canola meal

Nutrient	Unit	A	B	C	D	E	F	G
Crude Protein	%	20.2	20.5	21.4	23.3	20.4	2.05	22.2
Calcium	%	0.63	0.65	0.71	0.72	0.65	0.68	0.69
Total P	%	0.60	0.59	0.75	0.76	0.59	0.73	0.73
Non-Phytate P	%	0.35	0.34	35.00	0.34	0.34	0.33	0.32
ME	Kcal/lb	1370.45	1372.73	1385.45	1391.36	1364.55	1297.73	1279.55
ME	Kcal/kg	3015.00	3020.00	3048.00	3061.00	3002.00	2855.00	2815.00
Met	%	0.57	0.55	0.48	0.47	0.54	0.45	0.43
Lys	%	1.19	1.19	1.29	1.30	1.18	1.21	1.21
Thr	%	0.87	0.88	0.93	0.99	0.87	0.89	0.94
Val	%	1.15	1.11	1.16	1.24	1.11	1.11	1.18
TSAA	%	0.89	0.90	0.96	0.98	0.89	0.91	0.93
dMet	%	0.56	0.54	0.47	0.44	0.53	0.42	0.40
dLys	%	1.10	1.09	1.13	1.12	1.08	1.06	1.04
dThr	%	0.76	0.76	0.76	0.80	0.76	0.73	0.76
dVal	%	1.03	1.00	1.00	1.07	1.00	0.96	1.01
dTSAA	%	0.84	0.83	0.73	0.73	0.83	0.67	0.69

Table 5. ANOVA of effects of feed formulation strategy, level of DDGS, level of canola, and treatment means

Probability > F												
Source of Variance	0-14 d				0-21 d				0-35 d			
	BW	FCR	CCR	Mort	BW	FCR	CCR	Mort	BW	FCR	CCR	Mort
Form x DDGS x CM	0.614	0.928	0.932	0.118	0.269	0.507	0.493	0.100	0.030	0.317	0.290	0.100
SEM	0.003	0.006	17.421	0.393	0.005	0.006	17.417	0.012	0.009	0.005	14.255	0.001
CV	8.045	5.209	5.286	6.139	7.421	4.717	4.693	13.676	4.998	4.097	3.517	0.170
Feed Form	0.001	0.001	0.258	1.000	0.001	0.001	0.486	1.000	0.001	0.001	0.922	1.000
DDGS	0.001	0.001	0.001	1.000	0.001	0.050	0.015	1.000	0.003	0.622	0.728	1.000
Canola (CM)	0.274	0.409	0.270	0.421	0.937	0.091	0.004	0.522	0.758	0.001	0.068	0.522
Form x DDGS	0.107	0.015	0.006	1.000	0.529	0.088	0.027	1.000	0.110	0.047	0.005	1.000
Form x CM	0.639	0.804	0.298	0.700	0.631	0.237	0.472	0.284	0.246	0.002	0.181	0.284
DDGS x CM	0.837	0.605	0.645	0.700	0.169	0.598	0.653	0.676	0.151	0.276	0.288	0.676

[a,b,c] means in a column with a common superscript do not differ significantly ($P \leq 0.05$)

Table 6. Effect of main effects of formulation strategy, level of DDGS, and level of canola meal on performance of broilers

Feed Type	DDGS%	Canola%	14d				21d				35d			
			BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort	BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort	BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort
ISO			.446^{a}	1.251^{b}	3800	0.556	.852^{a}	1.429^{b}	4340	1.111	2.140^{a}	1.534^{b}	4708	1.111
OPT			.418^{b}	1.306^{a}	3855	0.556	.803^{b}	1.481^{a}	4369	1.111	2.037^{b}	1.582^{a}	4711	1.111
	0		.411^{b}	1.308^{a}	3923^{a}	0.556	.800^{b}	1.468^{a}	4405^{a}	1.111	2.066^{b}	1.560	4714	1.111
	15		.453^{a}	1.250^{b}	3732^{b}	0.556	.855^{a}	1.441^{b}	4304^{b}	1.111	2.110^{a}	1.556	4705	1.111
		0	0.439	1.294	3926	0.000	0.831	1.490	4522^{a}	0.833	2.108	1.542^{b}	4725	0.833
		5	0.441	1.262	3809	0.000	0.815	1.454	4389^{ab}	1.667	2.087	1.547^{b}	4716	1.667
		10	0.436	1.268	3806	0.833	0.829	1.444	4334^{bc}	0.833	2.090	1.547^{b}	4689	0.833
		15	0.430	1.261	3765	1.670	0.832	1.418	4234^{c}	2.500	2.086	1.534^{b}	4625	2.500
		20	0.418	1.312	3895	0.000	0.824	1.456	4322^{bc}	0.000	2.090	1.590^{a}	4767	0.000
		25	0.428	1.275	3765	0.833	0.834	1.466	4328^{bc}	0.833	2.067	1.589^{a}	4735	0.833

^{a,b,c} means in a column with a common superscript do not differ significantly (P ≤ 0.05)

Figure 1. Interaction of feed formulation strategies (Isocaloric vs. Optimum nutrient density) and levels of canola meal on 0 – 35 d feed conversion ratio.

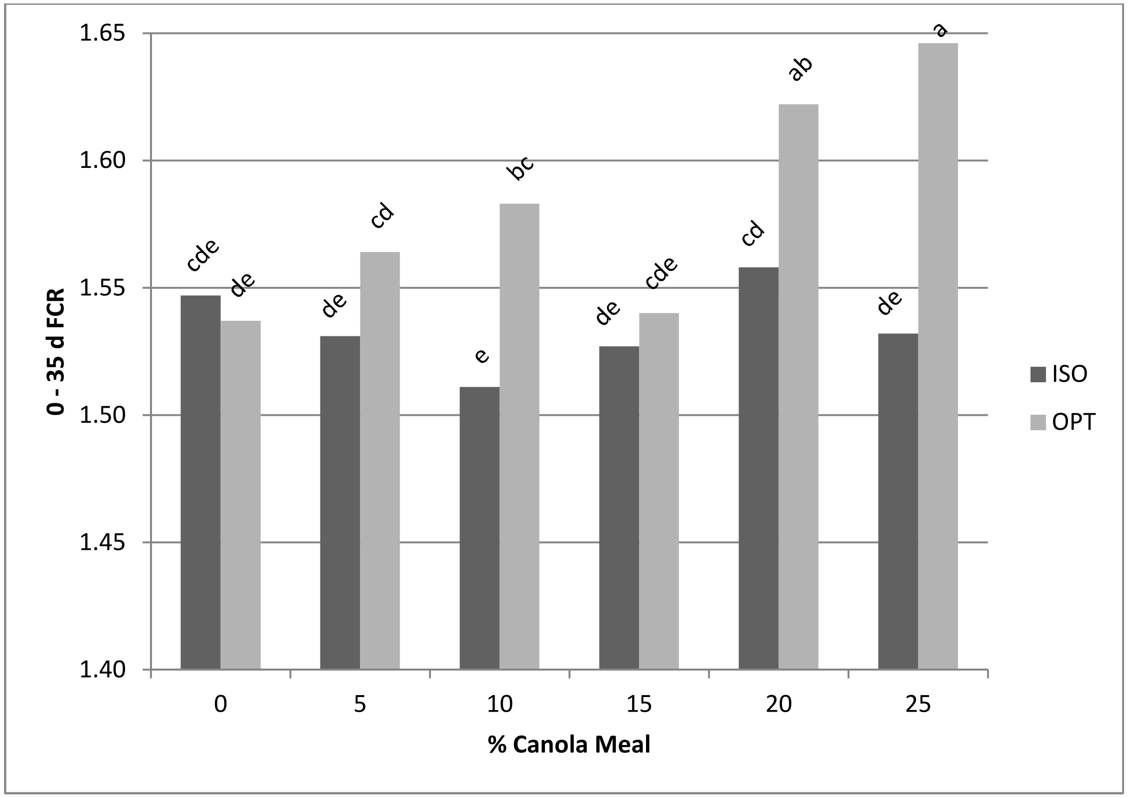


Table 7. Treatment means of formulation strategy, level of DDGS, and level of canola meal on performance of broilers.

Treatment Means														
Interaction			14 d				21 d				35 d			
Formulation x DDGS			BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort	BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort	BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort
ISO	0		.430	1.260	3828	.556	.828	1.431	4345	1.111	2.129	1.523	4674	1.111
ISO	15		.462	1.242	3773	.556	.876	1.427	4336	1.111	2.150	1.546	4742	1.111
OPT	0		.392	1.356	4019	.556	.772	1.506	4466	1.111	2.002	1.589	4755	1.111
OPT	15		.444	1.257	3691	.556	.834	1.455	4272	1.111	2.071	1.575	4668	1.111
Formulation x canola														
ISO		0	.448	1.274	3869	0.000	.846	1.472	4470	0.000	2.120	1.547	4748	0.000
ISO		5	.458	1.223	3715	0.000	.832	1.443	4382	3.333	2.143	1.531	4697	3.333
ISO		10	.450	1.218	3702	1.667	.850	1.406	4277	1.667	2.162	1.511	4636	1.667
ISO		15	.447	1.242	3774	1.667	.864	1.415	4296	1.667	2.141	1.527	4686	1.667
ISO		20	.441	1.295	3933	0.000	.868	1.428	4341	0.000	2.158	1.558	4681	0.000
ISO		25	.434	1.253	3808	0.000	.852	1.407	4277	0.000	2.114	1.532	4702	0.000
OPT		0	.431	1.314	3982	0.000	.816	1.508	4575	1.667	2.097	1.537	4703	1.667
OPT		5	.424	1.302	3903	0.000	.798	1.466	4396	0.000	2.031	1.564	4736	0.000
OPT		10	.422	1.318	3910	0.000	.810	1.481	4391	0.000	2.018	1.583	4742	0.000
OPT		15	.414	1.280	3756	1.667	.799	1.422	4171	3.333	2.031	1.540	4564	3.333
OPT		20	.400	1.329	3857	0.000	.780	1.483	4303	0.000	2.022	1.622	4754	0.000
OPT		25	.421	1.300	3723	1.667	.816	1.524	4378	1.667	2.021	1.646	4769	1.667

Table 7. Continued on next page

Continued from previous page

Table 7. Treatment means of formulation strategy, level of DDGS, and level of canola meal on performance of broilers

Treatment Means															
	DDGS	CM	14 d				21 d				35 d				
			BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort	BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort	BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort
	0	0	.413	1.330	4040	0.000	.791	1.509	4586	0.000	2.071	1.548	4750	0.000
	0	5	.428	1.302	3934	0.000	.810	1.487	4494	1.667	2.108	1.546	4720	1.667
	0	10	.414	1.302	3914	1.667	.786	1.464	4403	1.667	2.048	1.533	4658	1.667
	0	15	.405	1.303	3899	1.667	.792	1.417	4239	3.333	2.048	1.517	4588	3.333
	0	20	.398	1.339	3988	0.000	.795	1.473	4385	0.000	2.068	1.607	4833	0.000
	0	25	.408	1.271	3766	0.000	.828	1.460	4326	0.000	2.052	1.584	4738	0.000
	15	0	.466	1.258	3812	0.000	.872	1.470	4459	1.667	2.146	1.536	4701	1.667
	15	5	.454	1.223	3684	0.000	.820	1.423	4284	1.667	2.067	1.549	4712	1.667
	15	10	.457	1.235	3698	0.000	.873	1.423	4265	0.000	2.133	1.561	4720	0.000
	15	15	.456	1.219	3631	1.667	.871	1.420	4228	1.667	2.125	1.550	4662	1.667
	15	20	.438	1.284	3802	0.000	.853	1.438	4259	0.000	2.112	1.573	4702	0.000
	15	25	.447	1.279	3765	1.667	.840	1.472	4329	1.667	2.083	1.594	4733	1.667

Table 8. Treatment means of formulation strategy, level of DDGS, and level of canola meal on performance of broilers

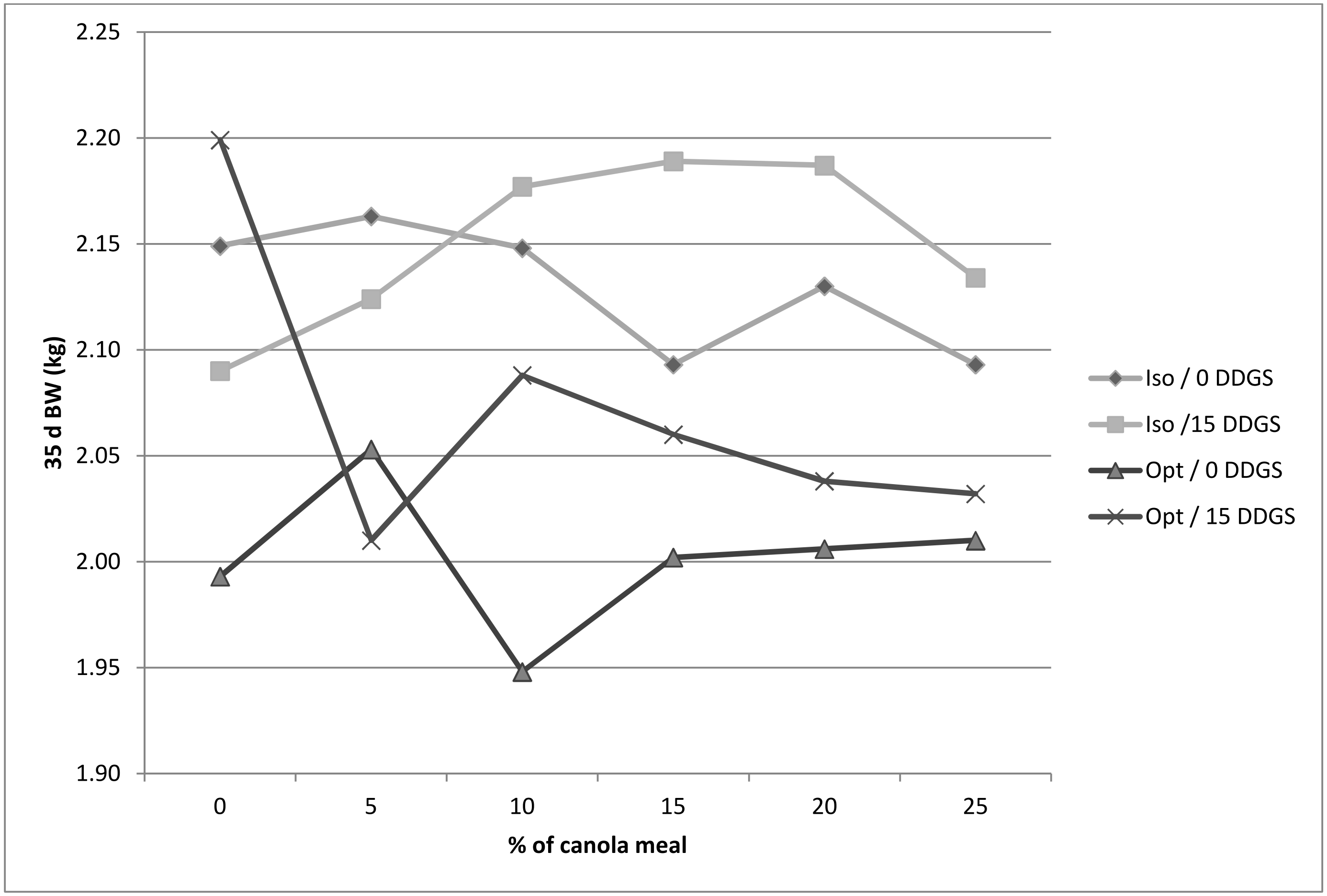
Treatment Means														
Form	DDGS	CM	14 d				21 d				35 d			
			BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort	BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort	BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort
ISO	0	0	.434	1.294	3931	0.000	.836	1.490	4524	0.000	2.149	1.542	4733	0.000
ISO	0	5	.453	1.237	3757	0.000	.840	1.465	4447	3.333	2.163	1.525	4680	3.333
ISO	0	10	.436	1.215	3691	3.333	.807	1.398	4253	3.333	2.148	1.482	4549	3.333
ISO	0	15	.416	1.277	3879	0.000	.815	1.418	4303	0.000	2.093	1.523	4675	0.000
ISO	0	20	.422	1.302	3957	0.000	.826	1.443	4382	0.000	2.130	1.554	4767	0.000
ISO	0	25	.420	1.234	3749	0.000	.845	1.368	4161	0.000	2.093	1.511	4642	0.000
ISO	15	0	.462	1.253	3807	0.000	.857	1.453	4416	0.000	2.090	1.553	4764	0.000
ISO	15	5	.464	1.209	3674	0.000	.824	1.422	4317	3.333	2.124	1.536	4715	3.333
ISO	15	10	.463	1.221	3712	0.000	.891	1.415	4300	0.000	2.177	1.539	4723	0.000
ISO	15	15	.478	1.207	3668	3.333	.914	1.412	4288	3.333	2.189	1.531	4696	3.333
ISO	15	20	.460	1.286	3909	0.000	.911	1.413	4299	0.000	2.187	1.563	4795	0.000
ISO	15	25	.448	1.272	3866	0.000	.859	1.446	4393	0.000	2.134	1.552	4762	0.000

Table 8. Continued on next page

Table 8. Continued from previous page

Treatment Means															
Form	DDGS	CM	14 d				21 d				35 d				
			BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort	BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort	BW (kg)	FCR (kg/kg)	CCR (cal/kg)	% Mort
OPT	0	0	.392	1.365	4149	0.000	.746	1.528	4649	0.000	1.993	1.553	4767	0.000
OPT	0	5	.403	1.367	4111	0.000	.780	1.508	4540	0.000	2.053	1.567	4761	0.000
OPT	0	10	.392	1.389	4136	0.000	.765	1.530	4553	0.000	1.948	1.584	4766	0.000
OPT	0	15	.394	1.328	3918	3.333	.769	1.415	4174	6.667	2.002	1.520	4501	6.667
OPT	0	20	.374	1.376	4019	0.000	.765	1.503	4387	0.000	2.006	1.661	4898	0.000
OPT	0	25	.396	1.308	3783	0.000	.810	1.552	4492	0.000	2.010	1.656	4833	0.000
OPT	15	0	.471	1.262	3816	0.000	.887	1.487	4501	3.333	2.199	1.511	4638	3.333
OPT	15	5	.445	1.236	3695	0.000	.815	1.423	4251	0.000	2.010	1.561	4710	0.000
OPT	15	10	.451	1.247	3684	0.000	.856	1.432	4229	0.000	2.088	1.582	4717	0.000
OPT	15	15	.434	1.231	3593	0.000	.829	1.428	4168	0.000	2.060	1.570	4627	0.000
OPT	15	20	.416	1.281	3695	0.000	.795	1.463	4220	0.000	2.038	1.583	4609	0.000
OPT	15	25	.447	1.286	3663	3.333	.822	1.497	4265	3.333	2.032	1.636	4704	3.333

Figure 2. Interaction of formulation strategies (Isocaloric vs. Optimum density) level of DDGS and Level of canola meal on 35 d BW



OVERALL CONCLUSION

Results from chapter 1 and 2 indicate canola meal can be used as a partial replacement for soybean meal in broiler diets if careful considerations are given by the nutritionists to the broilers metabolizable energy requirements. Results from chapter 3 indicate the addition of protease enzymes to the diets did not improve the broilers BW, but FCR did improve when ProAct was added at 2x the recommended amount. Data from chapter 4 and 5 suggest combinations of ≤ 15% DDGS and ≤ 20% CM can be used together however, owing to the lower energy level of canola meal careful attention still needs to be given by the nutritionists to the broilers metabolizable energy requirements.