AN ABSTRACT OF THE THESIS OF

Abdul-Rahman Nassar for the degree of Master of Science in Poultry Science presented on June 14, 1985.

Title: Canola Meal as a Protein Source in Chicken Diets

Abstract approved: Redacted for Privacy

George H. Arscott

Several experiments involving broilers and laying hens were conducted with the primary goal of evaluating the feeding value of Canola meal (CM) in both broiler and laying hen rations. A secondary goal was to study the growth response of broilers receiving higher concentrations of CM in their starter diets to supplements of protamone, arginine, methionine and/or zinc bacitracin.

In the broiler experiments, satisfactory performance was obtained by feeding diets in which CM replaced up to 50% of soybean meal (SBM). However, growth and/or feed consumption and efficiency of feed utilization were adversely influenced by feeding CM at replacement levels higher than 50%.

Protamone at 0.0025% of the diets containing CM at 50% and 100% reduced the enlarged thyroids of birds fed such diets to a size approaching that of controls, but a 0.005% level of protamone greatly reduced the size of the thyroids below that of birds fed the corn-SBM diet. No growth response was associated with the lower protamone dietary treatment, when a significant reduction in growth

was observed to feeding the diets containing the higher protamone rate.

Dietary supplements of arginine, methionine and zinc bacitracin did not appear to have a positive effect on performance of broiler chicks fed the starter diets at which CM substituted for higher levels of SBM.

In all the broiler trials, there were no significant differences between the dietary treatments for the incidence of a leg abnormality condition, however, in experiment 4, when the chicks were fed the starter rations in which CM replaced 50% and 100% of SBM, a numerical increase in the occurrance of this condition was observed.

In the laying hen experiment, CM which replaced up to 100% of SBM of the experimental rations, did not have any adverse effect on hen egg production, efficiency of feed utilization, external and internal egg quality or final body weight. Fertility and hatchability of fertile eggs as well as dropping scores were also not significantly influenced by such dietary treatments.

In both the broiler and laying hen trials, thyroid glands tended to be slightly enlarged with increasing levels of CM in the diets.

CANOLA MEAL AS A PROTEIN SOURCE IN CHICKEN DIETS

By

Abdul-Rahman H. Nassar

A THESIS

Submitted to

Oregon State University

in Partial Fulfillment of the Requirements for

the Degree of

Master of Science

Completed June 14, 1985

Commencement June 1986

APPROVED: Redacted for Privacy

Head of Department of Poultry Science and Professor in Charge of Major

Redacted for Privacy

Dean of Graduate School

Date thesis is presented June 14, 1985

Typed by Sherri Harkins for Abdul-Rahman Nassar

ACKNOWLEDGEMENTS

The author wishes to express his deep and sincere appreciation to Dr. George H. Arscott for serving as his major research professor, advisor and for his constant understanding, encouragement, guidance and friendship. Deep gratitude and appreciation is also extended to Dr. Donald H. Helfer, Yemen Poultry Extension and Training Program Director, for his wise advice, professional assistance and for serving as a co-major professor of his graduate committee.

Sincerest thanks are also extended to Dr. Peter Cheeke and Dr. William Brown for their comments, helpful suggestions, and their willingness to serve on the advisory committee. Also, special thanks to Dr. Roger Fendall, Program Director for the Faculty of Agriculture Project, for his review of this document and his constant encouragement.

Sincere admiration and thanks to Miss Sherri Harkins for typing this manuscript, Mrs. Mary Goeger for her valuable advice and constant assistance, Mr. Sommai Tachasirinugune for his friendship and constant help and to all the staff members of the Poultry Science Department at Oregon State University who helped in conducting this research and in collecting the experimental data.

Special appreciation and thanks go to Sana'a University, Faculty of Agriculture, in the Yemen Arab Republic for giving me the chance to continue my higher education towards the Ph.D. degree. I am hoping that I will be able to return part of this generosity by serving as a member of the faculty at that university in the near future.

Special appreciation is extended to the Agency for International Development (AID) for financial support through the Yemen Title XII Agricultural Development Support Program (ADSP) (USAID Project 279-0052), the Consortium for International Development (CID) and the Faculty of Agriculture Subproject, O.S.U. Additionally, the author is grateful for support received from the South Willamette Broiler Growers' Association for financial support through the Agricultural Research Foundation in the conduct of the broiler experiments. Support from the Canola Council of Canada; the Alberta Agriculture Marketing Development Group of Canada; Lamont's Featherland Farms, Coburg, Oregon; and the Agricultural Experiment Station of Oregon State University are gratefully acknowledged.

Finally, I wish to gratefully thank my parents, brothers and sisters for their support and patience and to my wife and daughters for their love and understanding.

TABLE OF CONTENTS

LIST OF TABLES

CANOLA MEAL AS A PROTEIN SOURCE IN CHICKEN DIETS

CHAPTER I

INTRODUCTION

Meal from conventional rapeseed (RS) has been extensively evaluated as a vegetable protein source in poultry diets. Thyroid enlargement, poor performance and a higher mortality rate are adverse effects associated with birds fed diets containing relatively high levels of this meal. The negative effects of meals of the old varieties of RS were found to be related to the high content of toxic substances such as erucic acid and glucosinolates.

However, meals from new cultivars given the designation of "Canola", which have been genetically developed by plant geneticists for their low level of these substances, might be utilized in poultry diets to replace a higher portion of soybean meal (SBM) with no severe effects on bird productivity.

The objectives of this study were:

1. To determine the replacement value of Canola meal (CM) for SBM in broiler diets, and to study the possibility of improving performance of broilers

fed diets containing high levels of CM by using different supplements of certain nutrients and additives.

2. To evaluate the replacement value of CM for SBM in diets for laying hens.

CHAPTER II

REVIEW OF LITERATURE

A - Background

RS has been grown primarily for its edible oil. Canada is considered to be the world's leader in production of RS and its by-products.

Until 1936, RS *Brassica campestris* and *Brassica napus*, which are classified in the Crucifera family were grown in Canada as pasture crops. However, after that date, RS has been widely grown as a source of oil used for human and industrial applications (Bell, 1982). As a result of the extensive increase in production of RS, there arose a need to study the possibility of utilizing its seed by-products in livestock diets as a vegetable protein source.

In poultry, the first study on the possibility of incorporating rapeseed meal (RSM) in poultry feed as a replacement for part of SBM, the traditional source of vegetable protein in poultry rations, was conducted at the Ontario Agricultural College at Guelph by Petit *et al*. (1944). The results of this investigation showed that goitrogenicity and high mortality were associated with RSM inclusion in starter chicken diets.

Since then, many investigators have tested the nutritional value of RSM as a feedstuff in poultry diets.

The results of most of these studies revealed that RSM, in addition to its relatively high content of protein, contains significant levels of several deleterious substances such as, glucosinolates and their hydrolytic products (thiocyanate, isothiocyanates, goitrin and nitriles), erucic acid tannins and sinapine in addition to a high content of fiber which separately or together adversely affects performance parameters (Rutowski, 1971; Fenwick and Curtis, 1980a).

In Canada, plant breeders have now developed several new cultivars of RS for their low levels of erucic acid and glucosinolates and for their lighter and thinner seed coat. These new varieties are now known either as "double zero" cultivars or as "Canola" in order to be distinguished from the conventional RS varieties.

The cultivars B. napus cv. Tower (low erucic acid, low glucosinolate) and B. campestris cv. Candle (low erucic acid, low glucosinolate and low fibers) now are the most widely grown cultivars in Canada on a commercial basis (Biely and Salmon, 1980; Fenwick and Curtis, 1980b). Meal from these new cultivars have been reported to be utilized in poultry rations at fairly high levels with no adverse effect on performance (Clandinin and Robblee, 1983).

B - Rapeseed Meal in Poultry Diets

The nutritional value of RS from the old cultivars and its by-products has been determined by many investigators to be inferior to SBM as a protein feedstuff in poultry diets. Excellent comprehensive reviews on this subject have been presented by Bell (1955), Clandinin and Robblee (1966), Fenwick and Curtis (1980a and 1980b) and Hill (1979).

Since CM and its utilization, from the nutritional point of view in broiler and laying hen diets was the subject for this research, the emphasis in the general literature review section of this chapter will be placed mainly on the investigations focused on meals from the developed cultivars of RS and their use in poultry diets.

C - Canola Meal in Poultry Diets

1 - Broilers

The adverse effects on weight gain and feed efficiency associated with including RSM from conventional varieties in animal feeds, was found to be attributed to the high levels of erucic acid, glucosinolates and/or fiber content of meals of these cultivars. The level of these undesirable substances are significantly reduced in the new varieties of RSM now referred to as CM.

Hulan and Proudfoot (1981a) conducted a study in which the nutritional value of meals from Tower and Candle RS were evaluated as a partial or complete replacement for SBM in broiler starter and finisher diets. The nutritional value of fish meal (FM) as a complementary source of dietary protein to CM in broiler diets has also been evaluated. In both starter and finisher diets Tower RSM (TRSM) replaced up to 60% of the SBM and Candle RSM (CRSM) replaced up to 100% of the SBM. In both cases no attempt was made to keep these diets isonitrogenous or isocaloric. In contrast, in another experiment, TRSM and CRSM were used to replace up to 100% and 80% of SBM, respectively, in both starter and finisher diets which were kept isonitrogenous and isocaloric by using dietary supplements of FM and animal fat. The results of this study indicated that TRSM and CRSM could be utilized in starter and finisher diets to replace up to 80% TRSM on a straight replacement basis with no adverse effect on body weight or feed efficiency. Moreover, the meals from these varieties of CM were found to successfully replace all the SBM in both broiler starter and finisher diets when energy, protein and amino acid differences were considered. FM showed not only to keep the diets containing RSM isonitrogenous, but also to maintain dietary amino acid balance. It was, therefore, suggested that FM could be used as a complementary source of dietary protein in diets containing high levels of CM.

The effects of CM in broiler diets on performance, carcass grade and meat yield were evaluated by Salmon (1981). In this study CRSM was used in wheat-based starter diets at up to 281g of CRSM/kg with either 230 or 210g of protein/kg and up to 121g in finisher diets with either

190 or 170g of protein/kg. Each combination of CRSM and protein level was fed in diets of low and high nutrient density to assess the value of added fat in maintaining constancy of true metabolizable energy content of diets containing CRSM. Results of this study showed that no adverse effect on live weight gains from either CRSM or nutrient density was found. Feed efficiency was also not affected by CRSM when nutrient density was maintained with fat, but was reduced in diets of lower protein density. A reduction in live weight; feed efficiency; carcass fleshing, grade and edible meat yield; and an increase in abdominal fat were associated with low protein diets. When the diets contained 281g of CRSM/kg in the starter and 121g of CRSM/kg in the finisher, intensity of chicken flavor decreased and frequency of the off flavors increased. No adverse sensory effects occurred when CRSM was incorporated at up to 210g/kg in the starter and up to 90g/kg in the finisher diets. Summers and Leeson (1977a), on the other hand, reported that incorporating TRSM in isonitrogenous, isocaloric male-broiler diets at a level of 20% resulted in a significant reduction in body weight and feed conversion, compared with those of birds fed the control SBM containing diet.

Low glucosinolate RSM (LG-RSM) produced from several cultivars of RS such as Bronowski, Tower and Candle was reported by Clandinin and Robblee (1981) to be utilized in broiler diets at levels up to 20% with no adverse effect on growth or feed conversion parameters, after adjusting the diets for metabolizable energy (ME) by using a suitable energy source. Bahraga and O'Neil (1979), in studying the nutritional value of CRSM and TRSM as sources of protein in broiler diets, indicated that CRSM when completely replacing SBM in starter and finisher rations resulted in a significant reduction in body weights, but no adverse effect on feed efficiency was noted. A similar result was obtained with incorporating TRSM in starter diets. Thyroids of birds fed the starter TRSM containing diets were significantly enlarged, but not with birds fed CRSM compared with thyroids of control birds fed SBM. Tibia ash of broilers fed CRSM or TRSM starter diets, as total replacements for SBM, and carcass grade of birds fed CRSM in trials of 4 and 7 week duration, respectively, were not adversely affected. The use of RSM of various LG-RSM Swedish cultivars in broiler diets was investigated by Thomke et al. (1983). Results showed that LG-RSM, when included in the diets at levels up to 15% or 18% did not adversely influence feed intake. However, with the lowest level there was no alteration in performance in relation to the SBM control diet. The highest level resulted in a slight decrease in performance. Leg weakness and thyroid size enlargement defects showed a tendency to increase significantly with increasing levels of LG-RSM in the diets.

Huyghebaert et al. (1983) compared the nutritive value, apparent metabolizable energy (AME) content and protein and amino acid digestibility of meals produced from Tower (TRSM), Erglu (ERSM) and Jet Neuf rapeseed (JRSM), which have various levels of glucosinolates, with SBM in broiler and rooster rations. The effect of steam pelleting on nutritive value of the experimental RSM's was also investigated. Meals of RS were incorporated in broiler growing diets at levels of 25% and 28.6% in the adult cock rations. The nutritive values were measured as ME content and apparent digestibility coefficients (ADC) of crude protein and amino acids, the latter only with roosters. The determined AME for SBM, TRSM, ERSM and JRSM were 2700, 1804, 1879 and 1152 kcal/kg with broiler chicks and 2752, 1972, 2049 and 1850 kcal/kg using adult roosters, respectively . A marked negative effect for glucosinolate on ME was noted only with broiler chicks. Steam pelleting resulted in improvement of ME of RSM in both of broilers and roosters. Amino acids and crude protein ADC for SBM and the examined RSM's were 87% and ± 81% (79-83%), respectively.

True amino acid availability (TAAA) values of samples of SBM (49% crude protein), whole Tower and Candle RS, and meals of these two cultivars of RS were also evaluated by Muztar et al. (1980a) using the true metabolizable energy (TME) assay method in two different laboratories. TAAA determined values were 90-97, 82-94, 84-95 and 86-96%, when these ingredients were fed as the sole feed, for SBM, TRSM, CRSM and TRS as well as CRS, respectively, with an exception for cystine and tyrosine values from the two laboratories which caused wider ranges than the rest of amino acids. In contrast, a large variation in TAAA values of the RSM's between the two laboratories was noted when these feedstuffs were fed as parts of basal diets. Protein quality of several samples of RSM was determined biologically by using the total protein efficiency method which ranged from 2.57-2.71 but was found not to be significantly different from that of SBM (2.65) as was also reported by Goh et al. (1980). Values of 83.5-84.8, 90.4-89.8 and 76.2-76.4 for protein quality measurements, true digestibility (TD) %, biological value (BV) % and net protein utilization (NPU) %, respectively, were determined in meals of Canola cultivars, Tower, Candle and Erglu as was shown in a study conducted by Campbell et al. (1981).

In studying RSM amino acid balance and interrelationships, some investigators have suggested that arginine, may not be available for anabolic purposes for growing chicks maintained on RSM containing diets, due possibly to arginine involvement in tannin excretion as an ornithine precursor. However, in the presence of methyl donors such as methionine, some of the dietary arginine might be freed for anabolic purposes.

In a number of experiments using Single Comb White Leghorn chicks, a significant improvement in body weights, feed conversion and feed intake was obtained with dietary supplements of arginine or methionine or arginine + methionine to isonitrogenous, isocaloric diets in which RSM replaced all protein of SBM (Leslie et al., 1976). Similar results were reported by Leslie and Summers (1975) when they attempted to evaluate the amino acid profile of RSM.

Summers and Leeson (1978a), in a series of experiments evaluated the feeding value and amino acid balance of TRSM in diets using White Leghorn chicks. Practical and semi-purified type diets containing TRSM at different levels replacing part or all protein of SBM were utilized. Diets containing TRSM were supplemented with various levels of arginine, methionine and lysine. The addition of amino acid supplements resulted in improved performance of chicks fed the semi-purified containing TRSM. No improvement or adverse effects on chick performance were noticed with dietary supplements of these amino acids in practical type diets. In the semi-purified diets, optimal weight gain was achieved with dietary supplementation of 0.75% L-arginine-HCl, 0.75% L-lysine-HCl and 0.3% DL methionine. As a general conclusion, these investigators suggested that TRSM could be utilized in practical broiler type diets up to 15% with no detrimental effects.

The amount and nature of condensed tannins in RSM (Cv. Tower) were detected in a study by Eung et al. (1979). Results of this study showed that no condensed tannins were detected in RSM (endosperm and germ). However, 0.1% of such tannins were extracted from the RSM hulls by using 70% aqueous acetone solvent. Leucocyanidin was found to be the basic unit of isolated polymeric flavanols. In view of this result, the authors suggested that insignificant effects might be encountered in absorption of the detected level of these polymeric compounds by birds fed diets containing RSM.

Mitaru et al. (1981) undertook research to determine the influence of tannins in rapeseed hulls (RSH) on performance of broilers and on inhibition of alpha-amylase in vitro. For this study, two experiments were performed. In the first trial, RSH's were extracted and the liquid extract was added to both RSM and RSH's which were incorporated in diets fed to broilers for 4 weeks. The second trial involved feeding broilers diets containing 10% and 20% RSH's or soybean hulls (SBH) and continued for a three week experimental period. SBM-basal diets were used as control diets in both experiments. No reduction in weight gain was found as a result of these treatments in either experiment. The birds fed RSH's however, showed a higher feed conversion than those fed SBH's and control SBM diets. Tannins in RSH's were determined to be as low as 0.1% which showed zero values in inhibition alpha amylase (in vitro). Therefore, it was concluded that tannins in RS are of only minor nutritional significance. A similar result was also reported by Mitaru _et_ _al_. (1983).

RSM in general contains a high level of fiber resulting in lower ME content compared with SBM. Goh _et_ _al_. (1982a) conducted a study to determine the effect of dietary supplement of cellulolytic enzyme (Driselase) on growth performance and feed efficiency in broilers fed diets containing RSM and possible alteration in goitrogenic activity of the RSM containing diets. Meals from Regent, Candle and Turret cultivars of RS were incorporated in the experimental diets at levels of 20% as a partial replacement for SBM. There was no improvement in growth rate or feed conversion in response to the added enzyme. Chicks fed the RSM containing diet showed varying degrees of thyroid enlargement depending on the cultivar from which the meal was obtained. A lower degree of thyroid enlargement was found to be caused by the meal of the Candle variety. No adverse effects from inclusion of that level of RSM (20%) on body weight or feed efficiency was reported.

In studying the influence of a steam pelleting process on the feeding value of meal of Tower and Candle for broilers, Slinger _et_ _al_. (1978a) reported that steam pelleting of isonitrogenous, isocaloric diets containing

Tower and Candle RSM at levels of 30 and 20%, respectively, did not result in improvement of growth rate or feed efficiency of males fed these rations compared with mash diets. However, a significant improvement was noted in both of growth rate and feed efficiency attributed to the steam pelleted control corn-SBM diets versus the control mash-type diets. The non-improved growth rate and feed conversion observed with the pelleted diets containing RSM were then related to a reduction in amino acid availability, particularly arginine which was noted to be involved in excretion of RSM tannic acid. Growth rate and feed efficiency of birds fed TRSM up to 30% and CRSM up to 20% of their diets were not significantly influenced by these dietary treatments.

Goh et al. (1982b) evaluated the sparging effect of CM with ammonia, in the presence or absence of steam, on its amino acid composition and feeding value for broilers. They found that sparging treatments did not have any significant effects on the meal's amino acid content, thyroid size or growth rate. However, sparging with steam was shown to improve lysine availability and feeding value of the treated meal. In a subsequent study dealing with the influence of the desolventization process and the removal of fibrous material on the nutritional value of CM from Regent cultivar, Shires et al. (1983) showed that the feeding value of CM was improved by desolventizing at

100^{o}C which was due to complete destruction of the myrosinase enzyme in the meal. Steam use during the desolventization process did not result in a further nutritional improvement of the meal. It was also found that broiler performance was not improved by feeding CM in which fiber was reduced to half its normal content.

The use of RSM, particularly from conventional RS, in practical type diets for poultry has been limited due to several deletrious factors present in this meal. Low concentration of available energy in general is one of the drawbacks which is associated with the high fiber content of the meal. An improvement in ME value was presumably mentioned to be associated with the reduction of the high fiber and the tannin seed coat in some recently developed triple cultivars, such as Candle.

RSM's derived from Brassica napus, Altex and Regent cultivars, were compared with meal from Brassica Campestris, Candle cultivar, for their TME. Meal from the Regent variety showed a significantly higher TME (2.54 kcal/g) compared with that of Candle or Altex (2.31 or 2.39 kcal/g), when these ingredients were fed as a sole feed. No significant differences between the TME values of the tested samples were found when they were fed as a part of basal diets (Muztar and Slinger, 1982). A value of 9.17 kj/g of TME was also determined as the average TME of meals of the Canola cultivars, Tower, Candle and Erglu, and no significant variation between their TME values was found as noted by Campbell (1981). In an earlier study Muztar and Slinger (1980b) in studying the AME of Tower and Candle RS products have shown that AME values of meal from both Tower and Candle RSM were essentially identical (2.24 and 2.25 kcal/g, respectively), but those values were significantly lower than that of soybean meal (2.94 kcal/g).

TME values for samples of Tower and Candle RSM tend to increase with increasing level of feed intake (Muztar and Slinger, 1979). Bayley et al. (1974) had earlier reported, in reviewing other investigations, that the level of dietary RSM, its variety, subsequent factory processing, the duration of feeding and the age of the birds involved had an effect on RSM metabolizable energy values.

Clandinin and Robblee (1983a) suggested, as a result of reviewing some studies done on this subject, that 1900 kcal/kg and 2000 kcal/kg are appropriate apparent metabolizable energy (AMEn) to be used for growing and adult poultry, respectively.

The possibility that the use of feed ingredients containing a potentially high level of methyl groups in poultry diets may adversely influence the palatability of poultry meat has received some attention from several investigators.

Meal from Canola varieties still contain a high level of sinapine as was reported by Mueller et al. (1978a). As an example, meal from Canola (Tower cv.) was found to contain up to 2.5% sinapine. Thus the extra methyl groups which are provided by this substance may be the factor responsible for the production of undesirable odor and flavor in meat of chickens fed conventional RS. Steedman et al. (1979a, 1979b) evaluated the eating quality of meat of broilers fed up to 15% medium glucosinolate RSM from Span cultivar (SRSM) with and without dietary supplementation of 5.0% herring meal, 0.1% DL methionine and 0.05% choline to enhance taint development. Both trained taste panels and consumer taste panels techniques were used in this evaluation. Meat from birds fed diets containing 15% SRSM was overall described as entirely acceptable in comparison with that of broilers fed the control corn-SBM diet. However, meat of birds fed diets containing SRSM plus additional supplements of herring meal, methionine, and choline was rated significantly lower in odor, flavor and overall acceptability than that of birds fed either SRSM or control diets. Similar results were obtained in other studies which evaluated the effect of meal from several cultivars of Canola, such as Regent, Candle or Tower on meat quality when incorporated at level of 20% in broiler diets (Hawrysh et al., 1982; Hawrysh et al., 1980a; Hawrysh et al., 1980b). Griffiths et al.

(1980) showed that incorporating meals from several high glucosinolate RS at level of 10% in broiler diets resulted in a slightly lower flavor scores for meat, especially meat from legs, compared with that of birds fed the control diet. However, overall results showed that flavor of meat from birds fed RSM was not adversely effected by such dietary treatments.

The relatively high fiber and phytic acid contents of RSM from the old or new cultivars could be important factors that influence the availability of minerals in such meals when included in poultry diets. Nowkolo and Bragg (1980) evaluated meals of various varieties of RS, including Tower cv., for their mineral contents and mineral availability. A limited variation in Ca, P and Mg content of the tested samples was noted and average values of 0.65%, 1.22% and 0.5% were determined for those minerals, respectively. A wide range for Mn and Zn was noticed which was of 49-67 mg/kg and 49-64 mg/kg, respectively, in the samples. Availability of Ca was 59.7 to 75.6%, P was 65.0 to 81.0%, Mn was 45 to 60% and 23% to 57.6% for Zn. Feeding broilers up to two weeks with starter rations containing 20% CM in which phosphorus was calculated as 75% available in the feed formulation was shown by Summers _et_ _al_. (1983) to result in severe growth depression and a marked reduction in bone ash as compared to broilers fed a similar diet in which phosphorus availability was considered at 30% available when the diet was formulated. With this availability value of P comparable performance to that of birds fed the control soybean meal diet was obtained when the birds were fed CM up to 20% of their diet. No adverse effects on leg strength of broilers fed either diets was noted.

The influence of dietary phytic acid and crude fiber on availability of minerals in several feed ingredients including RSM was the goal of a study conducted by Nowkolo and Bragg (1977). The results showed that there was a significant negative correlation between the phytic acid, fiber content and mineral availability in the evaluated feedstuffs. Phytic acid and fiber content of both of RSM and SBM were 1.92% and 0.85% and 12% and 6.5%, respectively. Determined availability values of P, Ca, Mn and Zn were 74.8, 71.7, 56.7 and 44.0 %, respectively for RSM versus 89.3, 85.6, 76.1 and 66.5% for SBM.

2 - Growing Chicks and Laying Hens

Meal from the old varieties of RSM when utilized in laying hen diets at levels as low as 5% have resulted in several adverse effects, such as increased mortality and depressed feed efficiency and egg production. Such effects have been attributed to the erucic acid, glucosinolates and/or fiber content of these meals. Now, with the "double zero" cultivars which contain significantly lower concentrations of these deleterious compounds, meals can be safely fed to laying hens at higher levels without severely affecting their general productive performance.

Thomas et al. (1978) investigated the maximum added level of Tower RSM in White Leghorn laying hen diets. Results of this study showed that when TRSM was incorporated up to 15% in laying hen diets there was no negative influence on egg production, egg weight, specific gravity and Haugh Unit values compared to those from hens fed the control corn-SBM diet. Thyroids from hens fed the tested meal were slightly enlarged, and no incidence of liver haemorrhagic syndrome (LHS) was found. Similar results were obtained by Ibrahim and Hill (1980) with a 20% level of TRSM in brown-shelled laying hen diets, in relation to egg production and the slightly enlarged thyroids, but in this study a low degree of the incidence of LHS and the production of tainted eggs were observed.

Vogt and Torges (1976) reported that when isonitrogenous, isocaloric diets containing up to 15% meal from Summer RS Erglu cv. (low glucosinolate, low erucic acid) was fed to white-egg laying hens, no adverse affects on either the hen's general performance or mortality was shown. However, a slight thyroid enlargement was associated with feeding the ERSM compared to the corn-SBM basal diet. Hulan and Proudfoot (1981b) demonstrated that when CRSM and TRSM were utilized in White Leghorn hen diets at a concentration of 15%, egg weight and mean body weight values were as satisfactory as those of controls with both meals, but a drop in egg production and feed efficiency was shown only by hens fed the CRSM diet.

The possibility of utilizing meal from TRS to replace all SBM in rations fed to hens from two different white egg strains was evaluated by March et al (1978). The results of this investigation showed that the utilized strains showed significant differences in response to the TRSM diet in relation to egg production; however, overall results indicated that egg production was not adversely affected by such treatments. Poorer feed conversion and a slight reduction in hen and egg weights were observations associated with totally replacing SBM in diets with such meal.

Hulan and Proudfoot (1980a) studied the effect of feeding diets containing RSM from Candle and Tower cultivars on the mortality and the general performance of layers raised in pens during the growing and laying periods. Commercial Single Comb White Leghorn chicks were utilized in this investigation. The results showed that meal from both the Candle and Tower varieties can be used in pullet starter and grower diets to replace up to 74% of SBM without affecting mortality, feed consumption or age at sexual maturity but a slight depression in body weight was noticed at 20 weeks of age compared with control birds. On the other hand, feeding RSM from both types at a level of 15% in the layer diet did not adversely effect body weight, egg production, feed conversion or Haugh Units. However, a significant depression in egg size and specific gravity was noted at the end of the 497 day experiment. In both stages of the trial feeding RSM did not appear to have a significant effect on mortality attributed to the incidence of the LHS.

In a comparative study involving the nutritional value of Candle and Tower RSM in diets for pullets and laying hens raised in cages, Hulan and Proudfoot (1980b) carried out an experiment in which chicks from two different SCWL genotypes were fed these meals at a level of 20% during the starting and growing period and at levels of 10 or 15% during the production cycle. RSM from both cultivars was found to be utilized in pullet (starter and grower) and production rations at 20 and 15%, respectively, without an adverse effect on mortality, feed efficiency and egg production. A significant reduction in specific gravity and a slight reduction in Haugh unit values was attributed to feeding both meals at the highest level. The mortality was higher among birds switched from SBM diet to a 15% RSM diet. During the growing and production period, birds fed TRSM generally showed heavier body weights, earlier sexual maturity, higher egg production and improved feed efficiency over birds fed CRSM. Except for mortality both genotypes showed different responses to the tested diets.

Feeding RSM from Tower cultivar in White Leghorn laying hen diets at the 15% level did not have adverse effects on mortality, incidence of liver haemorrhagic syndrome or egg production. However, a slight but insignificant reduction in egg production, egg size and hen body weights at the end of the ten-28 day period experiment were noted (Leeson et al., 1977). In a similar study with CRSM Slinger et al. (1978b) reported that such a meal when fed to White Leghorn laying hens at levels up to 15% did not adversely influence feed intake, egg production, egg weight and egg shell thickness, but egg size was slightly reduced even when birds were fed diets containing as low as 10% CRSM. Birds did not show any increase in mortality rate or incidence of LHS when they were fed the experimental diets.

Effects of feeding RSM from the new varieties on hatchability and fertility as well as the general performance of progeny have been evaluated. Results obtained in several studies revealed that such meal did not appear to have an effect on these traits. Summer et al. (1978b) showed that TRSM when fed to different strains of laying hens, at levels up to 15%, fertility, hatchability and performance of subsequent offspring were not adversely influenced by such treatment. Similar results were obtained by Proudfoot et al (1982) who studied the effect of incorporating CRSM and TRSM in diets of several meat breeder genotypes at the 6.5% level on their reproductive performance. Hatchability, fertility and progeny performance were as satisfactory as those of controls. Moreover, hatchability of eggs laid by breeders fed RSM was numerically higher than that of controls.

Proudfoot et al. (1983) working with several meat breeder genotypes investigated the feeding value of a mixture of different levels of CRSM and TRSM in juvenile and adult rations. RSM was included in starter, grower and breeder diets at levels of 5%, 5% and 6.5%, respectively. Hatchability, fertility and progeny performance during the growing and adult stages were found to be comparable to those of birds fed the control corn-SBM diet and the various genotypes exhibited different degrees of response to the tested diets.

The influence of feeding LG-RSM from the Regent cultivar to White Leghorn chickens during both the rearing and laying periods was researched by Kiiskinen (1983a). Regent rapeseed meal (RRSM) was utilized in starter, grower and layer diets at levels up to 7.5%, 15% and 17%, respectively. Results of this investigation showed that no effect on mortality or feed consumption among the pullets fed the experimental meal, but a depression in body weights at sexual maturity was evident. The layer diet containing 17% RRSM resulted in significant increases in mortality and the incidence of LHS in addition to depression in both egg production and egg specific gravity scores. A negative correlation between feed consumption, body weight gain and level of RRSM in the diets was also observed. In contrast, no effect of feeding any of the tested levels of RRSM on hatchability, fertility or progeny performance was found. Based on the general results of this study, the author suggested that RRSM is not recommended for long term use when fed to laying hens at levels higher than 10%. Clandinin et al. (1983b) in reviewing results of several recent studies in evaluating CM for laying hens, stated that CM at 15% inclusion might be safely utilized in laying hen rations. However, in an earlier article Clandinin and Robblee (1981) reported that as high as 20% of LG-RSM could be incorporated in layer diets with generally satisfactory performance. However, in spite of that, for safety a conservative level of 10% was selected to be the recommended level in breeder and layer chickens.

3 - Turkeys

A limited amount of work on the use of meal from the new cultivars of RS in turkey rations has been reported. Salmon et al. (1979) in investigating the potential of CM in diets for broiler-type turkeys, undertook a study in which meal of the Candle variety was fed to small broiler turkeys at four different levels of 0, 7.5, 15 and 22.5% from one day old up to the market age (98 days). Results of this study, in comparison with the controls, showed that only the highest level of CM resulted in an adverse reduction in body weights to 63 day of age and a severe depression in this parameter was noted with all CM groups after that age. No significant differences in efficiency of feed utilization, as an overall the experimental average, or mortality were observed between the CM and the control treatments. However, a significant reduction in carcass finish was found with the highest level of CM in the tested diets.

Hulan et al. (1980) included meals from both CRS, TRS or combination of both in broiler turkey prestarter, starter, grower, developer and finisher diets at levels of 10, 20, 30, 30 and 30%, respectively. Diets containing meal from both cultivars of RS were found to result in higher live weights, improved feed conversion, higher percentage of grade A carcass, lower mortality and improved monetary returns over the control corn-SBM diets.

An investigation was conducted by Moody et al. (1978) in which the feeding value of TRSM, in large white turkey diets was evaluated. Results obtained showed that CM as high as the 20% level from day one up to 112 day of age, resulted in comparable performance to that of controls without any adverse effect on productive performance. Slinger (1977) reported that when Nicholas Large White turkey poults were fed TRSM at a level of 25%, from hatching through 16 weeks of age, a satisfactory weight gain, feed consumption and feed conversion was achieved compared to those of birds fed the control corn-SBM diets. In a similar study, Salmon (1979), included meal from TRS or CRS in medium white broiler turkey diets at various levels up to 30% from 6 to 56 day of age. Results showed that, for either meal at any level, no adverse effects on growth rate, feed efficiency, feed intake or carcass finish values were evident at the time of the experiment's termination.

The hypothesis that CM utilization in turkey starter rations at a fairly high level should involve FM was investigated by Salmon (1982). In this study, white female poults were fed CM at four different levels of 0, 15, 30 and 45% combined with 0, 6 and 12% of FM from 2 to 6 weeks of age. At 42 days of age, there were no significant differences in body weights of birds fed CM containing diets with or without FM compared to those of controls. However, a slight reduction in feed efficiency was noted with birds fed CM diets, and an improvement in feed utilization was obtained when such diets were supplemented with FM at either the 6 or 12% level. The investigator, as a final conclusion to this study, stated that FM did not appear to improve growth rate when added to turkey starter-CM containing diets. Larmon et al. (1983) indicated that CRSM when fed to small broiler turkeys at several levels up to 21.1% did not adversely effect the meat flavor scores which were measured by trained taste panelists.

Clandinin et al. (1983c) reported that CM can be successfully fed to starting and growing turkeys at levels as high as 20% resulting in growth rate, feed conversion and meat quality values equal to those of birds fed the control corn-SBM diets. No reports on the use of LG-RSM in rations for turkey breeders have been published. Clandinin and Robblee (1981), in view of unpublished works, suggested that CM at 10% level might give as satisfactory egg production, feed efficiency and hatchability as those of the turkey breeders fed the basal corn-SBM diets.

D - Adverse Effects of Canola Meal

1 - Thyroid Enlargement

In evaluating the nutritional value of RSM for poultry, several problems have been reported to be associated with this feedstuff, especially from the conventional cultivars. Glucosinolate content of the meal is a primary source of these problems. However, intact glucosinolates are not particularly very harmful themselves, but RS in addition contains the enzyme myrosinase (thioglucoside glucohydrolase) which degrades these compounds resulting in the production of several toxic substances, namely aglucones. This enzyme can also be synthesized in bird's intestinal tract by some microflora bacteria. Isothiocyanates, organic thiocyanates, nitriles and goitrin [(-)-5-vinyl-2-oxazolidinethione] are such aglucones found in varying levels in RSM depending upon the variety from which the meal is obtained and the method of processing used in producing such meal. Organic thiocyanates and isothiocyanates have minor goitrogenic activity compared to oxazolidinethione which is the major goitrogenic substance identified in RS (Hill, 1979).

Meal from Canola cultivars contains a very low glucosinolate content compared with those of the old varieties of RS, 10 micro Mol/g for meal from Tower RSM versus 105 micro Mol/g for the meal from the conventional variety Target. However, even with this low level of glucosinolates, meal from Canola when utilized in poultry diets still has the ability to slightly induce thyroid enlargement (Leeson, 1984). Clandinin et al. (1966) reported that goitrin when fed to White Leghorn chicks resulted in reduction in iodine uptake by thyroid gland and an increase in iodine secretion, but after chicks received the goitrin for a 4 week period, iodine uptake and iodine secretion from the gland returned to normal. As a consequence, it was suggested by these investigators that birds fed goitrogen increase the thyroid to body weight ratio to reach a physiological equilibrium state.

In evaluating performance of broiler chickens fed rations containing CM's, effects on thyroids were also studied by Robblee _et al_. (1981). In this investigation a slight enlargement in thyroid size of chicks was shown to be induced by CM inclusion when compared with thyroids of birds fed the control diet corn-SBM. Thyroid-body weight ratio of 4-week old broilers fed TRSM at levels of 10% and 20% averaged 8.08 mg/100g and 8.48 mg/100g, respectively, with averages of 9.13 mg/100g and 9.22 mg/100g for thyroids from birds fed CRSM at levels of 10% and 20%, respectively, compared to 7.45 mg/100g of control birds. In a comparable study with laying hens Thomas _et al_. (1978) reported similar results.

Even though inclusion of RSM in poultry diets induce thyroid enlargement, no severe effects on the pituitary or thyroid hormones in blood plasma or on the general performance of birds have been detected. Chiasson _et al_. (1979), showed that thyroid enlargement of male broilers fed high glucosinolate rapeseed meal (HG-RSM) at 10% level had no adverse effect on concentration of plasma of thyroxine (T_4), growth hormone (GH), luteinizing hormone (LH) and prolactin. However, at age 3-5 weeks the concentration of plasma triiodothyronine (T_3) was adversely suppressed. No adverse effect on growth rate, as a result of that depression in T_3 was reported.

Summers and Leeson (1977b) studied the influence of dietary supplements of protamone (iodinated casein) on serum T_4 concentration and growth performance of chicks fed RSM from Span cultivars at level of 39.5%. Results indicated that in spite of thyroid enlargement of birds fed RSM containing diet, the reduction in T_4 level in blood was not significant. Additionally, protamone supplements significantly reduced thyroid size and elevated blood T_4, but the increment in blood T_4 was not accompanied with an improvement in chicks growth rate. It was, therefore, suggested that there might be some other major factors associated with RSM which are more responsible for the adverse influence on growth performance rather than a simple depression in blood T_4 level.

Effects of RSM glucosinolates and their hydrolytic products on laying hen's thyroids and iodine transfer to eggs was investigated by Papas et al. (1978). A slight increase in thyroid size of laying hens fed TRSM was noted compared with that caused by feeding HG-RSM, but in both cases there were no significant effect on blood T_4. A reduction in egg iodine content was determined from eggs laid by hens fed both HG-RSM and LG-RSM, however, more adverse effect on iodine transfer to the eggs appeared to be caused by HG-RSM. Thiocyanate ion was shown to be more associated with this effect than other glucosinolate hydrolytic products present in RSM.

In relation to the reduction in iodine content of eggs laid by hen fed RSM, similar findings were reported by Goh and Clandinin (1977). Chicks hatched from eggs laid by breeder hens fed RSM showed thyroid enlargement and growth depression during the first few weeks of age compared with control chicks, however, by the fourth week of age thyroid size and growth rate of these chicks was back to normal (March et al., 1972).

2 - Leg Weakness

Including RSM even from the new cultivars has been reported by some researchers to enhance the tendency towards increased leg abnormalities in growing chicks, especially when relatively high levels of RSM are included in diets. Dietary supplements of Zn, Mn and P have failed to correct this defect.

Seth and Clandinin (1973) reported that a significant increase in the incidence of perosis was noticed among broilers fed RSM at level of 20% versus birds fed the control diets, with a higher incidence among the heaviest birds. Results also showed that dietary supplements of Mn proved ineffective. Low zinc availability in RSM was postulated to be involved in development of this condition in birds fed RSM containing diets, however Motzok (cited by Hill 1979), showed that dietary supplements of Zn had no apparent influence on leg deformity. Summer and Leeson (1983) stated that a marked reduction in bone ash from broilers fed CM at 20% when phosphorus availability of CM was calculated as 75%, but no leg weakness per se was found as a subsequent result.

Turkey poults at 4 weeks of age showed abnormal hock joints when fed a diet containing 20% HG-RSM, from the Target cultivar, but a similar observation was not noticed in poults fed meal from Tower RS at the same level. Therefore, it was suggested that the problem might be eliminated with development of the new variety of RS (Moody et al., 1978). Paika et al. (1981) presented results on the affectiveness of both LG-RSM, Tower cv., and HG-RSM Midas cv., on the incidence of perosis in broilers when utilized at a level of 20% in the experimental diets. These results showed that neither meals appeared to have an adverse effect on the occurrence of this disorder. Similar findings were also noted by Kiiskinen (1983b) who indicated that inclusion of 22% of CM from Regent cultivar in broiler diets did not have any adverse effect on leg strength. An abnormal leg condition was reported by Benmoussa (1983) which appeared to increase numerically but not significantly with increasing level of CM in broiler diets. Thomke et al. (1983) also reported that the incidence of leg weakness was significantly raised with increasing levels of RSM, from low glucosinolate Swedish varieties, in broiler diets. It has been suggested by Fenwick et al. (1980a) that thyroid disfunction by feeding RSM might in some way be related to this defect.

3 - Liver Haemorrhagic Syndrome (LHS)

Laying hens and broilers fed diets containing RSM with high or low glucosinolate content appear to show different degrees of susceptibility to LHS. The disorder which results in relatively high mortality depending upon the cultivar from which the meal is obtained and strain of birds utilized. Glucosinolate content of RSM has been implicated in development of this adverse effect, however, the exact relationship between LHS and glucosinolates is unclear.

Results reported by Campbell and Smith (1979) showed that low incidence of mortality attributed to LHS was evident among the broiler chicks fed diets of high RSM content (300-550 g/kg). The mortality rate was found to be higher for diets containing meal from the high glucosinolate cultivar, Target, and lower among birds fed meal of Span variety, a medium glucosinolate RS, with no adverse effect noted for diets containing low glucosinolate meal from the Bronowski cultivar. Yamashiro et al. (1978) reported that LHS in 4-week old broilers was caused by the hepatocytic necrosis which was found to be induced by feeding diets containing RSM from the Span cultivar at the 50% level.

Incorporating meal from LG-RS Tower cv. and from several other HG-RS cultivars in laying hen diets up to levels of 150 g/kg in a study conducted by Thomas et al. (1978) did not increase the incidence of LHS. From a total of 1260 birds used in this trial 96 were killed at the end of the experimental period, which lasted for 40 weeks, and just three of the sacrificed birds, from those had been fed TRSM, showed the LHS condition. Grandhi et al (1977) in a comparative study to determine the effect of including HG-RSM and LG-RSM at 10% and 20% levels in the diets, on two different strains of laying hens, found that mortality due to LHS was significantly higher in hens fed HG-RSM than in those fed LG-RSM. However, no differences between laying hens from the utilized strains for this effect were found.

Influence of feeding RSM of various cultivars containing different levels of glucosinolates on laying hens of several strains was also the objective of a study carried out by Campbell (1977). The results indicated that susceptibility of laying hens to LHS varied between strains and among hens within strains, and a higher positive correlation between such defect and RSM inclusion level in addition to its content of glucosinolates was also evident. However, the exact relationship between the LHS and RSM glucosinolate was not known. Another study conducted by Papas et al. (1979) also revealed similar results to those previously cited in addition to several others, such as the usefulness of vitamin K supplements for chickens fed RSM to reduce the mortality rate attributed to LHS, and the possibility of correlating this disorder to both hydroxy nitriles and the intact glucosinolate content of RSM.

4 - Fishy Flavor

Sinapine, the choline ester of sinapic acid, in RSM has been shown to be the precursor of trimethylamine (TMA) which is consistently found to be responsible for production of "fishy" flavor in eggs laid by susceptible hens fed RSM even from Canola cultivars. Some brown-shelled egg laying hens originating from Rhode Island Red breeding stock tend to exhibit this trait to a greater extent than do layers from white-egg strains.

Hobson-Frohock et al. (1977) in studying the association of sinapine content of meals from different varieties of RS fed to susceptible layers and the "fishy" taint in eggs laid by those birds, found a high degree of association between the presence of sinapine in RSM and the egg-yolk content of TMA which causes the undesirable flavor. Meals from Canola cultivars, such as that from Tower cv. were found to contain enough concentration of sinapine (7.1 g/kg) to induce occurrence the fishy flavor in tainter-hen eggs. Similar results in relation to the positive correlation between sinapine content of RSM and tainted eggs laid by birds from susceptible strains was described in a study conducted by Goh et al. (1977). In this study it was also found that when choline in a free form was fed to susceptible hens, no influence on the egg content of TMA was observed in contrast to when fed in a bound form as sinapine. However, Mueller et al. (1978b) demonstrated in an in vitro study that microflora from laying hen caeca appeared to degrade both choline and sinapine, at a higher rate for the former compound, producing TMA.

Tainter hens showed a higher level of TMA in their blood than non-tainter hens when fed diets containing RSM. Damage to the TMA oxidation system in tainter hens, was therefore suggested by Pearson et al. (1979a). In an in vivo investigation, Lee et al. (1982) showed that tainter hens fed RSM containing diets exhibited a reduced capability in metabolizing TMA to TMAO (TMA Oxidation) and a slight inefficiency to TMA urine excretion compared with non-tainter hens. Pearson et al. (1979b) studied the effect of feeding RSM on hepatic TMA oxidase in laying hens. Results showed that RSM when fed to susceptible versus non-susceptible laying hens at 10% level of inclusion tended to reduce the TMA oxidase activity, but this effect was of a higher magnitude in the tainter birds than the non-tainter ones. Sinapine present in RSM was reported here to be the major compound in RSM responsible for inhibition this enzyme. The tainter layers which were maintained on the control diet showed also a lower hepatic TMA oxidase activity than the non-tainters. Subsequently, it was suggested that the tainters might have a lower genetic capability to synthesize TMA oxidase. An autosomal semi-dominant mutant gene in both heterozygous or homozygous state had been described by Bolton et al. (1976) to be responsible for the fishy flavor in eggs laid by tainter hens fed on RSM.

Glucosinolates and oxazolidinethione (OZT) present in RSM were postulated by some investigators to have some influence on production of tainted eggs by hens from susceptible strains fed such a meal. This hypothesis was investigated in a study undertaken by Goh et al. (1983). In this study tainter hens were fed aqueous extracts of RSM produced from high, medium and low glucosinolate varieties (Oro, Span and Tower) with different levels in corn-SBM diets to provide sinapine at a rate equal to that of feeding RSM 10% level. Result of feeding these experimental diets to tainter hens indicated that eggs from hens fed the Tower extract diet contained a significantly higher level of TMA than eggs from the hens fed the other diets containing extracts from Oro or Span cultivars. In light of this finding it was concluded that intact glucosinolate in RSM had no effect on TMA content of eggs laid by the tainters.

Since sinapine in RSM is the major factor in producing the fishy flavor in eggs from brown-shelled laying hens, several attempts have been made to reduce the sinapine content through subjecting RSM to certain treatments. Fenwick et al. (1979) indicated that when RSM was treated with calcium hydroxide suspension, the sinapine content of the meal was reduced by up to 90% and eggs laid by tainters fed the treated meal at 10% concentration did not provide a level of TMA which was required to produce taint. Moreover, when RSM from Candle cv. was treated with steam in the presence of ammonia during the desolventization process a significant reduction in its content of sinapine occurred to the degree that when such meal was fed to susceptible hens at 10% inclusion level did not appear to enhance production of the undesirable flavor as was demonstrated by Goh et al. (1984).

CHAPTER III

Effect of Canola Meal (CM) for Broilers, and the Potential Improvement in Diets Containing CM Supplemented with Various Levels of Protamone, Arginine, Methionine and/or Zinc Bacitracin

Abdul-Rahman H. Nassar and G. H. Arscott
Department of Poultry Science
Oregon State University
Corvallis, OR 97331

ABSTRACT

A series of four and seven week experiments were conducted to evaluate the feeding value of Canola Meal (CM) in broiler diets as a protein supplement substituting for part or all of soybean meal (SBM) on a protein equivalent basis. The growth response of broiler chicks fed CM to dietary supplements of arginine, methionine and certain feed additives, such as protamone (iodinated casein) and zinc bacitracin (ZB) was also investigated.

Satisfactory performance was obtained when CM was used in both broiler starter and finisher diets to replace up to 50% of SBM, but a significant depression in growth and/or feed consumption and feed conversion was associated with inclusion of levels above 50%.

Protamone at a 0.0025% level caused the enlarged thyroids of chicks fed CM to decrease to a size approaching those of controls, however, no growth response was found. The 0.005% level of protamone depressed thyroid size significantly below those of the control and accompanied a reduction in bird body weights.

Supplements of arginine, methionine, alone or together, or ZB to CM-containing diets did not have a positive effect on broiler performance.

These results show that CM adversely influences broiler performance when included in starter and finisher diets as a replacement for SBM at levels above 50%.

INTRODUCTION

The adverse effects on growth and feed efficiency associated with feeding rapeseed meal (RSM) in poultry rations produced from conventional varieties have been attributed to their high content of several deleterious substances, namely erucic acid, glucosinolates and fiber (Bell, 1982). In view of this, plant breeders have developed several new cultivars of rapeseed, such as Brassica napus, Tower cv. and Brassica campestris, Candle cv., which are known as "Canola", for their low levels of two or all such constituents. As a consequence, meal of such varieties can be fed to poultry at a relatively high level resulting in comparable performance to that of birds fed control corn-SBM diets (Biely and Salmon, 1980; Clandinin and Robblee, 1983).

Meals from Canola cultivars have been reported by Clandinin and Robblee (1981), Goh et al. (1982) and Slinger et al. (1978) to be included in broiler rations at levels as high as 20% without adversely affecting bird performance. However, when CM completely replaced SBM a significant reduction in broiler growth rate was observed (Bahraga and O'Neil, 1979). Dietary supplementation of herring fish meal to similar diets resulted in comparable performance to that of controls (Hulan and Proudfoot, 1981).

Even though meal from the improved cultivars of rapeseed contains a very low level of glucosinolate (progoitrin) enough is present to induce an enlargement of thyroids, but to a lesser degree than that from the conventional varieties (Leeson, 1984; Robblee et al., 1981). However, no adverse effect on plasma thyroxin level or general performance has been attributed to the enlarged thyroids. Such enlargement, moreover, was reversed by dietary supplementation of protamone, but no growth improvement was obtained (Summers and Leeson, 1977).

Broiler leg weakness is another defect that has been found in some cases to be associated with feeding RSM, even from Canola cultivars (Seth and Clandinin, 1973; Thomke, et al., 1983). It was suggested by Fenwick and Curtis (1980) that thyroid disfunction might in some way be related to this disorder. In contrast, no such defect was noted among chicks fed either the old or new varieties of RSM as has been reported by Paika et al. (1981) and Kiiskinen (1983).

A part of the growth depression in broilers fed a high level of RSM might be related to unavailability of arginine for anabolic purposes which may be due to its involvement in excretion of tannins present in RSM working as a precursor of ornithine which in chicken is derived mainly from dietary arginine (Nesheim and Garlich, 1963). Dietary supplementation with arginine and methionine resulted in improved broiler performance (Leslie *et al*., 1975; Leslie and Summers, 1976). On the other hand, tannins in rapeseed are mainly concentrated in the hull and at levels as low as 0.1% (Eung *et al*., 1979; Mitarue *et al*., 1981; Mitarue *et al*., 1983). These findings support those obtained by Summers and Leeson (1978) who indicated that no improvement in broiler performance was gained from feeding CM containing diets supplemented with different levels of methionine and arginine.

The goal of this study was to evaluate the feeding value of CM as a source of vegetable protein in broiler rations, and to test the possibility of improving broiler performance fed high levels of CM by providing diets with different levels of arginine and methionine and other feed additives, such as protamone and zinc bacitracin.

MATERIALS AND METHODS

Commercial feather sexed day-old broiler chicks were used in all experiments. The chicks were housed in either standard electrically heated chick batteries or in floor pens in which infra red lamps provided heat during the brooding period as will be described later. Treatments for the floor pen experiments involved triplicate lots of 24 chicks in Exp. 1 or of a single lot of 8 chicks each in Exp. 2. Treatments in the battery experiments consisted of four replicates of ten chicks each in Exp. 3 and 4. In all trials, equal numbers of males and females were used in each treatment. The chicks received feed and water *ad libitum*, were provided with 24 hours of incandescent light per day and were reared under a forced draft, positive pressure ventilation system that was manually adjusted to maintain comfort of the chicks.

For both the basal starter and finisher feeds CM replaced SBM at concentrations of 0, 25, 50, 75 or 100%. The diets in each case were made isonitrogenous and nearly isocaloric by including varying levels of animal fat and by making adjustments in the amount of corn (Tables III. 1 and III. 2).

Experiment 1. This trial was designed to evaluate the nutritional value of CM as a protein supplement when utilized in both starter and finisher diets to replace part or all of SBM. The chicks were raised for seven weeks in floor pens and fed the starter (0-4 weeks) and finisher (4-7 weeks) diets (Tables III. 1 and III. 2). Body weights, feed intake and cumulative mortality were determined at 4 and 7 weeks of age and the chicks were examined at the termination of the experiment for the incidence of leg abnormalities.

Experiment 2. The effect of different concentrations of CM and dietary supplemental thyroxine in the form of protamone on the hypothyrotic condition of birds fed CM containing diets and the subsequent influence on growth were investigated in a four week experiment. Since

TABLE III. 1. Composition of the basal-starter rations

Ingredient	Canola Meal Replacement[1], %				
	0	25	50	75	100
Corn, yellow	58.35	54.06	49.05	44.44	39.72
Fat, animal	2.00	3.75	5.50	7.25	9.00
Soybean meal, solv. (47.5% CP)	32.25	25.72	19.19	9.59	--
Canola meal (37 CP)	--	9.59	19.18	31.84	44.50
Meat meal with bone (50% CP)	5.00	5.00	5.00	5.00	5.00
Alfalfa meal, dehy. (17% CP)	1.00	1.00	1.00	1.00	1.00
Defluo. phos. (32% Ca:18% P)	0.42	0.20	0.20	--	--
Limestone flour	0.35	0.25	0.25	0.25	0.15
Salt (iodized)	0.25	0.25	0.25	0.25	0.25
Trace mineral mix-65[1]	0.05	0.05	0.05	0.05	0.05
Vitamin premix 1-75[2]	0.20	0.20	0.20	0.20	0.20
DL-methionine (98%)	0.13	0.13	0.13	0.13	0.13
<u>Calculated Analysis</u>					
Crude protein, %	23.16	23.27	23.41	23.25	23.08
ME, kcal/kg	3022.00	3016.00	2997.00	2970.00	2940.00
Calcium, %	0.97	0.90	0.95	0.94	0.96
Available phosphorus, %	0.48	0.46	0.47	0.46	0.48
Methionine, %	0.49	0.50	0.52	0.53	0.54
Methionine + cystine, %	0.88	0.88	0.88	0.86	0.85
Arginine, %	1.57	1.55	1.53	1.47	1.42

[1]Supplied per kilogram of ration: Calcium, 97.5 mg.; Manganese, 60 mg.; Iron, 20 mg.; Copper, 2 mg.; Iodine, 1.2 mg.; Zinc, 27.5 mg.

[2]Supplied per kilogram of ration: Vit. A, 3304 I.U.; Vit. D, 1111 I.C.U.; riboflavin, 3.3 mg.; d-pantothenic acid, 5.51 mg.; niacin, 22.01 mg.; choline, 191 mg.; Vit. B_{12}, 5.51 mcg.; Vit. E, 1.1 I.U.; Vit. K, 0.55 mg.; folacin, .22 mg.

TABLE III. 2. Composition of the basal-finisher rations

Ingredient	Canola meal replacement[1], %				
	0	25	50	75	100
Corn, yellow	63.52	59.22	54.92	50.47	46.27
Fat, animal	2.00	3.75	5.50	7.25	9.00
Soybean meal, solv. (47.5% CP)	27.50	21.90	16.30	8.15	--
Canola meal (37% CP)	--	8.15	16.30	27.15	38.00
Meat meal with bone (50% CP)	5.00	5.00	5.00	5.00	5.00
Alfalfa meal, dehy. (17% CP)	1.00	1.00	1.00	1.00	1.00
Defluo. phos. (32% Ca:18% P)	0.25	0.25	0.25	0.25	--
Limestone flour	0.13	0.13	0.13	0.13	0.13
Salt (iodized)	0.25	0.25	0.25	0.25	0.25
Trace mineral mix-6[1]	0.05	0.05	0.05	0.05	0.05
Vitamin premix 1-75[2]	0.20	0.20	0.20	0.20	0.20
DL-methionine (98%)	0.10	0.10	0.10	0.10	0.10
<u>Calculated analysis</u>					
Crude protein, %	21.37	21.42	21.47	21.32	21.19
ME, kcal/kg	3086.00	3080.00	3074.00	3053.00	3041.00
Calcium, %	0.82	0.86	0.90	0.94	0.91
Available phosphorus, %	0.44	0.46	0.47	0.49	0.46
Methionine, %	0.44	0.45	0.46	0.47	0.47
Methionine + cystine, %	0.80	0.80	0.79	0.78	0.77
Arginine, %	1.44	1.42	1.39	1.35	1.30

[1]Supplied per kilogram of ration: Calcium, 97.5 mg.; Manganese, 60 mg.; Iron, 20 mg.; Copper, 2 mg.; Iodine, 1.2 mg.; Zinc, 27.5 mg.

[2]Supplied per kilogram of ration: Vit. A, 3304 I.U.; Vit. D, 1111 I.C.U.; riboflavin, 3.3 mg.; d-pantothenic acid, 5.51 mg.; niacin, 22.01 mg.; choline, 191 mg.; Vit. B_{12}, 5.51 mcg.; Vit. E, 1.1 I.U.; Vit. K, 0.55 mg.; folacin, .22 mg.

Benmoussa (1983) found that 0.01% level of protamone tended to reduce the size of thyroids of birds fed a high rate of CM (50% and 100%) to a size significantly lower than those of birds fed the control diet, lower protamone levels were used. The chicks were housed in floor pens and fed the basal starter rations (Table III. 1), with additional treatments in which protamone was added to the diets in which CM replaced 50 and 100% of SBM at either the 0.005% or 0.0025% level. At the end of the experiment all birds were individually weighed and sacrificed by electrocution. After refrigerating the chicks overnight thyroids were removed and weighed individually.

Experiment 3. The effect of arginine and/or methionine supplementation in enhancing the performance of chicks fed rations containing CM was studied in this four week experiment. Chicks were reared in battery pens and fed starter diets in which CM replaced 50 or 75% of SBM. The diets were supplemented with arginine, methionine or a combination of both at levels of 0.1 and 0.2%. These levels are lower than those (0.3% arginine and 0.22% methionine) reported by Leslie and Summers (1975) to result in growth improvement of chicks fed RSM containing diets. Body weights, feed intake, cumulative mortality and the incidence of leg weakness were determined at the end of four weeks.

Experiment 4. Zinc bacitracin (baciferm) was added to starter diets containing 0, 50 and 100% CM, as replacement for SBM, at three different levels of 0, 27.5, and 55 ppm. MacAuliff and McGinnis (1971) reported that addition of antibiotics to diets containing high levels of rye, which contains some deleterious factors, resulted in a significant improvement in its feeding value. Therefore, ZB was fed to chicks housed in batteries to four weeks of age to investigate the growth response of birds fed CM to antibiotics. At the termination of the experiment, body weights, feed consumption and incidence of leg problems were determined. In addition, these chicks were examined for the presence of crooked toes.

All data was subjected to analysis of variance (Steel and Torrie, 1960).

RESULTS

Experiment 1. Birds fed the starter and finisher diets in which CM replaced up to half of SBM performed comparably to birds fed the corn-SBM diets (Tables III. 3 and III. 4). However, a significant depression in both body weights and feed consumption was observed when CM replaced SBM at levels above 50%. No differences in feed conversion between the treatments were evident at either 4 or 7 weeks with one exception noted at 4 weeks for chicks fed the 100% CM replacement starter ration. There was no evidence for any increase in the incidence of leg problems attributed to the CM treatments (Table III. 4).

TABLE III. 3. Performance of Broiler Chicks Fed Starter Diets in Which Canola Meal Replaced Different Proportions of Soybean Meal for 4 Weeks (Exp. 1)

TMT No.	Dietary Treatments	Chicks (no.)	Body wt.[1] (kg)	Feed cons. (kg)	Feed conv.
1	100% SBM-0% CM	72 (2)[2]	0.835^{a}	1.305^{a}	1.56^{a}
2	75% SBM-25% CM	72 (4)	0.829^{a}	1.273^{a}	1.54^{a}
3	50% SBM-50% CM	72 (0)	0.803^{a}	1.294^{a}	1.61^{a}
4	25% SBM-75% CM	72 (0)	0.700^{b}	1.125^{b}	1.61^{a}
5	0% SBM-100% CM	72 (3)	0.570^{c}	1.003^{c}	1.76^{b}

[1]Means followed by the same superscript are not significantly different at ($P<.05$).
[2]Numbers in the parentheses are number dead per treatment.

TABLE III. 4. Performance of Broiler Chicks Fed Starter and Finisher Diets in Which Canola Meal Replaced Different Proportions of Soybean Meal for 7 Weeks (Exp. 1)

TMT No.	Dietary Treatment	Chicks per TMT	Body wt.[1] (kg)	Feed cons. (kg)	Feed conv.	Leg Abnormality (%)
1	100% SBM-0% CM	72 (4)[2]	2.186[a]	4.522[a]	2.07[a]	17.22[a]
2	75% SBM-25% CM	72 (4)	2.154[ab]	4.472[a]	2.08[a]	18.89[a]
3	50% SBM-50% CM	72 (2)	2.186[a]	4.571[a]	2.09[a]	6.94[a]
4	25% SBM-75% CM	72 (2)	2.077[b]	4.222[b]	2.03[a]	7.13[a]
5	0% SBM-100% CM	72(2)	1.891[c]	3.819[c]	2.02[a]	10.36[a]

[1]Means followed by the same superscript are not significantly different at $(P<.05)$.
[2]Numbers in parenthesis are number dead per treatment.

Experiment 2. Thyroid size of birds fed CM-containing diets tended to increase with increasing levels of CM (Table III. 5). Dietary supplements of protamone at a level of 0.005% reduced the thyroid weights in birds fed CM at either the 50 or 100% level to a size about 60% below those of the controls. A level of 0.0025% protamone brought a reduction in thyroid weight that more nearly approached the control, being 89% and 74% for the 50 and 100% level of CM, respectively. The depression in thyroid size contributed by the highest level of protamone was accompanied with a significant reduction in body weights. However, no adverse or beneficial effects in performance were evident for any of the other protamone treatments. CM at replacement levels higher than 50% again adversely affected bird productivities. Analysis of variance for body weights and thyroid weights used individual values as replicates in each treatment.

Experiment 3. The addition of arginine or methionine alone or in combination at both levels (0.1% and 0.2%) did not appear to have a positive influence on the performance of chicks fed CM at either 50 or 75% level (Tables III. 6 and III. 7). Satisfactory performance was also evident in chicks fed 50% CM without added arginine or methionine. However, a significant reduction in both growth and efficiency of feed utilization was observed when CM replaced SBM at the 75% level and no such effect on feed

TABLE III. 5. Effect of Incorporating Different Levels of Canola Meal and Supplemental Protamone in Broiler Starter Diets on Growth and Thyroid Status in 4 Week Trial (Exp. 2)

TMT No.	Dietary Treatments	Chicks per TMT	Body wt.[1] (kg)	Average Thyroid Wt. (mg)	Av. mg Thyroid /100 gm body wt.
1	100% SBM-0% CM + 0% Pr.	8 (0)[2]	0.950[ab]	94.8	10.0±2.13[b3]
2	75% SBM-25% CM + 0% Pr.	8 (0)	1.001[a]	134.6	13.5±4.73[a]
3	50% SMB-50% CM + 0% Pr.	8 (0)	0.958[ab]	134.3	14.0±2.43[a]
4	25% SBM-75% CM + 0% Pr.	8 (0)	0.831[c]	111.0	13.4±2.40[a]
5	100% CM + 0% Pr.	8 (1)	0.680[d]	98.7	14.5±5.59[a]
6	50% SBM-50% CM + 0.005% Pr.	8 (0)	0.845[c]	34.5	4.1±2.55[c]
7	50% SBM-50% CM + 0.0025% Pr.	8 (0)	0.928[b]	83.0	9.0±1.84[b]
8	0% SBM-100% CM + 0.005% Pr.	8 (0)	0.584[e]	21.7	3.7±1.31[c]
9	0% SBM-100% CM + 0.0025% Pr.	8 (0)	0.720[d]	53.5	7.4± 1.76[b]

[1]Means followed by the same superscript are not significantly different at (P<.05).
[2]Numbers in parenthesis are number dead per treatment.
[3]Means ± SE.

TABLE III. 6. Effect of Arginine and Methionine Supplementation on Performance of Chicks Receiving CM at 50% Replacement Level for 4 Weeks (Exp. 3)

TMT No.	Dietary Treatment	Chicks per TMT	Body wt.[1] (kg)	Feed cons. (kg)	Feed conv.	Leg Abnormality (%)
1	100% SBM-0% CM + 0 Arg + 0 Met	40 (1)[2]	0.912[a]	1.379[a]	1.51[a]	7.8[a]
2	50% SBM-50% CM + 0 Arg + 0 Met	40 (2)	0.921[a]	1.397[a]	1.59[a]	2.5[a]
3	50% SBM-50% CM + 0.1% Arg	40 (0)	0.884[a]	1.397[a]	1.58[a]	8.3[a]
4	50% SBM-50% CM + 0.2% Arg	40 (2)	0.952[a]	1.483[a]	1.56[a]	7.8[a]
5	50% SBM-50% CM + 0.1% Met	40 (2)	0.893[a]	1.442[a]	1.62[a]	8.1[a]
6	50% SBM-50% CM + 0.2% Met	40 (1)	0.907[a]	1.447[a]	1.60[a]	2.5[a]
7	50% SBM-50% CM + 0.1% Arg + 0.1% Met	40 (0)	0.943[a]	1.501[a]	1.59[a]	10.3[a]
8	50% SBM-50% CM + 0.2% Arg + 0.2% Met	40 (0)	0.907[a]	1.415[a]	1.56[a]	5.6[a]

[1]Means followed by the same superscript are not significantly different at (P<.05).
[2]Numbers in parenthesis are number dead per treatment.

TABLE III. 7. Effect of Arginine and Methionine Supplementation on Performance of Chicks Receiving CM at 75% Replacement Level for 4 Weeks (Exp. 3)

TMT No.	Dietary Treatment	Chicks per TMT	Body wt.[1] (kg)	Feed cons. (kg)	Feed conv.	Leg Abnormality (%)
1	100% SBM-0% CM + 0 Arg + 0 Met	40 (1)[2]	0.912[a]	1.379[a]	1.51[a]	7.8[a]
2	25% SBM-75% CM + 0 Arg + 0 Met	40 (1)	0.853[b]	1.406[a]	1.65[b]	13.3[a]
3	25% SBM-75% CM + 0.1% Arg	40 (2)	0.825[b]	1.365[a]	1.66[b]	15.0[a]
4	25% SBM-75% CM + 0.2% Arg	40 (1)	0.839[b]	1.342[a]	1.60[b]	15.6[a]
5	25% SBM-75% CM + 0.1% Met	40 (1)	0.821[b]	1.329[a]	1.62[b]	13.3[a]
6	25% SBM-75% CM + 0.2% Met	40 (1)	0.825[b]	1.370[a]	1.66[b]	10.6[a]
7	25% SBM-75% CM + 0.1% Arg + 0.1% Met	40 (1)	0.825[b]	1.347[a]	1.63[b]	7.5[a]
8	25% SBM-75% CM + 0.2% Arg + 0.2% Met	40 (1)	0.834[b]	1.347[a]	1.62[b]	7.5[a]

[1]Means followed by the same superscript are not significantly different at ($P<.05$).
[2]Numbers in parenthesis are number dead per treatment.

intake was noticed. As in Experiment 1, no significant difference among treatments for the incidence of leg abnormalities was found.

Experiment 4. Zinc bacitracin, added to the control ration only at the lowest level, 27.5 ppm, improved chick growth and feed conversion, but no positive effects were noted for the other dietary treatments at either concentration of 27.5 ppm or 55 ppm (Table III. 8). No significant differences in the incidence of leg weakness or crooked toes were observed. Except for the chicks fed the 100% CM replacement which was supplemented with the lower level of ZB, leg abnormalities seemed numerically to increase with increasing level of CM in the diets. As was found from the previous trials, CM replacing SBM at levels higher than 50% also resulted in poor performance.

DISCUSSION

There was a general tendency in all the experiments for both body weights and/or feed conversion and feed consumption to be depressed as the replacement rate of CM exceeded 50% in both the starter and finisher diets. With the exception of chicks in Exp. 3, birds fed CM at replacement levels higher than 50% consumed less feed than the birds fed the corn-SBM ration. No explanation can be given to why a reduction in feed intake did not occur with birds in Experiment 3. These results are in agreement with Goh et al. (1982) and in disagreement with Hulan and

TABLE III. 8. Effect of Dietary Supplements of Zinc Bacitracin on Performance of Broiler Chicks Fed CM at 50% and 100% Replacement Levels up to 4 Weeks of Age (Exp. 4)

TMT No.	Dietary Treatment	Chicks per TMT	Body wt.[1] (kg)	Feed cons. (kg)	Feed conv.	Leg Abnormality (%)	Crooked toes (%)
1	100% SBM-0% CM + 0 ZB	40 (0)[2]	0.821^{b}	1.252^{b}	1.53^{ab}	0.0^{a}	2.5^{a}
2	100% SBM-0% CM + 27.5 PPM ZB	40 (1)	0.884^{a}	1.302^{ab}	1.47^{a}	5.0^{a}	5.0^{a}
3	100% SBM-0% CM + 55 PPM ZB	40 (1)	0.853^{ab}	1.297^{ab}	1.52^{ab}	5.0^{a}	5.3^{a}
4	50% SBM-50% CM + 0 ZB	40 (0)	0.830^{ab}	1.324^{ab}	1.60^{b}	15.0^{a}	2.5^{a}
5	50% SBM-50% CM + 27.5 PPM ZB	40 (1)	0.866^{ab}	1.383^{a}	1.60^{b}	10.8^{a}	0.0^{a}
6	50% SBM-50% CM + 55 PPM ZB	40 (0)	0.825^{b}	1.324^{ab}	1.61^{b}	12.5^{a}	0.0^{a}
7	0% SBM-100% CM + 0 ZB	40 (0)	0.612^{cd}	1.066^{c}	1.74^{c}	25.0^{a}	7.5^{a}
8	0% SBM-100% CM + 27.5 PPM ZB	40 (0)	0.603^{d}	1.043^{c}	1.73^{c}	25.0^{a}	7.5^{a}
9	0% SBM-100% CM + 55 PPM ZB	40 (0)	0.671^{c}	1.098^{c}	1.64^{bc}	2.5^{a}	7.8^{a}

[1]Means followed by the same superscript are not significantly different at ($P<.05$).
[2]Numbers in parenthesis are number dead per treatment.

Proudfoot (1981) who reported that CM can replace up to 80% of SBM in both starter and finisher feeds without affecting their performance.

Dietary supplementation with protamone prevented thyroid enlargement of birds fed CM, but did not appear to improve chick performance. This may indicate that enlarged thyroids are of only minor significance as related to chick performance. Chiasson _et_ _al_. (1979) reported that no effect on plasma thyroxine or growth rate was found as a result of enlargement of thyroids of birds fed RSM.

Arginine and methionine additions alone or together failed to reduce the adverse effect of feeding a high level of CM in starter rations. Summers and Leeson (1978) reported similar results in a study using higher levels of these amino acids.

Dietary supplements of zinc bacitracin also did not appear to result in improvement growth or feed efficiency when added to CM containing diets. The occasional absence of response to antibiotics has been noted by many researchers. Menge (1973) stated that depression in bird response could be related to continuously using the same antibiotic in a given environment for a long period of time. This may result from reducing the number of harmful organisms in the environment to a degree in which even control chicks grow more rapidly. Cleaning practices were also indicated by Waible _et_ _al_. (1954) in causing a lower response to antibiotics. Since ZB has been utilized in this laboratory as a growth promoter for a relatively long period of time, and since birds were raised in batteries which were thoroughly cleaned, the findings in Exp. 4 seem to concur with the above reports.

Chicks fed CM at various levels did not show an increase in the incidence of leg weakness compared with controls. These results are in agreement with Summers *et al*. (1983). In Exp. 4, however, a tendency for a numerical but not statistical increase in the occurrence of leg weakness with increasing levels of CM in the diets was noticed. Benmoussa (1983), working with CM in broiler rations, reported a similar observation.

Results of the present study indicate that CM still contains sufficient levels of certain deleterious factors that adversely effect performance when included in broiler diets to substitute SBM at concentrations exceeding 50%.

REFERENCES

Bahraga, K. K., and J. B. O'Neil, 1979. Candle and Tower rapeseed meal as a protein supplement for broilers. Poultry Sci. 58:1036.

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

Benmoussa, M., 1983. The study of canola meal in broilers. Unpublished paper. Poultry Sci. Dept., Oregon State Univ., Corvallis, OR.

Biely, J., and R. E. Salmon, 1980. Canola meal for livestock and poultry. D.R. Clandinin, Ed.., Canola Council of Canada, Pub. No. 59, p. 1.

Chiasson, R. B., P. J. Sharp, H. Klandorf, C. G. Scanes, and S. Harvey, 1979. The effect of rapeseed meal and methimazole on levels of plasma hormones in growing broiler cockerels. Poultry Sci. 58:1575-1583.

Clandinin, D. R., and A. R. Robblee, 1981. Rapeseed meal in animal nutrition. II. non-ruminant animals. J. Ame. Oil Chem. Soc. 58:682-686.

Clandinin, D. R., and A. R. Robblee, 1983. Canola meal can be good source of high quality protein for poultry. Canadian researchers. Feedstuffs, April 18, pp. 36-37.

Eung, J., T. W. Fenton, M. M. Muller, and D. R. Clandinin, 1979. Condensed tannins of rapeseed meal. J. Food Sci. 44:1313-1361.

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

Goh, Y. K., A. Shires, A. R. Robblee, and D. R. Clandinin, 1982. Influence of supplementary cellulolytic enzymes (Driselase) on the performance of broilers fed rations containing rapeseed meal. Can. J. Anim. Sci. 62:269-273.

Hulan, H. W., and F. G. Proudfoot, 1981. Replacement of soybean meal in chicken broiler diets by rapeseed meal and fish meal as complementary sources of dietary protein. Can. J. Anim. Sci. 61:999-1004.

Kiiskinen, T., 1983. The effect of diets supplemented with Regent rapeseed meal on performance of broiler chicks. Annales Agriculturae Fenniae 22:206-213.

Leeson, S., 1984. Rapeseed products in poultry nutrition. Feed management, July 35(7):20-30.

Leslie, A. J., and J. D. Summers, 1975. Amino acid balance of rapeseed meal. Poultry Sci. 54:532-538.

Leslie, A. J., J. D. Summers, R. Grandhi, and S. Leeson, 1976. Arginine-lysine relationship in rapeseed meal. Poultry Sci. 55:631-637.

MacAuliffe, T., and J. McGinnis, 1971. Effect of antibiotic supplements to diets containing rye on chicken growth. Poultry Sci. 50:1130-1134.

Menge, H., 1973. Lack of growth response of eight week-old broilers to certain antibiotics. Poultry Sci. 52:1891-1895.

Mitaru, B. N., R. Blair, and J. M. Bell, 1981. The effect of rapeseed tannins on growth performance of broiler chickens. Poultry Sci. 60:2557.

Mitaru, B. N., R. Blair, J. M. Bell, and R. Reichert, 1983. Effect of canola hulls on growth, feed efficiency, and protein and energy utilization in broiler chickens. Can. J. Anim. Sci. 63:655-662.

Nesheim, M. C., and J. D. Garlich, 1963. Studies on ornithine synthesis in relation to benzoic acid excretion in the domestic fowl. J. Nutr. 79:311-317.

Paika, I. K., A. R. Robblee, and D. R. Clandinin, 1981. The effect of heat treatment and enzyme hydrolysis of rapeseed mealon the performance of broiler chicks. Can. J. Anim. Sci. 61:181-189.

Robblee, A.R., D. R. Clandinin, and S. J. Slinger, 1981. Canola meal for poultry. In research on canola meal for livestock and poultry. Pub. No. 59. Ed. by D. R. Clandinin, pp. 13-16.

Seth, P. C. C., and D. R. Clandinin, 1973. Effect of including rapeseed meal in the ration for broiler type chickens on the incidence of perosis and the ineffectiveness of supplemental manganese. Poultry Sci. 52:1158-1160.

Slinger, S. J., S. Leeson, J. D. Summers, and M. Sadiq, 1978. Influence of steam pelleting on the feeding value of Tower and Candle rapeseed products for broiler chicks. Anim. Feed Sci. Technol. 3:251-259.

Steel, R. G. D., and J. H. Torrie, 1960. Principles and Procedures of Statistics, McGraw-Hill Book Co., New York.

Summers, J. D., and S. Leeson, 1977. Effect of thyroxine and thiouracil additions to diets containing rapeseed meal, on chick growth and carcass composition. Poultry Sci. 56:25-35.

Summers, J. D., and S. Leeson, 1978. Feeding value and amino acid balance of low glucosinolate Brassica napus (cv. Tower) rapeseed meal. Poultry Sci. 57:235-241.

Summers, J. D., B. D. Lee, S. Leeson, 1983. Potassium and phosphorus in canola and soybean meal. Nutrition Rept. International 28:955-963.

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

Waible, P. E. O., J. Abbott, C. A. Baumann, and H. R. Bird, 1954. Disappearance of the growth response of chicks to dietary antibiotics in an "old" environment. Poultry Sci. 33:1141-1146.

CHAPTER IV

Effect of Canola Meal in Laying Hen Diets

Abdul Rahman H. Nassar, M. P. Goeger and G. H. Arscott
Department of Poultry Science
Oregon State University
Corvallis, OR 97331

ABSTRACT

An experiment was conducted to evaluate the performance of Single Comb White Leghorn laying hens fed isocaloric and isonitrogenous diets in which Canola meal (CM) replaced all or part of soybean meal (SBM) on a protein equivalent basis.

Mash diets were formulated to replace 0, 1/3, 2/3 or all of the protein from soybean. Egg production, feed per dozen eggs, final body weight, and internal and external egg quality were not adversely influenced by any level of CM. Average daily feed consumption decreased significantly with the highest level of CM. No adverse effects from CM were noted on the fertility and hatchability of fertile eggs. Dropping scores were also not affected. However, thyroids of birds fed CM were significantly enlarged compared with those of the control.

It would appear from the results obtained in this trial that CM may be used in practical-type diets to replace part or all of SBM in laying hen diets without any detrimental effects.

INTRODUCTION

Canola meal (CM) consists of several varieties of rapeseed (RM) which have been developed in Canada through plant breeding programs for their low levels of toxic substances (glucosinolates and erucic acid) and reduced fiber content, both of which affect poultry performance parameters. *Brassica napus* cv. Tower (low glucosinolates, low erucic acid) and *Brassica campestris* cv. Candle (low glucosinolates, low erucic acid, low fiber) are the varieties most recently developed for commercial production. The meals of these varieties can be incorporated in poultry rations at fairly high levels to replace a reasonable portion of soybean meal (SBM) as a primary protein source without adversely affecting poultry performance (1, 2).

Thomas *et al*. (3) and Leeson *et al* (4) reported that including CM in laying hen rations up to 15% had no adverse effects on egg production, feed per dozen eggs, or body weight change during the laying cycle (5, 6). However, it was noted that this level of CM increased mortality rate (7, 8), most often diagnosed as fatty liver hemorrhagic syndrome (9, 10). It was also noted by March and MacMillan (11) that the genetic background of the bird has an influence on the incidence of mortality when CM is fed to laying birds. Moreover, incorporating CM in laying hen diets resulted in a minor thyroid enlargement compared to that caused by meals from the older varieties of RM (12, 13, 14).

In addition, March and MacMillan (11) and Lee *et al*. (15) found that feeding RM, even the new varieties, to certain breeds of brown egg-laying hens resulted in the production of fishy-flavor eggs, shown to be due to the presence of trimethylamine in the eggs.

Fenwick and Curtis (16), Hulan and Proudfoot (17) and Slinger et al. (18) noted that inclusion of CM in laying hen rations at 15% resulted in a significant improvement in egg shell quality which was reported to be associated with a significant reduction in egg size. However, Haugh unit scores were not adversely affected.

In studying the effects on laying hen reproduction, O'Neil (19), Summers et al. (21) indicated that fertility and hatchability of eggs laid by Single Comb White Leghorn (SCWL) hens fed diets in which CM or RM replaced all or part of SBM on a protein equivalent basis were as satisfactory as those of the control SBM diets.

The purpose of this trial was to study the effect of incorporating CM in laying hen diets at different levels replacing all the SBM on a protein equivalent basis, on hen performance parameters.

MATERIALS AND METHODS

A total of 768 SCWL (Shaver 288) layers were fed for ten 28-day periods. The pullets were housed in a positive pressure ventilated windowless building. The experiment commenced when the birds reached 25% egg production. Prior to the start of the experiment, the hens were assigned to individual laying cages and fed a corn-soybean ration similar to the first ration (Table IV. 1) after which they received the isocaloric experimental diets shown in the same table in which SBM was decreased in one-third increments and replaced with feedgrade CM.

There were 96 layers in each of the eight treatments, distributed in four replicates of 24 birds each. The birds were kept on a 14 hour light cycle during the laying period. Water was provided during eight 15-minute watering periods of approximately two hour intervals beginning 15 minutes after the onset of, and 30 minutes before the end of the light period. Feed was provided ad libitum.

Egg production, feed consumption, feed per dozen eggs and mortality were measured at 28-day periods. Body weights of four birds per replicate and egg weights were collected over three days at the start, 2nd, 5th and 10th periods. All eggs collected at the 5th and 10th periods were measured for specific gravity (shell quality). Internal egg quality (Haugh units) was measured from two eggs per replicate during these periods.

Six hens per replicate were artificially inseminated with 0.05 cc of pooled semen from SCWL males during the 5th and 10th periods. The eggs were saved for eight days from the second day following the insemination, and the fertility and hatchability of those eggs were determined.

Table IV 1.Composition of SCWL layer rations.

Ingredient	Prot. level	15%	15%	15%	15%	17%	17%	17%	17%
	CM replacement level	0	1/3	2/3	all	0	1/3	2/3	all
Corn, yellow		64.80	62.99	61.11	59.30	64.70	59.60	54.30	49.20
Barley		6.00	4.02	1.96	-	1.50	1.00	.50	-
Soybean meal (48.5%)		17.50	11.72	5.78	-	22.10	14.80	7.30	-
Canola meal (36.5%)		-	8.60	17.42	26.00	-	11.05	22.35	33.40
Animal fat		-	1.10	2.30	3.40	-	2.05	4.20	6.25
Alfalfa meal, dehy (17%)		2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Limestone flour		3.65	3.65	3.65	3.65	3.65	3.65	3.75	3.75
Oystershell, med.		3.00	2.95	2.90	2.85	3.00	2.90	2.80	2.70
Defluorinated phosphate		2.00	1.92	1.83	1.75	2.00	1.90	1.75	1.65
Salt (iodized)		.25	.25	.25	.25	.25	.25	.25	.25
Vitamin premix[1]		.20	.20	.20	.20	.20	.20	.20	.20
Trace mineral mix 65[2]		.05	.05	.05	.05	.05	.05	.05	.05
DL-Methionine (98%)		.05	.05	.05	.05	.05	.05	.05	.05

[1]Supplied per kilogram of diet: vitamin A, 3,300 IU; vitamin D_3, 1,100 ICU; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg; niacin, 22 mg; choline, 191 mg; vitamin B_{12}, 5.5 g; vitamin E, 1.1 mg; menadione sodium bisulfate complex, .55 mg; folacin, .22 mg; ethoxyquin, 62.4 mg.

[2]Supplied per kilogram of diet: Mn, 60 mg; Fe, 20 mg; Cu, 2.0 mg; I, 1.2 mg; Zn, 27.5 mg; Co, .2 mg.

Droppings were scored on a scale of one to four, with four being a perfect, dry cone and one being a flat, watery mass. Upon termination of the experiment, eight birds per treatment were sacrificed by electrocution, and thyroids were excised and weighed individually after the birds were refrigerated overnight.

All the treatments were evaluated at periods 2, 5 and 10, and analysis of variance (22) was used to statistically analyze the data.

RESULTS AND DISCUSSION

Following statistical analyses of the data, as no interaction differences were found due to protein level, the data were pooled and subsequent analyses performed on the four CM treatments only.

Layer performance data is summarized in Table IV. 2 No statistical differences were found between the treatments for percent hen-day egg production. A slight numerical but non-significant increase was noted in birds fed CM as a replacement for one-third of the SBM. Average daily feed consumption differed significantly ($P<.05$), with the highest CM level having the lowest feed intake, in spite of the higher fiber content. The fact that the diets were isocaloric as well as isonitrogenous accounts for the lack of adverse affects. The reason for the lower feed intake is not known. Feed per dozen eggs did not differ between treatments; however, a small downward numerical trend in favor of the highest CM level was observed. Final body weights were similar, as were average and final egg weights. These results show that CM (29.7%; 26-33.4%) may replace all the SBM in a layer ration and are in agreement with Ibrahim and Hill (23), who revealed that RM (Tower var.) can be incorporated in laying hen diets up to 20% without adversely affecting production parameters. However, experiments done with older varieties of RM have shown that using only 10% resulted in significant reduction of egg production, egg weight, body weight gain and a significant increase in feed consumption and feed conversion on a feed per dozen egg basis (6, 24).

Egg quality, both external and internal, was not unfavorably influenced by any CM level (Table IV. 3). Shell thickness during the 10th period was actually significantly increased ($P<.05$) over that of the control, and a trend toward better Haugh unit scores was noted in both periods 5 and 10 as CM in the diet increased.

As noted in Table IV. 4, CM had no adverse effect on fertility of hatching eggs. Hatchability (HFE), however, was in fact increased significantly ($P\leq.01$) with increasing CM levels during period 5. At the conclusion of the experiment (per. 10), there were no differences between treatments, as was also true of the average % HFE.

Table IV 2. Performance of SCWL layers fed four levels of canola meal.

Canola replacement level	Egg Prod. (%)	Daily Fd. Cons. (lb.)	Av. Fd/dz. eggs (lb.)	Final B.W. (lb.)	Final Egg wt. (g)	Av. E.W. (g)
0	77.26^{a}	$.239^{ab}$	3.76^{a}	4.1^{a}	59.3^{a}	56.9^{a}
1/3	80.25^{a}	$.242^{a}$	3.64^{a}	4.4^{a}	59.9^{a}	56.9^{a}
2/3	77.85^{a}	$.234^{bc}$	3.65^{a}	4.2^{a}	59.7^{a}	56.5^{a}
All	77.96^{a}	$.233^{c}$	3.61^{a}	4.2^{a}	58.9^{a}	55.6^{a}

Means within a column with different superscripts are significantly different at $P \leq .05$.

Table IV 3. Effect of four levels of canola meal on egg quality of SCWL layers

Canola replacement level	Spec. Grav. per. 5	Spec. Grav. per. 10	H.U. per. 5	H.U. per. 10
0	1.0828^{a}	1.0720^{b}	80.80^{a}	70.59^{a}
1/3	1.0836^{a}	1.0743^{a}	82.91^{a}	71.97^{a}
2/3	1.0827^{a}	1.0730^{ab}	82.73^{a}	71.52^{a}
All	1.0830^{a}	1.0735^{ab}	84.17^{a}	73.37^{a}

Means within a column with different superscripts are significantly different at $P \leq .05$.

Table IV 4. Effect of four levels of canola meal on fertility and hatchability of SCWL layers.

Canola replacement level	Fert. per. 5 (%)	Fert. per. 10 (%)	Av. Fert. (%)	HFE per. 5 (%)	HFE per. 10 (%)	Av. HFE (%)
0	95.41[a]	91.15[a]	93.28[a]	82.94[a]	89.24[a]	86.09[a]
1/3	95.48[a]	87.39[a]	91.43[a]	88.33[ab]	90.61[a]	89.47[a]
2/3	94.68[a]	90.05[a]	92.36[a]	91.41[b]	89.38[a]	90.39[a]
All	94.34[a]	85.21[a]	89.78[a]	92.58[b]	91.59[a]	92.08[a]

Means within a column with different superscripts are significantly different at $P \leq .01$.

Table IV 5. Effect of four levels of canola meal on fecal cones of SCWL layers.

Canola replacement level	mg thyroid/ 100g live B.W.	Dropping score per. 2	Dropping score per. 5	Dropping score per. 10	Av. Dropping score
0	6.54[a]	2.9[a]	2.9[a]	3.3[a]	3.0[a]
1/3	8.33[ab]	3.1[a]	2.0[a]	3.4[a]	3.1[a]
2/3	9.46[b]	3.0[a]	3.0[a]	3.4[a]	3.1[a]
All	9.91[b]	3.2[a]	3.1[a]	3.5[a]	3.3[a]

Means within a column with different superscripts are significantly different ($P \leq .01$).

Although CM caused a significant increase ($P \leq .01$) in thyroid weight when expressed as mg thyroid per 100g live body weight, the increase apparently did not adversely affect bird performance in any of the parameters measured (Table IV. 5). Dropping scores were also not affected by addition of CM. A numerical trend toward drier, more conical fecal piles was observed as CM in the diet increased at both periods 5 and 10.

Overall, it appears from this experiment that CM can completely replace SBM in layer diets with no adverse effects. Whether or not higher levels of CM can be recommended with the higher level of animal fat involved, will be dependent on ingredient costs relative to fat, and the increased amount of protein concentrate required. In some cases, the complete replacement diets gave significantly better results than the control (daily feed consumption and HFE at period 5), and, although thyroid weights were significantly elevated at the high level, no adverse effects were observed. In no instances were there results that adversely affected performance by any level of CM.

REFERENCES

1. Biely, J., and R. E. Salmon. Canola meal for livestock and poultry. D.R. Clandinin, Ed.., Canola Council of Canada, Pub. No. 59, p. 1 (1981).

2. Bell, J. M. From rapeseed to Canola: A brief history of research for superior meal and edible oil. Poultry Sci. 61:613-622 (1982).

3. Thomas, D., A. R. Robblee, and D. R. Clandinin. Effects of low and high glucosinolate rapeseed meal on productive performance, egg quality composition of liver and incidence of haemorrhagic liver syndrome in laying birds. Br. Poultry Sci. 19:449-454 (1978).

4. Leeson, S., S. J. Slinger, and J. D. Summers. Performance of laying hens fed diets containing gum derived from Tower rapeseed. Can. J. Anim. Sci. 57:479-483 (1977).

5. Slinger, S. J., J. D. Summers, and S. Leeson. Utilization of meal from a new rapeseed varieties, Brassica campestris cv. Candle in layer diets. Can. J. Anim. Sci. 58:593-596 (1978).

6. Summers, J. D., G. Rajaratnam, and W. F. Pepper. Evaluation of rapeseed meal as a protein supplement for laying hen diets. Poultry Sci. 50:1382 (1971).

7. Hulan, H. W., and F. G. Proudfoot. The nutritional value of rapeseed meal for caged layers. Can. J. Anim. Sci. 60:139-147 (1980).

8. Hill, R., and A. Marangos. The effect of a range of rapeseed meals and mustardseed meal on the health and production of hybrid laying pullets. Proc. 15th World's Poultry Congress, pp. 608-610 (1974).

9. Hulan, H. W., and F. G. Proudfoot. Performance of laying hens fed diets containing soybean gums, rapeseed gums or rapeseed meals with and without gums. Can. J. Anim. Sci. 61:1030-1040 (1981).

10. Campbell, L. D. Incidence of liver haemorrhage among White Leghorn strains fed on diets containing different types of rapeseed meal. Br. Poultry Sci. 20:239-246 (1979).

11. March, B. E., and C. MacMillan. Why some laying birds produce fishy eggs when they are fed Canola meal. Research on canola seed, oil, meal, and meal fractions. 6th Progress Rept. Canola Council of Canada, Pub. No. 57, p. 260 (1980).

12. Papas, A., L. D. Campbell, and J. R. Ingalls. The effect of glucosinolates on egg iodine and thyroid status of poultry. Can. J. Anim. Sci. 59:119-131 (1979).

13. Clandinin, D. R., and A. R. Robblee. Canola meal can be good source of high quality protein for poultry. Canadian researchers. Feedstuffs, April 18, pp. 36-37 (1983).

14. Clandinin, D. R., S. L. Chikawa, A. R. Robblee, and D. Thomas, 1980. Canola meal for poultry. Canadian Canols. Canola Council of Canada. Research Summary No. 1, p. 7 (1980).

15. Lee, D. J. E., L. Martindale, and I. R. Paton. Rapeseed meal and egg tainting: In vivo metabolism and excretion of C^{14}-trimethylamine by tainter and non-tainter hens. Br. Poultry Sci. 23:175-182 (1982).

16. Fenwick, G. R., and R. F. Curtis. Rapeseed meal in ration for laying hens: A review of the effect on egg quality. J. Sci. Food Agric. 31:515-525 (1980).

17. Hulan, H. W., and F. G. Proudfoot. The nutritional value of rapeseed meal for layer genotypes housed in pens. Poultry Sci. 59:585-593 (1980).

18. Slinger, S. J., J. D. Summers, and S. Leeson. Canola meal for laying hens. Canadian Canola. Canola Council of Canada. Research Summary No. 1, p. 6 (1980).

19. O'Neil, J. B. Rapeseed oil meal as a vegetable protein supplement in the diet of laying and breeding hens. Poultry Sci. 36:1146 (1957).

20. Summers, J. D., S. Leeson, and S. J. Slinger. Performance of egg strain birds during their commercial life cycle when continuously fed diets containing Tower rapeseed gums. Can. J. Anim. Sci. 58:183-189 (1978).

21. March, B. E., J. Biely, and R. Soong. Rapeseed meal in the chicken breeder diet. Effect on production, mortality, hatchability, and progeny. Poultry Sci. 47:1323-1329 (1972).

22. Steel, R. G. D., and J. H. Torrie. Principles and Procedures of Statistics, McGraw-Hill Book Co., New York (1960).

23. Ibrahim, I. K., and R. Hill. The effects of rapeseed meal from Brassica napus varieties and the variety Tower on the production and health of laying fowl. Br. Poultry Sci. 21:423-430 (1980).

CHAPTER V

BIBLIOGRAPHY

Bayley, H. S., S. J. Slinger, J. D. Summers, and G. C. Ashton, 1974. Factors in influencing the metabolizable energy value of rapeseed meal level in diet, effect of steam pelleting, age of chick, length of time on diet, variety of rapeseed and oil extraction procedure. Can. J. Anim. Sci. 54:465-480.

Bahraga, K. K., and J. B. O'Neil, 1979. Candle and Tower rapeseed meal as a protein supplement for broilers. Poultry Sci. 58:1036.

Bell, J. M., 1955. The nutritional value of rapeseed oil meal: A review. Canada J. of Agric. Sci. 39(3):242-251.

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

Benmoussa, M., 1983. The study of canola meal in broilers. Unpublished paper. Poultry Sci. Dept., Oregon State Univ., Corvallis, OR.

Biely, J., and R. E. Salmon, 1980. Canola meal for livestock and poultry. D.R. Clandinin, Ed.., Canola Council of Canada, Pub. No. 59, p. 1.

Bolton, W., T. C. Carter, and R. Morley-Jones, 1976. The hens eggs: genetics of taint in eggs from hens fed on rapeseed meal. Br. Poultry Sci., 17:313-320.

Campbell, L. D., 1977. Incidence of liver haemorrhage among White Leghorn strains fed on diets containing different types of rapeseed meal. Br. Poultry Sci. 20:239-246.

Campbell, L. D., and T. K. Smith, 1979. Responses of growing chicken to high dietary contents of rapeseed meal. Br. Poultry Sci. 20:231-237.

Campbell, L. D., B. O. Eggum, and I. Jacobsen, 1981. Biological value, amino acid availability and true metabolizable energy of low glucosinolate RSM (Canola) determined with rats and/or rooster. Nutrition Repts. International 24:791.

Chiasson, R. B., P. J. Sharp, H. Klandorf, C. G. Scanes, and S. Harvey, 1979. The effect of rapeseed meal and methimazole on levels of plasma hormones in growing broiler cockerels. Poultry Sci. 58:1575-1583.

Clandinin, D. R., and A. R. Robblee, 1966. Rapeseed meal for poultry. A review. World's Poultry Sci. J. 22(3):217-232.

Clandinin, D. R., L. Bayly, and A. Caballero, 1966. Effects of (±)-5-vinyl-2-oxazolidenthione, a goitrogen in rapeseed meal, on the rate of growth and thyroid function of chicks. Poultry Sci. 45:833-838.

Clandinin, D. R., S. L. Chikawa, A. R. Robblee, and D. Thomas, 1980. Canola meal for poultry. Canadian Canols. Canola Council of Canada. Research Summary No. 1, p. 7.

Clandinin, D. R., and A. R. Robblée, 1981. Rapeseed meal in animal nutrition. II. non-ruminant animals. J. Ame. Oil Chem. Soc. 58:682-686.

Clandinin, D. R., and A. R. Robblee, 1983a. Canola meal can be good source of high quality protein for poultry. Canadian researchers. Feedstuffs, April 18, pp. 36-37.

Clandinin, D. R., A. R. Robblee, R. T. Hardin, and K. Darlington, 1983b. Canola meal for laying hens. Canadian Canola Research Summary No. 2. Canola Council of Canada, Pub. No 62, p. 5.

Clandinin, D. R., and A. R. Robblee, 1983c. Canola meal for turkey broilers. Canadian Canola Research Summary No. 2. Canola Council of Canada, Pub. No. 62.

Eung, J., T. W. Fenton, M. M. Muller, and D. R. Clandinin, 1979. Condensed tannins of rapeseed meal. J. Food Sci. 44:1313-1361.

Fenwick, G. R., A. Hobson-Frohock, D. G. Land, and R. F. Curtis, 1979. Rapeseed meal and egg taint: treatment of rapeseed meal to reduce tainting potential. Br. Poultry Sci. 20:323-329.

Fenwick, G. R., and R. F. Curtis, 1980a. Rapeseed meal and it use in poultry diets. A review. Anim. Feed Sci. and Tech., 5:255-298.

Fenwick, G. R., and R. F. Curtis, 1980b. Rapeseed meal in ration for laying hens: A review of the effect on egg quality. J. Sci. Food Agric. 31:515-525.

Goh, Y. K., and D. R. Clandinin, 1977. Transfer of I^{125} to eggs in hens fed on diets containing high- and low-glucosinolate rapeseed meals. Br. Poultry Sci. 18:705-710.

Goh, Y. K., A. R. Robblee, and D. R. Clandinin, 1983. Influence of glucosinolates and free oxazolidinethione in a laying diet containing a constant amount of sinapine, on trimethylamine content and fishy odor of eggs from brown-shelled egg layers. Can. J. Anim. Sci. 63:671-676.

Goh, Y. K., D. R. Clandinin, and A. R. Robblee, 1980. Protein quality evaluation of commercial rapeseed meal by chemical and biological assay. Can. J. Anim. Sci. 60:473-480.

Goh, Y. K., A. Shires, A. R. Robblee, and D. R. Clandinin, 1982a. Influence of supplementary cellulolytic enzymes (Driselase) on the performance of broilers fed rations containing rapeseed meal. Can. J. Anim. Sci. 62:269-273.

Goh, Y. K., A. Shires, A. R. Robblee, and D. R. Clandinin, 1982b. The effects of hydrous and anhydrous ammonia treatments on the nutritive value of low glucosinolate-type rapeseed meal (Canola meal) for chicks. Can. J. Anim. Sci. 62:915-918.

Goh, Y. K., M. Mueller, D. R. Clandinin, and A. R. Robblee, 1977. The effect of choline and sinapine bisulfate in laying rations on the incidence of fishy odor in eggs from brown-shelled egg layers. Can. J. Anim. Sci. 59:545-549.

Goh, Y. K., M. Rebolledo, A. R. Robblee, D. R. Clandinin, 1984. Effect of ammoniation of canola meal on the fishy odor and trimethylamine contents of eggs produced by brown-egg layers. Poultry Sci. 63:706-709.

Grandhi, R. R., S. J. Slinger, and J. D. Summers, 1977. Productive performance and liver lessions in two strains of laying hens receiving two RSM. Poultry Sci. 56:1904-1908.

Griffiths, N. M., G. R. Fenwick, A. W. Pearson, N. M. Green-Wood, and E. D. Butler, 1980. Effect of rapeseed meal on broilers: Studies of meat flavor, liver haemorrhage, and trimethyl amine oxidase activity. J. Sci. Food Agric. 31:188-193.

Hawrysh, Z. J., C. D. Steedman-Douglas, A. R. Robblee, R. T. Hardin and R. M. Sam, 1980a. Influence of low glucosinolate (cv. Tower) rapeseed meal on the eating quality of broiler chicks. I. Subjective evaluation by a trained taste panel and objective measurements. Poultry Sci. 59:550-557.

Hawrysh, Z. J., C. D. Steedman-Douglas, A. R. Robblee, R. T. Hardin, and R. M. Sam, 1980b. Influence of low glucosinolate (cv. Tower) rapeseed meal on the eating quality of broiler chicks. II. Subjective evaluation by a consumer panel. Poultry Sci. 59:558-562.

Hawrysh, Z. J., R. M. Sam, A. R. Robblee, R. T. Hardin, 1982. Influence of low glusinolate canola meal (cv. Regent and Candle) on the eating quality of broiler chickens. Poultry Sci. 61:2375-2384.

Hill, R., 1979. A review of the toxic effects of rapeseed meals with observations on meal from improved varieties. Br. Vet. J. 135:3-16.

Hill, R., and A. Marangos, 1974. The effect of a range of rapeseed meals and mustardseed meal on the health and production of hybrid laying pullets. Proc. 15th World's Poultry Congress, pp. 608-610.

Hobson-Frohock, A., G. R. Fenwick, R. K. Heanery, D. G. Land, and R. F. Curtis, 1977. Rapeseed meal and egg taint: Association with sinapine. Br. Poultry Sci. 18:539-541.

Hughebaert, V. G., G. Fontaine, and G. DeGroote, 1983. The feeding value of rapeseed meals with different glucosinolate contents (Brassica sp.) as measured by digestability experiments with broiler chicks and adult roosters. Arch. Geflugelk 47:50-60.

Hulan, H. W., and F. G. Proudfoot, 1980a. The nutritional value of rapeseed meal for layer genotypes housed in pens. Poultry Sci. 59:585-593.

Hulan, H. W., and F. G. Proudfoot, 1980b. The nutritional value of rapeseed meal for caged layers. Can. J. Anim. Sci. 60:139-147.

Hulan, H. W., F. G. Proudfoot, and K. B. McRae, 1980. The nutritional value of Tower and Candle rapeseed meals for turkey broilers housed under different lighting conditions. Poultry Sci. 59:100-109.

Hulan, H. W., and F. G. Proudfoot, 1981a. Replacement of soybean meal in chicken broiler diets by rapeseed meal and fish meal as complementary sources of dietary protein. Can. J. Anim. Sci. 61:999-1004.

Hulan, H. W., and F. G. Proudfoot, 1981b. Performance of laying hens fed diets containing soybean gums, rapeseed gums or rapeseed meals with and without gums. Can. J. Anim. Sci. 61:1030-1040.

Ibrahim, I. K., and R. Hill, 1980. The effects of rapeseed meal from Brassica napus varieties and the variety Tower on the production and health of laying fowl. Br. Poultry Sci. 21:423-430.

Kiiskinen, T., 1983a. Effect of Regent rapeseem meal fed during the rearing and laying period on the performance of chickens. Annales, Agriculturae Fenniae, 22:221-231.

Kiiskinen, T., 1983b. The effect of diets supplemented with Regent rapeseed meal on performance of broiler chicks. Annales Agriculturae Fenniae 22:206-213.

Larmon, E., R. E. Salmon, K. K. Klein, 1983. Effect of canola meal on the sensory quality of turkey meat. Poultry Sci. 62:397-400.

Lee, D. J. E., L. Martindale, and I. R. Paton, 1982. Rapeseed meal and egg tainting: In vivo metabolism and excretion of C^{14}-trimethylamine by tainter and non-tainter hens. Br. Poultry Sci. 23:175-182.

Leeson, S., 1984. Rapeseed products in poultry nutrition. Feed management, July 35(7):20-30.

Leeson, S., S. J. Slinger, and J. D. Summers, 1977. Performance of laying hens fed diets containing gum derived from Tower rapeseed. Can. J. Anim. Sci. 57:479-483.

Leslie, A. J., and J. D. Summers, 1975. Amino acid balance of rapeseed meal. Poultry Sci. 54:532-538.

Leslie, A. J., J. D. Summers, R. Grandhi, and S. Leeson, 1976. Arginine-lysine relationship in rapeseed meal. Poultry Sci. 55:631-637.

MacAuliffe, T., and J. McGinnis, 1971. Effect of antibiotic supplements to diets containing rye on chicken growth. Poultry Sci. 50:1130-1134.

March, B. E., and C. MacMillan, 1980. Why some laying birds produce fishy eggs when they are fed Canola meal. Research on canola seed, oil, meal, and meal fractions. 6th Progress Rept. Canola Council of Canada, Pub. No. 57, p. 260.

March, B. E., D. B. Bragg, and R. Soong, 1978. Low erucic acid, low glucosinolate rapeseed meal, with and without added gums in the layer diet. Poultry Sci. 57:1599-1604.

March, B. E., J. Biely, and R. Soong, 1972. Rapeseed meal in the chicken breeder diet. Effect on production, mortality, hatchability, and progeny. Poultry Sci. 47:1323-1329.

Menge, H., 1973. Lack of growth response of eight week-old broilers to certain antibiotics. Poultry Sci. 52:1891-1895.

Mitaru, B. N., R. Blair, and J. M. Bell, 1981. The effect of rapeseed tannins on growth performance of broiler chickens. Poultry Sci. 60:2557.

Mitaru, B. N., R. Blair, J. M. Bell, and R. Reichert, 1983. Effect of canola hulls on growth, feed efficiency, and protein and energy utilization in broiler chickens. Can. J. Anim. Sci. 63:655-662.

Moody, D. L., S. J. Slinger, S. Leeson, and J. D. Summers, 1978. Utilization of dietary Tower rapeseed products by growing turkeys. Can. J. Anim. Sci. 58:585-592.

Mueller, M. M., E. B. Ryl, T. Fenton, and D. R. Clandinin, 1978a. Cultivar and growing location differences on the sinapine content of rapeseed. Can. J. Anim. Sci. 58:579-583.

Mueller, M. M., R. N. Coleman, and D. R. Clandinin, 1978b. Trimethylamine production from sinapine by enteric bacteria from laying hens. Proceedings of the 5th International Rapeseed Congress, pp. 303-306.

Muztar, A. J., and S. J. Slinger, 1979. Some factors affecting the true metabolizable energy values of soybean meal and rapeseed meals. Can. J. Anim. Sci. 59:317-321.

Muztar, A. J., S. J. Slinger, H. J. A. Likuski, and H. G. Dorrell, 1980a. True amino acid availability values for soybean meal and Tower and Candle rapeseed and rapeseed meals determined in two laboratories. Poultry Sci. 59:605-610.

Muztar, A. J., and S. J. Slinger, 1980b. Apparent amino acid availability and apparent metabolizable energy values of Tower and Candle rapeseeds and rapeseed meals. Poultry Sci. 59:1430-1433.

Muztar, A. J., and S. J. Slinger, 1982. The true metabolizable energy and amino acid content of Candle, Altex and Regent canola meals. Can. J. Anim. Sci. 62:521-525.

Nesheim, M. C., and J. D. Garlich, 1963. Studies on ornithine synthesis in relation to benzoic acid excretion in the domestic fowl. J. Nutr. 79:311-317.

Nwokolo, E. N., and D. B. Bragg, 1977. Influence of phytic acid and crude fiber on the availability of minerals from four protein supplements in growing chicks. Can. J. Anim. Sci. 57:475-477.

Nwokolo, E., and D. B. Bragg, 1980. Biological availability of mineral in rapeseed meal. Poultry Sci. 59:155-158.

O'Neil, J. B., 1957. Rapeseed oil meal as a vegetable protein supplement in the diet of laying and breeding hens. Poultry Sci. 36:1146.

Paika, I. K., A. R. Robblee, and D. R. Clandinin, 1981. The effect of heat treatment and enzyme hydrolysis of rapeseed mealon the performance of broiler chicks. Can. J. Anim. Sci. 61:181-189.

Papas, A., L. D. Campbell, and P. E. Cansfield, 1979. A study of the association of glucosinolates to rapeseed meal-induced haemorrhagic liver in poultry and the influence of supplemental vitamin K. Can. J. Anim. Sci. 59:133-144.

Papas, A., L. D. Campbell, and J. R. Ingalls, 1978. The effect of glucosinolates on egg iodine and thyroid status of poultry. Can. J. Anim. Sci. 59:119-131.

Pearson, A. W., E. J. Butler, R. F. Curtis, G. R. Fenwick, A. Hobson-Frohock, and D. G. Land, 1979a. Rapeseed meal and egg taint: Demonstration of the metabolic defect in male and female chicks. Vet. Rec. 104:318-319.

Pearson, A. W., E. J. Butler, R. F. Curtis, G. R. Fenwick, A. Hobson-Frohock, and D. G. Land, 1979b. Effect of rapeseed meal on hepatic trimethylamine oxidase activity in the domestic fowl in relation to egg taint. J. Sci. of Food Agric. 30:291-298.

Petit, J. A., S. J. Slinger, E. V. Evans, and F. N. Marcellus, 1944. The utilization of sunflower seed oil meal, wheat distillers, dried grains and rapeseed oil meal in poultry rations. Sci. Agric. 24:201-213.

Proudfoot, F. G., H. W. Hulan, and K. B. McRae, 1982. The effect of diets supplemented with Tower or Candle rapeseed meal on the performance of meat chicken breeders. Can. J. Anim. Sci., 62:239-247.

Proudfoot, F. G., H. W. Hulan, and K. B. McRae, 1983. Effect of feeding poultry diet supplemented with rapeseed meal as a primary protein source to juvenile and adult meat breeder genotype. Can. J. Anim. Sci. 63:957-965.

Robblee, A.R., D. R. Clandinin, and S. J. Slinger, 1981. Canola meal for poultry. In research on canola meal for livestock and poultry. Pub. No. 59. Ed. by D. R. Clandinin, pp. 13-16.

Rutowski, A., 1971. The feed value of rapeseed meal. J. American Oil Chem. Soc. 48:863-868.

Salmon, R. E., 1979. Rapeseed meal in turkey starter diets. Poultry Sci. 58:410-415.

Salmon, R. E., 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. Poultry Sci. 60:2519-2528.

Salmon, R. E., 1982. Canola meal and fish meal in turkey starter diets. Poultry Sci. 61:2126-2128.

Salmon, R. E., K. K. Klein, E. Larmond, 1979. Low glucosinolate rapeseed meal in turkey broiler diets of varying nutrient density. Poultry Sci. 58:1514-1523.

Seth, P. C. C., and D. R. Clandinin, 1973. Effect of including rapeseed meal in the ration for broiler type chickens on the incidence of perosis and the ineffectiveness of supplemental manganese. Poultry Sci. 52:1158-1160.

Shires, A., J. M. Bell, W. H. Laverty, P. Fedes, J. A. Blake, D. I. McGregor, 1983. Effect of desolventization conditions and removal of fibrous material by screening on the nutritional value of canola meal for broiler chicks. Poultry Sci. 62:2234-2244.

Slinger, S. J., 1977. Improving the nutritional properties of rapeseed. J. Am. Oil Chem. Soc. 54:94A-99A.

Slinger, S. J., J. D. Summers, and S. Leeson, 1980. Canola meal for laying hens. Canadian Canola. Canola Council of Canada. Research Summary No. 1, p. 6.

Slinger, S. J., S. Leeson, J. D. Summers, and M. Sadiq, 1978a. Influence of steam pelleting on the feeding value of Tower and Candle rapeseed products for broiler chicks. Anim. Feed Sci. Technol. 3:251-259.

Slinger, S. J., J. D. Summers, and S. Leeson, 1978b. Utilization of meal from a new rapeseed varieties, Brassica campestris cv. Candle in layer diets. Can. J. Anim. Sci. 58:593-596.

Steedman, C. D., Z. J. Hawrysh, R. T. Hardin, and A. R. Robblee, 1979a. Influence of rapeseed meal on the eating quality of chicken. I. Subjective evaluation by a trained taste panel and objective measurements. Poultry Sci. 58:148-155.

Steedman, C. D., Z. J. Hawrysh, R. T. hardin, and A. R. Robblee, 1979b. Influence of rapeseed meal on the eating quality of chicken. II. Subjective evaluation by a consumer taste panel. Poultry Sci. 58:337-340.

Steel, R. G. D., and J. H. Torrie, 1960. Principles and Procedures of Statistics, McGraw-Hill Book Co., New York.

Summers, J. D., and S. Leeson, 1977a. Performance and carcass grading characteristics of broiler chickens fed rapeseed gums. Can. J. Anim. Sci. 57:485-488.

Summers, J. D., and S. Leeson, 1977b. Effect of thyroxine and thiouracil additions to diets containing rapeseed meal, on chick growth and carcass composition. Poultry Sci. 56:25-35.

Summers, J. D., and S. Leeson, 1978a. Feeding value and amino acid balance of low glucosinolate Brassica napus (cv. Tower) rapeseed meal. Poultry Sci. 57:235-241.

Summers, J. D., S. Leeson, and S. J. Slinger, 1978b. Performance of egg strain birds during their commercial life cycle when continuously fed diets containing Tower rapeseed gums. Can. J. Anim. Sci. 58:183-189.

Summers, J. D., B. D. Lee, S. Leeson, 1983. Potassium and phosphorus in canola and soybean meal. Nutrition Rept. International 28:955-963.

Summers, J. D., G. Rajaratnam, and W. F. Pepper, 1971. Evaluation of rapeseed meal as a protein supplement for laying hen diets. Poultry Sci. 50:1382.

Thomas, D., A. R. Robblee, and D. R. Clandinin, 1978. Effects of low and high glucosinolate rapeseed meal on productive performance, egg quality composition of liver and incidence of haemorrhagic liver syndrome in laying birds. Br. Poultry Sci. 19:449-454.

Thomas, D., A. R. Robblee, and D. R. Clandinin, 1983. Dietary phosphorus requirements of laying hens kept in floor pens and fed diets containing canola meal. Can. J. Anim. Sci. 63:225-232.

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

Vogt, H., H. G. Torges, 1976. Rapeseed oil meal from variety of Summer rape, low in erucic acid and glucosinolate in feed for laying hens. Archiv fur Geflugelkundae 40:225-231.

Waible, P. E. O., J. Abbott, C. A. Baumann, and H. R. Bird, 1954. Disappearance of the growth response of chicks to dietary antibiotics in an "old" environment. Poultry Sci. 33:1141-1146.

Yamashiro, S., and T. Bast, 1978. Ultrastructure of livers of broiler chickens fed diets containing rapeseed meal. Res. in Vet. Sci. 25:21-24.

Appendix I

Data

A complete record of data collected in both the broiler and laying hen studies has been kept at the Oregon State University Agricultural Experiment Station, Department of Poultry Science. Reference should be made to projects 15-84-09, 15-84-14 and 15-84-20 for broilers and 15-84-06 for layers.

Appendix II

Analysis of Variance Tables

Analysis of Variance (ANOVA) Tables

(Values with * are significant at P<.05)
(Values with ** are significant at P<.01)

ANOVA: Table III 3, page 50:

Canola Meal, and Broiler Performance (4 week data, Exp. 1)

Body Weight

Source	DF	MS	F
Diet	4	0.375	69.041*
Replicate	2	0.008	1.553
Error A	8	-	-
Sex	1	0.072	8.040*
Sex X Diet	4	0.011	1.247
Error B	10	0.009	

		Feed Consumption		Feed Conversion	
Source	DF	MS	F	MS	F
Diet	4	0.2543	49.42*	0.0221	8.56*
Replicate	2	0.0204	3.97	0.0018	0.68
Error	8	0.0051		0.008	

ANOVA: Table III 4, page 51:

Canola Meal and Broiler Performance (7 week data, Exp. 1)

Body Weight

Source	DF	MS	F
Diet	4	0.458	15.380*
Replicate	2	0.013	0.429
Error A	8	0.03	
Sex	1	3.936	161.62*
Sex X Diet	4	0.069	2.83
Error B	10	0.024	

ANOVA: Table III 4, cont.

		Feed Consumption		Feed Conversion	
Source	DF	MS	F	MS	F
Diet	4	1.416	67.86*	0.0014	1.40
Replicate	2	0.165	7.92*	0.0012	1.22
Error	8	0.021		0.0010	

Leg Abnormality

Source	DF	MS	F
Diet	4	95.0	3.362
Error	10	28.3	

ANOVA: Table III 5, page 53:

Canola Meal, Protamone, Thyroid and Body Weights

Body Weight

Source	DF	MS	F
Diet	8	0.163	17.53*
Error	62	0.009	

mg thyroid/100g live body weight

Source	DF	MS	F
Diet	8	135.833	15.241*
Error	60	8.912	

ANOVA: Table III 6, page 54:

50% Canola Meal, Arginine + Methionine and Broiler Performance (Exp. 3)

Body Weight

Source	DF	MS	F
Diet	7	0.022	1.76
Replicate	3	0.0	0.037
Error A	21	0.013	
Sex	1	0.168	13.43*
Sex X Diet	7	0.023	1.87
Error B	24	0.012	

		Feed Consumption		Feed Conversion	
Source	DF	MS	F	MS	F
Diet	7	0.0333	1.28	0.0039	1.28
Replicate	3	0.0008	0.26	0.0008	0.26
Error	21	0.0031		0.0031	

Leg Abnormality

Source	DF	MS	F
Diet	7	46.80	0.6
Error	24	77.95	

ANOVA: Table III 7, page 55:

75% Canola Meal, Arginine + Methionine and Broiler Performance (Exp. 3)

Body Weight

Source	DF	MS	F
Diet	7	0.034	4.38*
Replicate	3	0.006	0.824
Error A	21	0.008	
Sex	1	0.203	34.331*
Sex X Diet	7	0.008	1.43
Error B	24	0.006	

ANOVA: Table III 7, cont.

Source	DF	Feed Consumption MS	F	Feed Conversion MS	F
Diet	7	0.0115	0.661	0.0088	4.14*
Replicate	3	0.0979	5.268*	0.0134	6.26*
Error	21	0.0174		0.0021	

Source	DF	Leg Abnormality MS	F
Diet	7	31.09	0.506
Error	24	63.22	

ANOVA: Table III 8, page 57:

Zinc Bacitracin and Broiler Performance (Exp. 4)

Source	DF	Body Weight MS	F
Diet	8	0.494	27.608*
Replicate	3	0.089	4.972*
Error A	24	0.018	
Sex	1	0.599	38.831*
Sex X Diet	8	0.909	0.598
Error B	27	0.015	

Source	DF	Feed Consumption MS	F	Feed Conversion MS	F
Diet	8	0.317	14.32*	0.035	4.38*
Replicate	3	0.234	10.53*	0.017	2.37
Error	24	0.022	-	0.007	

Source	DF	Leg Abnormality MS	F	Crooked Toes MS	F
Diet	8	337.92	2.05	38.72	1.05
Error	27	164.85		36.80	

ANOVA: Table IV 2, page 71:

Canola Meal and Laying Hen Performance

		Egg Prod. (%)		Feed Cons. (lb.)		Feed/Doz. Eggs	
Source	DF	MS	F	MS	F	MS	F
Diet	3	13.90	0.93	0.000133	3.97*	0.0236	0.853
Error	28	15.00		0.000034		0.0383	

		Final Body Weight		Ave. Egg Wt.	
Source	DF	MS	F	MS	F
Diet	3	2.88	2.60	2.88	2.6
Error	28	1.11		1.11	

ANOVA: Table IV 3, page 71:

Canola Meal and Egg Quality

Specific Gravity:

		(Period 5)		(Period 10)	
Source	DF	MS	F	MS	F
Diet	3	0.0000	0.77	0.0000	3.65*
Error	28	0.0000		0.0000	

Haugh Units:

		(Period 5)		(Period 10)	
Source	DF	MS	F	MS	F
Diet	3	15.48	1.76	10.67	0.93
Error	28	8.81		11.50	

ANOVA: Table IV 4, page 72:

Canola Meal, Fertility and Hatchability

Fertility:

		(Period 5)		(Period 10)		(Average)	
Source	DF	MS	F	MS	F	MS	F
Diet	3	2.501	0.104	57.228	0.61	17.91	0.6
Error	28	24.004		93.811		30.03	

Hatchability:

		(Period 5)		(Period 10)		(Average)	
Source	DF	MS	F	MS	F	MS	F
Diet	3	148.5	5.35**	9.873	0.351	50.95	2.82
Error	28	776.7		28.125		18.07	

ANOVA: Table IV 5, page 72:

Canola Meal, Thyroid Weights and Fecal Scores

Mg Thyroid/100g Live Body Wt.

Source	DF	MS	F
Diet	3	18.11	4.46**
Error	28	4.06	

Fecal Scores:

		(Period 2)		(Period 5)		(Period 10)		(Av. Fecal scores)	
Source	DF	MS	F	MS	F	MS	F	MS	F
Diet	3	0.117	1.673	0.065	0.93	0.076	1.063	0.084	2.30
Error	28	0.070		0.070		0.072		0.034	