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EVALUATION OF CANOLA MEAL AS A PROTEIN SUPPLEMENT FOR SWINE

by

(C) SAMUEL BAIDOO

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

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..J.P. Bowland..

..T.A. Peterson..

Date..June 26,..1984......

DEDICATION

This work is dedicated to the memory of my late father whose unfailing encouragement helped me throughout my educational career.

ABSTRACT

A series of experiments(8) were undertaken at The University of Alberta Swine Unit to determine the replacement value of Canola Meal(CM) for Soybean Meal (SBM) in the diets of starting(6-20kg liveweight), growing (20-60kg liveweight)and finishing(60-90kg liveweight) pigs. The effect of flavor additives on the feed intake of diets containing CM was also studied.A total of 712 pigs were used in these studies.

Diets were based on barley and wheat and CM replaced 0,25,50,75 and 100% of the protein supplied by SBM on an isonitrogenous basis.

In the first three experiments (Section A) the replacement value of CM in the diets for starter pigs was studied. In experiment one, the results indicated that with 3wk-weaned pigs fed to 10kg liveweight on 20% crude protein(CP) diets, average daily gain(ADG) and average daily feed(ADF) were reduced($P<0.05$) when CM replaced more than 50% of the SBM protein. The performance of these pigs was significantly reduced when CM replaced more than 25% SBM protein in an 18% CP diet fed to the pigs from 10 to 20kg liveweight. In experiment two, pigs were weaned at 3wks and fed 20% CP diets to a 20kg liveweight. The results showed that CM can replace 25% of SBM protein without significantly affecting pig performance. In experiment three, ADF and ADG of 5wk-weaned pigs fed on 18% CP diets were depressed($P<0.05$) when CM replaced more than 25% of the SBM

protein. Feed conversion efficiency(FCE) was not affected by the level of CM in the diets. Regression analyses of the results of these starting pig experiments indicated that replacement of 25% SBM protein by CM protein (8% CM in the diet) did not reduce the performance of the pigs fed CM supplemented diet.

In two experiments (Section B) the effect of flavor additives on the palatability of CM supplemented diets fed to 4-wk weaned pigs was studied. In experiment one, results showed that feed intake of pigs fed diets containing 100% CM with flavors added was significantly higher than that of pigs fed the 100% CM diets without flavor. In experiment two, in a single stimulus trial, pigs consumed more($P<0.05$) of the flavored diets than the non-flavored diets.

In three experiments (Section C), the replacement value of CM for SBM in the diets of growing-finishing pigs was studied. The inclusion of up to 75% CM as a replacement for SBM protein did not significantly affect the performance of growing (20-60kg liveweight) pigs. The number of days to attain 60kg increased as the level of dietary CM increased. No significant differences were found in the digestibility coefficients of dry matter, protein and energy. Plasma levels of the thyroid hormones were not significantly reduced in growing pigs fed these diets. Dietary level of CM did not significantly affect the performance of finishing (60-90kg liveweight) pigs. Canola meal levels did not greatly affect any of the carcass parameters studied.

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1. INTRODUCTION

Rape is a member of the *Cruciferae* family. Two summer species are commonly grown in Canada:*Brassica campestris* L. commonly called Polish rape or turnip rape and *Brassica napus* L. commonly called Argentine rape. Although *B. napus* was initially the major species grown, the shorter growing period, greater drought and shattering resistance of the pods during harvesting of *B. campestris* has made it the cultivar of choice in the northern areas where the bulk of the rapeseed production is concentrated(Downey and Klassan, 1977).

The limitations imposed by glucosinolates and erucic acid in rapeseed have provided a major incentive for plant breeders to develop varieties of rape with reduced amounts of these compounds(Bell,1982).Since the discovery of the low-glucosinolate variety Bronowski in 1967, there are available commercially in Canada at least six double low(low erucic acid, low glucosinolate) rapeseed cultivars: Andor, Regent, Tower, Altex, Candle and Tobin. The oil and meal from these varieties is called Canola because the oil contains less than 5 percent erucic acid and the meal contains less than 3mg per gram of glucosinolates.

The commercial production of Canola in Alberta has increased rapidly during the last decade, from 0.8 million hectares to 1.01 million hectares (Statistics Canada 1984a).The availability of large supplies of Canola has resulted in the development of an oil seed processing industry based primarily on Canola. In 1983, production of Canola in Western Canada was 2,687,000 tonnes which yielded about 1,061,365 tonnes of oil and 1,620,261 tonnes of meal(Statistics Canada 1984b). Canola oil now supplies approximately 50% of the oil used by Canada's edible oil industry (Mag,1983). The meal, a by-product of oil extraction, is used as a protein supplement in diets for livestock and poultry.

Limitations to the use of Canola Meal (CM) in livestock and poultry diets have been due to the presence of goitrogenic subtances derived from the enzymatic hydrolysis of glucosinolates. This, coupled with the low digestible energy, high fiber and tannin levels, reduced feed intake due to palatability of the CM supplemented diets and lower amino acid availability have limited the inclusion rate of CM in the diets for pigs and poultry.

Numerous studies have been undertaken to determine the optimum inclusion rate of CM in swine diets. There is a lack of concensus as to the optimum level of inclusion of CM in the diets of young pigs. This is due in part to differences in :

1. methods used in producing the CM;
2. the age and weight of pigs used in the test;
3. the duration of the test;
4. the composition and nutrient levels of the diets;
5. the number of animals used in the experiments;
6. the method of feeding:*ad libitum* versus restricted.

Based on inconclusive data, Bell and Aherne(1981) recommended that CM can be included in pig starter diets at levels up to 12 percent and for growing-finishing pigs 10 to 15 percent of the diets.

The following studies were undertaken to determine the optimum levels of inclusion of CM in the diets of starting, growing and finishing pigs and also to determine if flavor additives might increase feed intake of starter pigs fed CM supplemented diets.

2. LITERATURE REVIEW

2.1 NUTRIENT CONTENT OF CANOLA MEAL

2.1.1 Protein and Amino Acids

Canola Meal (CM) may contain 35 to 39 percent protein (Bell and Aherne, 1981). This protein content may vary with cultivar, growing conditions and processing. The crude protein content of CM from candle is approximately 35 percent while that from Tower, Regent or Altex is 38 to 39 percent (Clandinin and Robblee, 1981).

The amino acid contents of both low and high glucosinolate canola varieties do not differ appreciably (Clandinin and Robblee, 1978). Lysine is generally the first limiting amino acid in pratical swine diets(NAS-NRC 1979). Canola meal protein is lower in lysine and higher in sulfur-containing amino acids than soybean meal (SBM) (Bell, 1975). The processing methods used in the production of CM can affect the level and availability of lysine in the meal. Clandinin (1967) reported that rapeseed meal (RSM) produced by prepress solvent or solvent extraction is higher in available lysine than expeller type meals. According to Clandinin (1967), the differences in lysine content are mainly attributable to the reduced heat damage occurring in the solvent extraction process.

Both ileal and fecal amino acid availabilities of CM for pigs are lower than those observed for SBM (Nwokolo et al. 1979; Sauer et al. 1981). The true ileal availability of lysine and threonine in CM is approximately 10 percent lower than the lysine and threonine in SBM (Sauer et al. 1982). Fenwick (1982), suggested that if CM is used to replace SBM on a weight-for-weight basis then lysine supplementation would be required.

2.1.2 Fiber

Canola meal contains a substantially higher crude fiber level than SBM and this may contribute to the lower performance observed when CM is fed as the sole protein supplement in diets for pigs (Aherne et al. 1977; Castell,1977). The crude fiber levels of CM range from 11 to 13 percent (Fenwick, 1982, Bell, 1984). Values as high as 16 percent have been reported by Jones (1979). The high fiber content of CM results in lower values of digestible energy (DE) and metabolizable energy (ME) (Bowland, 1976; Fenwick, 1982). Aherne and Kennelly (1982) reported that French and Swedish workers removed the hull from canola seed before oil extraction which resulted in a CM that was more acceptable as a feed supplement than the CM produced by Canadian methods. The seed hull forms an appreciable part of the canola seed, thus increasing the difficulties of reducing the fiber content through genetic selection (Bayley and Hill, 1975). However, Bell and Shires (1982) reported that the seed coat of yellow coated varieties of CM is thinner and constitutes a smaller percentage of the whole seed and that a reduction of about 4 percent crude fiber was possible through the cultivation of yellow seeded cultivars. Aherne and Kennelly (1982) confirmed that varieties with a yellow seed coat reduced the crude fiber content of the CM by 1 to 2 percent.

2.1.3 Energy

Gross energy of full-fat canola seed was determined as 27.6 KJ/Kg (Bowland, 1971). This high energy value is due primarily to the high (40 percent) oil content of the seed (Mag, 1983). The energy content of the CM, however, varies depending on the level of oil remaining in the meal after extraction and the amount of gums which are added back to the meal. The amount of gums added may be as high as 6 to 7 percent using the expeller process or as low as 2 percent using solvent extraction methods (Youngs et al. 1981). Gums had no net effect on the digestibility coefficient of energy in CM by growing-finishing pigs up to a dietary level of 10 percent (McCuaig and Bell,1981) The metabolizable energy (ME) and digestible energy (DE) values for CM are lower than those of SBM (Bell, 1984). Clandinin and Robblee (1981), reported the ME value of Tower CM to be 7.9 KJ/Kg and 8.3 KJ/Kg for growing and adult poultry respectively. The established ME value of CM for pigs is 11.6 KJ/Kg (Bowland, 1976; Clandinin and Robblee, 1981; Bell, 1984).

2.1.4 Minerals

Chemical analyses show that CM is generally a richer source of minerals than SBM (Clandinin and Robblee, 1981). However, the presence of fiber and phytate in CM reduces the availability of phosphorus (P), calcium (Ca), zinc (Zn), magnesium (Mg), manganese (Mn), and copper (Cu) (Nwokolo and Bragg, 1980; Bell, 1984). In spite of the lower availabilities of minerals in CM as compared to those of SBM, CM was shown to be a better source of Ca, iron (Fe), Mn, P, selenium (Se) and Mg than SBM, whereas SBM was shown to be a better source of Cu, Zn, and potassium (K) than CM (Clandinin and Robblee, 1981).

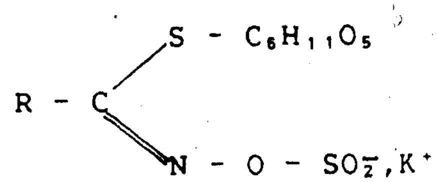
2.1.5 Vitamins

Aherne and Kennelly (1982) reported that CM is not generally looked upon as a major source of vitamins for livestock. However, Clandinin et al. (1978), showed that CM contains higher levels of choline, niacin, riboflavin, folic acid and thiamine, but lower levels of pantothenic acid than SBM.

2.2 FACTORS AFFECTING THE NUTRITIVE VALUE OF CANOLA MEAL

2.2.1 Glucosinolate

Glucosinolates are present in all cruciferous seeds and plants (Kjaer, 1960). The name "glucosinolate" was suggested by Ettlinger and Dateo (1961) but the compounds have also been called mustard oil glucosides or thioglucosides. The general structure of the glucosinolate, which was established for sinigrin (Ettlinger and Lundeem, 1956), is shown in the following formula:



Different glucosinolates vary only in the structure of the side chain -R in the formula. All glucosinolates are coupled with potassium (K) cation except sinalbin which is a salt of sinapine (Paik, 1980).

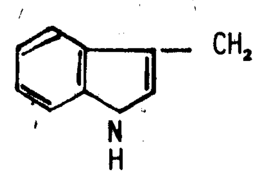
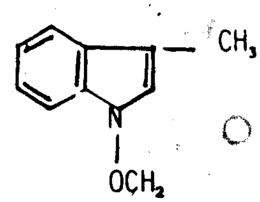
2.2.2 Catabolism of Glucosinolate

The presence of glucosinolate in CM represents the single most important factor limiting its potential as a protein supplement (Hill, 1979; Clandinin and Robblee, 1981). Although biologically inactive themselves, conditions leading to the hydrolysis of glucosinolates yield a variety of goitrogenic and toxic compounds (Josefsson, 1975). Six glucosinolate compounds shown in Table 2.1, are of significance in CM (Bell, 1984). It is these breakdown products which are responsible for the deletrious effects associated with feeding of CM (Fenwick and Curtis, 1980).

2.2.3 Myrosinase

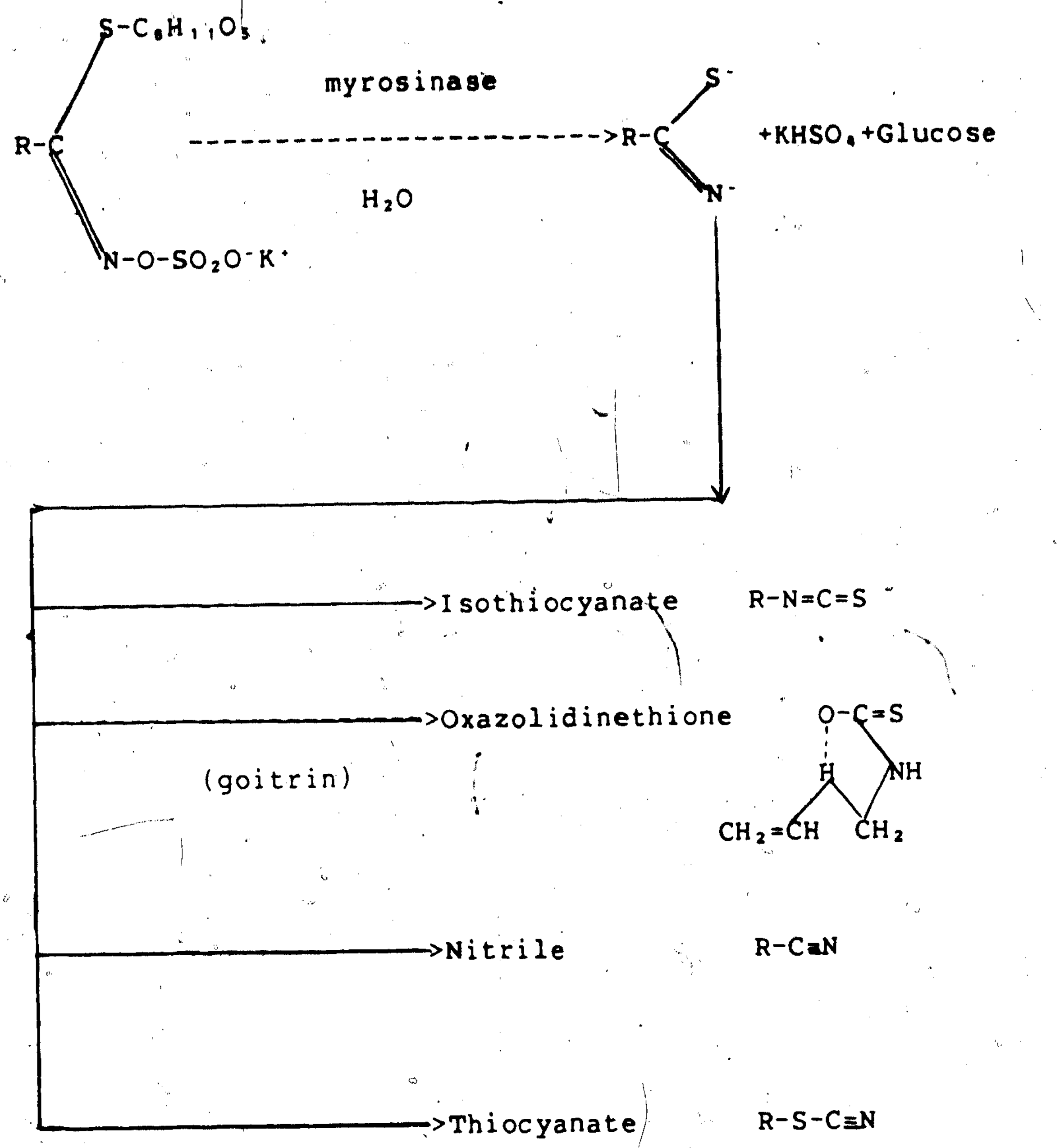
Myrosinases are a group of enzymes which occur in all cruciferous seeds and plants and have the systematic name: thioglucosidase glucohydrolase (E.C.3.2.3.1). In the presence of sufficient amounts of water (approximately 13 percent moisture in the seed) (Young et al. 1981) myrosinase hydrolyzes the glucosinolates into a variety of compounds (Figure 2.1)(Sarwar et al. 1981; Bell, 1984).

Table 2.1. Major Glucosinolates Found in Canola Meal[1]

Glucosinolate	Semi-systematic Name	R
Progoitrin	2-OH-3-butenyl-	CH_2=CH.CHOH.CH_3
Gluconapin	3-butenyl-	CH_2=CH$(CH_2)_2$
Glucobrassicanapin	3-pentenyl-	CH_2=CH$(CH_2)_3$
Napoleiferin	2-OH-4-pentenyl-	CH_2=CH.CH_2.CH(OH).CH_2
Glucobrassicin	3-indolyl-methyl	
Neoglucobrassicin	1-methoxy-3 -indolyl-methyl	

[1]Adapted from Bell(1984)

Figure2.1 Hydrolytic products of glucinolates in canola meal[1]



[1]Bell(1984)

The existence of myrosinase has also been demonstrated by Greer and Deeney (1959) in certain bacteria such as *Escherichia coli*. Chubb (1982) suggested that a portion of the glucosinolates in CM would be degraded by the gut microorganisms via an enzyme similar to the myrosinase found in CM. However, there is no information in the literature as to the extent of the activity of this enzyme in the gut and it does not appear to significantly influence the feeding quality of properly processed canola meal.

2.2.4 Anti-nutritional factors related to glucosinolates

Goitrin

Enzymatic hydrolysis of progroitrin (2-hydroxy-3-butenyl glucosinolate) yields 2-hydroxy-3-butenylisothiocyanate which is unstable and cyclizes to 5-vinyl-2-oxazolidinethione (OZT) whiuch is also called goitrin because of its strong goitrogenic effect (Kjaer, 1960). Goitrogens cause thyroid hypertrophy by diminishing the supply of thyroid hormone available to the body. This is accomplished by either inhibiting the uptake of iodine by the thyroid gland or preventing the binding of mono-iodotyrosine or diiodotyrosine with iodine to form either triiodothyronine (T_3) or thyroxine (T_4) (Ochetim et al. 1980). This results in a net reduction in circulating T_3 and T_4, resulting in stimulation of the hypophysis to produce thyroid stimulating hormone,causing an enlargement of the thyroid gland. Depressed concentrations of circulating T_4 (Aherne and Lewis, 1978; McKinnon and Bowland, 1979) and thyroid hypertrophy (Slinger, 1977; McKinnon and Bowland, 1979) have been associated with feeding CM to pigs.

2.2.5 Thiocyanate

Thiocyanate ion has been known to act as a goitrogenic compound inhibiting the uptake of iodine and suppressing its incorporation into diiodotyrosine and thyroxine (Franklin et al. 1944). The goitrogenic effect of thiocyanate ion can be prevented or inhibited by increasing the iodine content of the diet (Van Etten, 1969).

2.2.6 Nitriles

Another group of compounds produced by hydrolysis of glucosinolates are nitriles. Aherne and Kennelly (1982) from a review of the literature suggested that these compounds are not goitrogenic per se, but that the end-products of nitrile metabolism, such as thiocyanate, are goitrogenic. However, Van Etten et al. (1969) demonstrated that nitriles are toxic to rats causing lesions in the liver and kidneys. Feeding autolyzed CM, which contains a high level of nitrile, depressed the growth rates of rats and chickens (Srivastava et al. 1975).

2.2.7 **Tannins**

Tannins are polyflavoid compounds which tend to accumulate in the seeds of the canola plant (Leung et al.1979). Durkee (1971) indicated that most of the condensed tannins in canola seed are found in the hulls and that their removal by dehulling of canola seed has been shown to improve protein and energy digestibilities of the meal for rats (Leslie et al.1973) and pigs (Sarwar et al.1981)

Both hydrolyzable and condensed tannins have been shown to have adverse effects on the performance of mice (Glick and Joslyn, 1970), poultry (Clandinin 1961; Vohra et al. 1966) and pigs (Almond et al.1979) Yaper and Clandinin (1972) and Seth and Clandinin (1973) reported that tannins reduced the metabolizable energy of the diet of broiler chickens. However, Mitaru et al.(1983) suggest that tannins in canola hulls have no deleterious effect on the nutritive value of CM for non-ruminants.

2.2.8 **Sinapine**

Although the content of choline in CM is nearly three times that found in SBM, most of this occurs as sinapine, the ester of 4-hydroxy-3, 5-dimethoxy-cinnamic acid (Fenwich, 1982). Clandinin and Heard (1961) reported that sinapine produced no growth depressing effects on chickens. However, sinapine in CM has been suggested to be responsible for some of the palatability problems associated with the feeding of CM (Clandinin and Heard, 1961; Fenwick and

Curtis, 1980). Fenwick (1982) from a review of the literature concluded that, whilst methods have been proposed for the decomposition of the sinapine in CM, the economic advantages of such processes are doubtful.

2.2.9 Fiber

Canola meal contains a higher crude fiber level than SBM (13 percent versus 6 percent) and this may contribute to the lower performance observed when CM is fed as the sole protein supplement in the diets of young pigs (Aherne et al. 1977; Castell, 1977). The production of low-fiber and high energy fractions of canola suitable for inclusion in animal and poultry diets can be achieved by dehulling (Fenwick, 1982). The low-hull fraction contains significantly lower levels of both fiber and tannins and has digestibility and metabolizable energy values similar to those of SBM (Clandinin and Robblee, 1981). Yellow-hulled strains of CM contain less hull and and the hull contains less crude fiber and lignin than occur in brown hulls (Bell, 1984). Further improvement in the yellow seed coat varieties with their lower percentages of hulls might improve the nutritive value of CM for swine and poultry. However, Kennelly et al. (1978) reported that reducing the hull content of CM did not result in any significant improvement in its nutritive value for swine.

2.3 CANOLA MEAL AS A SOURCE OF PROTEIN FOR SWINE

Monogastric animals such as swine require a dietary source of protein sufficient to meet their essential amino acid requirements. It would be desirable that the protein requirements of swine for all phases of the life cycle be met by using feedstuffs available in the local geographic areas where swine production occurs. Plants will continue to supply a very high percentage of the protein in animal feeds. In Canada the main source of protein for swine is soybean meal (SBM). However, a great deal of research has been conducted to determine the nutritive value of canola meal (CM) for swine. The primary interest is economic as canola can be extensively grown in Western Canada, whereas soybeans cannot.

Several experiments have demonstrated the superiority of CM over rapeseed meal (RSM) (Aherne et al.1977; Clandinin and Robblee, 1981). However, historical prejudice against CM due to experiences with RSM coupled with difficulties of handling two proteins on the farm and low price differences per unit protein between CM and SBM has limited the inclusion of CM in the diets for swine.

High fiber, lower energy (Fenwick, 1982), low lysine availability (Sauer et al.1982) and the presence of glucosinolates, tannins and sinapine (Bell, 1984) limit the amount of CM used in swine diets. Both RSM and CM are reported to have a sharp bitter taste (Clandinin, 1960) and reduction in the voluntary feed intake of pigs has been reported when RSM or CM were included in swine diets (Manns and Bowland, 1963; Bowland and Schuld, 1968; McIntosh and Aherne, 1981). In a review, Aherne et al. (1977) indicated that CM was superior as a protein source to RSM due to its low content of glucosinolates. Considering the significant reduction in glucosinolate content of CM, there is lack of agreement as to the optimum levels of inclusion of CM in the diets of pigs (Aherne and Kennelly, 1982). Rundgren (1983) in a review noted that this lack of agreement may be due to differences in the experimental procedures used in testing CM, among such differences are : age and weight of animals used, levels of production achieved, basal ingredients used and their relative nutritional values, the processing methods employed during oil extraction and other experimental methods and procedures adopted.

2.3.1 Canola meal for starter pigs

Bowland (1975) used 19.5 to 22 percent CM as a complete replacement for SBM and did not observe any significant depression in weanling pig performance. In another experiment, Bowland et al. (1975) fed CM as partial replacement for SBM or faba beans in the diet of starting pigs. They observed no significant depression in pig performance.

The results of McKinnon and Bowland (1977), suggest that CM may be included in starter pig diets at levels as high as 25 percent of the diet, with no significant reduction in piglet performance. Ochetim et al.(1980), reported that levels of 17 to 20 percent CM in the diet of starter pigs (5 to 20 kg liveweight) will significantly reduce pig performance. Gold et al.(1976), found no reduction in performance when CM was included in the diet at a level of 9 percent, however, feed wastage significantly increased. Canola meal at 7.5 percent in the diet of starter pigs (10 to 32 kg) resulted in a significant decrease in growth rate and feed conversion efficiency compared with those fed SBM supplemented diets (Castell, 1977). But Salo (1980) reported no reduction in performance of pigs (11 to 25 kg) when 10 percent CM was included in barley-skim milk based diets. McIntosh (1983) reported decreased feed intakes and average daily gain (ADG) with increasing levels of CM in the diet. However, feed conversion efficiency (FCE) was not significantly reduced by inclusion of CM in the diets. McIntosh (1983) indicated that CM can safely replace up to 50 percent (16.6 to 18 percent CM in the diet) of the SBM protein without significantly reducing the growth rate or FCE of starter pigs (8 to 25 kg liveweight). The current recommended level of inclusion of CM in diets of starter pigs is 12 percent of the diet (Bell and Aherne, 1981).

2.3.2 Palatability of Canola meal supplemented diets

Clandinin (1960) suggested that the bitter taste in RSM was due to sinapine. Lee and Hill (1980) reported that the substances present in CM that may be associated with low palatability are glucosinolates, tannins, and sinapine. In another report, Hill and Lee (1980) suggested that the glucosinolates in CM are the major factor reducing its palatability. Chubb (1982) in a review article indicated that reduction in feed intake may be due to reduced palatability of the meal associated with the presence in the meal of fiber, tannins, phytic acid, sinapine, glucosinolates, and their breakdown products.

Experiments with starter pigs fed CM supplemented diets have consistently noted a reduction in feed intake (McKinnon and Bowland, 1979; Ochetim et al. 1980; McIntosh and Aherne, 1983). McIntosh (1983) suggested that 5 to 9 weeks old piglets were able to detect as little as 5 percent CM in their diet and consumed 2.5 to 7 times more of a SBM supplemented diet than of a CM diet when given a choice. In a free choice experiment, Castell (1980), observed that pigs preferred diets containing lower levels of CM. The use of selected flavors or feed processing procedures may:

1. increase the acceptance of diets of low palatability,
2. further increase intake of palatable diets,
3. increase acceptance of diets during periods of stress (Bradley,1978).

Success in the use of flavors for these purposes has been variable, partly because feeds preferred in free choice or single stimulus tests do not necessarily result in improved performance under conventional feeding practice McLaughlin et al. 1983) Aldinger et al.(1959) reported that pigs preferred sucrose to glucose or saccharin in free-choice tests, but the performance of pigs offered feed with sucrose did not differ from that of pigs offered feed containing glucose. McIntosh (1983) reported that no significant differences in feed intake or pig performance were attributed to the addition of monosodium glutamate (0.15 percent), dextrose (10 percent) and corn oil (4 to 5 percent) to diets in which CM replaced 50 or 100 percent of the protein supplied by SBM.

2.3.3 Canola meal for growing-finishing pigs

Aherne and Kennelly (1982) in a review indicated that most of the research determining the nutritive value of CM for pigs involved growing-finishing pigs (20 to 100 kg liveweight). In several of these experiments it is frequently impossible to separate the performance of the pigs during the growing and finishing periods. However, National Academy of Sciences - National Research Council, (NAS-NRC, 1979) indicated that growing pigs (20 to 60 kg liveweight) have different nutritive requirements than finishing (60 to 100 kg) hogs, and therefore should be fed different nutrient levels.

When CM completely (11.5 percent of the diet) replaced the SBM supplement in the diets of pigs from 6 to 100 kg liveweight, the performance of barrows fed the CM supplemented diet was not significantly different from that of barrows fed the SBM control diet (Bowland, 1974).

However, gilts fed the CM basal diet had lower average daily feed (ADF), average daily gain (ADG) and feed conversion efficiency (FCE) than gilts fed the SBM control diet. Bowland (1975) suggested that CM may completely (20 percent of the diet) replace SBM in diets of starting-growing pigs with no depression in performance. Bell (1975) reported that ADF, ADG, and FCE were depressed as the level of CM in the diets of growing-finishing pigs increased but the differences were not significant. Castell,(1977) observed a significant reduction in pig performance when SBM was replaced by 12.5 percent CM in the diets of growing-finishing pigs.

In a study with rats and pigs, Orok et al.(1975), reported that ADF, ADG, and FCE were significantly reduced when CM completely (19.8 percent CM) replaced SBM in diets of pigs and rats. McKinnon and Bowland (1977) observed that complete substitution of SBM by 19.8 percent CM in the diet of growing pigs significantly reduced ADG and FCE. In contrast, Rowan and Lawrence (1979) included CM at levels as high as 25 percent of the diet of pigs from 20 to 75 kg liveweight with no significant reduction in growth rate or FCE. However, in another experiment Singham and Lawrence (1979) reported that the inclusion of 23 or 25 percent CM in the diets of pigs from 23 to 67 kg significantly reduced growth rate and FCE. Aherne and Lewis (1978) reported that gilts (20 to 60 kg liveweight) fed a SBM supplemented diet grew significantly faster, and had better FCE than those fed

CM supplemented diets. However, partial replacement of SBM protein by CM protein (9 percent of the diet) or total replacement (19 percent) did not significantly affect the growth rate or FCE of the gilts during the period from 60 to 100 kg liveweight.

In a review, Aherne and Kennelly (1982) reported that there were no significant differences in performance of pigs fed diets containing 10 or 20 percent of a French low glucosinolate rapeseed meal (LGRSM) during the growing (30 to 60 kg) or finishing (60 to 100 kg) periods. However, the overall results (30 to 100 kg) indicated that pigs fed diets containing the 20 percent LGRSM had a slower growth rate and poorer FCE than SBM supplemented diets. No significant effects on any of the carcass measurements were noted. Bell et al.(1981) fed 5 or 15 percent CM in the diets of pigs from 23 to 88 kg liveweight and observed a significant reduction in growth rate and FCE, but no such differences were observed with pigs fed a 10 percent level of CM. There was a significant 7 or 8% advantage from amino acid supplementation of 15% CM diets when lysine and iodine treatments were combined(Bell et al.1981) In a review, Bell and Aherne (1981) indicated that levels of 15 percent CM in the diets of growing-finishing pigs would not significantly reduce pig performance.

A review of the literature involving the feeding value of CM for finishing pigs (60 to 90 kg liveweight) would suggest that CM can replace all of the protein supplement without adversely affecting performance or carcass quality (Bowland, 1976; Aherne et al.1977; Aherne and Kennelly, 1982). Aherne and Kennelly (1982) suggested that when CM is fed during the entire period (20 to 100 kg liveweight) or during the finishing period (60 to 100 kg liveweight), it may be used at 10 to 15 percent of the diet (total replacement of SBM) without significantly affecting growth rate, FCE or carcass quality.

2.3.4 Digestibilities of CM by growing pigs

Studies of the utilization of CM by starting and growing pigs have usually indicated that complete substitution of CM for SBM in diets resulted in a depression in feed intake and growth rate, but partial substitution usually had no significant influence on pig performance. This depression in performance has sometimes been accompanied by lowered digestibilities of energy and nitrogen in the diet.

Bowland (1975) reported no significant differences in the apparent nitrogen utilization whereas McKinnon and Bowland (1977) observed lower digestibility of energy, nitrogen and amino acids with complete replacement of SBM with CM. However, Bell et al.(1981) indicated that there were no significant treatment differences with the coefficients of digestibility for dry matter, energy, and protein in diets supplemented with SBM and CM or with CM as the sole protein supplement. Despite similar apparent digestibility coefficients for protein in CM supplemented diets, Sauer et al.(1981) showed that availability of amino acids in CM is generally lower than in SBM.

2.3.5 Carcass measurements

The carcass quality of pigs fed CM diets have usually been similar to those of pigs fed a control diet (McKinnon and Bowland, 1977; Aherne and Lewis, 1978; Castell, 1977). In a conclusion from a review, Rundgren (1983) stated that the taste quality of meat from pigs fed CM diets did not differ significantly from that of hogs fed SBM supplemented diets.

2.3.6 OBJECTIVES

The objectives of these studies were:

1. To determine the optimum nutritional level of inclusion of Canola Meal (CM) in the diets of starting(6-20kg), growing(20-60kg) and finishing(60-90kg) pigs.
2. To examine the effects, if any, of flavor additives in CM supplemented diets fed to starter pigs(4-9weeks).
3. To estimate the digestibility of CM supplemented diets fed to grower pigs.
4. To study the effect of CM supplemented diets fed to finishing pigs on carcass quality.

3. GENERAL EXPERIMENTAL PROCEDURES

3.1 Animals and Diets

A total of 712 crossbred(Yorkshire X Landrace) pigs equalized between barrows and gilts was used for these studies. Feed(steam-pelleted) was available *ad libitum* from self-feeders for all studies except the single stimulus experiment. Water was available free-choice in each pen. The environmental temperature was maintained at approximately 23°C for the starter and flavor experiments and at 21-23°C for the growing-finishing experiments. Pig weight and feed intake were recorded weekly.

Diets were based on wheat, barley, canola meal(CM) and soybean meal(SBM). The chemical composition of CM and SBM is shown in Table 3.1 and the corresponding amino acid compositions are shown in Appendix 1. With the exception of digestible energy(DE) all diets met or exceeded the nutrient requirement recommendations of the National Academy of Sciences -National Research Council (NAS-NRC)(1979) for starting (6-10-20kg), growing (20-60kg) and finishing (60-90kg) pigs.

The percent crude protein, gross energy, dry matter, crude fiber, ether extract and ash were determined according to the Association of Official Analytical Chemists(AOAC 1981).

Total dietary amino acid levels were determined following acid hydrolysis in 6N HCL(Blackburn,1968), using a

Table 3.1 Chemical Analysis of Protein Supplements

Protein Supplements	Soybean Meal	Canola Meal
Chemical Analysis		
Dry Matter(%)	90.4	91.5
Crude Protein(%)	46.3	35.9
Crude Fiber(%)	4.2	11.8
Ether Extract(%)	2.1	2.5
Ash(%)	5.7	6.9
Gross Energy(MJ/Kg)	17.2	17.5
Oxazolidinethione(mg/g)	0.00	1.02

Beckman 121MB amino acid analyser. The amino acid composition of diets and NAS-NRC(1979) requirements for 5-10kg pigs are shown in Appendix 2, for 10-20kg pigs in Appendix 3, 20-60kg pigs in Appendix 4 and 60-90kg pigs in Appendix 5. The relative cost of the diets were estimated with current (June, 1984) quoted market prices per tonne: soybean meal, $415; canola meal, $215; wheat, $151; barley, $119; and blended animal fat, $507; quoted prices of flavor additives per kg: Pig Krave, $6.63; Hy Sugr Ade, $8.06.

3.2 Statistical Analysis

Analysis of variance was performed on all the data collected according to Steel and Torrie(1980). Where appropriate, treatment means were tested for significance ($P<0.05$) using Student-Neuman Keuls(SNK) multiple range test when preceded by a significant F-test. Additional analyses were computed using linear response where appropriate according to Steel and Torrie (1980).

3.3 SECTION A

3.3.1 Canola Meal as a Protein Supplement for Starter Pigs

3.3.2 Materials and Methods

1. Experiment One

Sixty crossbred (Yorkshire X Landrace) pigs, 3-wks of age were weaned and randomly allotted within sex to one of five dietary treatments shown in Table 3.2. Canola meal(CM) replaced 0, 25, 50, 75, or 100 percent of the protein supplied by soybean meal(SBM). All diets were formulated to be isonitrogenous and in terms of digestible energy(DE) to be isoenergetic. Diets containing 20% crude crude protein (CP) (Table 3.2) were fed to 3wk-weaned from weaning until the pigs weighed 10kg liveweight and diets containing 18% CP were fed from 10 to 20kg liveweight as recommended by NAS-NRC(1979). The pigs were individually housed in 0.6m X 1.2m pens with Tenderfoot floors.

2. Experiment Two

Sixty crossbred (Yorkshire X Landrace) pigs averaging 6.1kg in weight at 3-4wk of age were allotted to the five dietary treatments (Table 3.2) and individually housed in 1.2m X 1.2m slatted floor pens. Canola meal replaced 0, 25, 50, 75, or 100 percent of the protein supplied by soybean meal (SBM). All diets were formulated to be isonitrogenous and in terms of digestible energy (DE) to be isoenergetic.

Table 3.2 Formulation and chemical composition of starter (6-10kg)pig diets supplemented with soybean meal(SBM) and canola meal(CM)

SBM/CM RATIO	100%SBM ---	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	100%CM
Level of CM in diets(%)	0.0	8.8	17.6	26.5	35.3
Ingredients					
Wheat	20.0	20.0	20.0	20.0	20.0
Barley	49.6	45.6	41.4	37.2	33.0
Soybean meal	25.4	19.0	12.7	6.3	0.0
Canola meal	0.0	8.8	17.6	26.5	35.3
Blended animal fat	0.0	1.5	3.3	5.0	6.7
Iodized salt	0.4	0.4	0.4	0.4	0.4
dicalcium phosphate	2.0	2.0	2.0	2.0	2.0
Ground limestone	1.5	1.5	1.5	1.5	1.5
Starter premix[1]	1.0	1.0	1.0	1.0	1.0
L-lysine(HCl)	0.10	0.12	0.13	0.14	0.15
Chemical Analysis[2]					
Dry matter(%)	86.1	86.6	89.7	87.2	87.2
Crude protein(%)	19.9	19.9	19.9	19.9	20.0
Gross energy(MJ/KG)	15.4	15.6	16.4	16.8	17.3
Ether extract(%)	1.3	2.7	4.7	6.5	8.0
Crude fiber(%)	4.0	4.3	5.0	5.6	6.2
Ash(%)	6.0	6.1	6.6	6.9	7.2
Lysine(%)	1.25	1.25	1.25	1.24	1.24
Relative cost	100	97	96	94	93

[1]Starter premix provided the following per kg of diet: 120mg zinc, 12mg manganese, 150mg iron, 12mg copper, 0.1mg selenium, 500mg choline chloride, 5000IU vitamin A, 500IU vitamin D_3, 22IU vitamin E, 12mg riboflavin, 45mg niacin, 200ug biotin, 25mg calcium pantothenate, 30ug vitamin B_{12}, 275mg ASP250.

[2]Determined values reported on an as-fed basis unless otherwise indicated

In contrast to experiment one, pigs were fed 20% CP diets from weaning to 20kg liveweight.

2. Experiment Three

Sixty 5-wk-old crossbred pigs (Yorkshire X Landrace) averaging 9.8kg in weight were randomly allotted within sex to one of five experimental diets shown in Table 3.3. The pigs were fed these diets until they reached 20kg liveweight. Thirty pigs were individually housed in 0.6m X 1.2m pens with Tenderfoot floors, the remaining 30 were individually housed in 1.2m X 1.2m slatted floor pens.

3.3.3 Results

1. Experiment One

The inclusion of up to 25.7 percent CM in the diets of 6 to 10kg liveweight pigs did not significantly reduce average daily feed intake (ADF). However, average daily gain (ADG) was depressed ($P<0.05$) when CM was included in the diet at a level of 16.8 percent (Table 3.4). Feed conversion efficiency (FCE) was not affected by level of CM in the diet. Regression analyses of the data indicated that each percent addition of CM to the diet resulted in a linear ($P<0.001$) decrease in ADF and ADG of 1.9g and 1.3g respectively, with an increase in the average number of days on test (ADT) by 0.16.

$$Y(ADF) = 0.380 - 0.0019\ (\%\ CM) \quad r = -.54$$

$$Y(ADG) = 0.208 - 0.0013\ (\%\ CM) \quad r = -.71$$

Table 3.3 Formulation and chemical composition of starter (10-20kg)pig diets supplemented with soybean meal(SBM) and canola meal(CM)

SBM/CM RATIO	100%SBM ---	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	100%CM
Level of CM in diets(%)	0.0	6.3	12.7	19.5	27.0
Ingredients(%)					
Wheat	20.0	20.0	20.0	20.0	20.0
Barley	56.3	53.9	50.9	47.9	44.8
Soybean meal	19.3	14.6	10.2	5.4	0.0
Canola meal	0.0	6.3	12.7	19.5	27.0
Blended animal fat	0.4	1.3	2.4	3.4	4.5
Iodized salt	0.4	0.4	0.4	0.4	0.4
dicalcium phosphate	1.5	1.5	1.5	1.5	1.5
Ground limestone	1.0	1.0	1.0	1.0	1.0
Starter premix[1]	1.0	1.0	1.0	1.0	1.0
L-lysine(HCl)	0.05	0.07	0.09	0.13	0.15
Chemical analysis					
Dry matter (%)	88.6	88.9	89.6	89.3	86.7
Crude protein (%)	18.1	18.2	18.1	18.1	18.1
Gross energy (MJ/kg)	15.9	16.4	16.4	16.9	17.1
Ether extract (%)	2.3	3.8	4.9	6.0	8.3
Crude fiber (%)	4.4	4.5	4.6	5.1	5.2
Ash (%)	7.4	7.9	7.7	7.2	8.3
Relative cost	100	98	97	96	94

[1]Starter premix provided the following per kg of diet: 120mg zinc,12mg manganese,150mg iron,12mg copper,0.1mg selenium,500mg choline chloride,5000IU vitamin A,500IU vitamin D_3,22IU vitamin E,12mg riboflavin,45mg niacin, 200ug biotin,25mg calcium pantothenate,30ug vitamin B_{12}, 275mg ASP250

Y(ADT) = 18.76 + 0.1600 (% CM) r = .68

During the period 10 to 20 kg liveweight ADF and ADG were decreased when (P<0.05) CM protein replaced more than 25 percent of the SBM protein (Table 3.4). Feed conversion efficiency was not significantly affected by the level of CM in the diet. Regression analyses of the results indicated that for every percent addition of CM to the diet, there was a linear (P<0.001) decrease in ADF and ADG of 9.7g and 7.5g and an increase in days on test by 0.32.

Y(ADF) = .996 - 0.0097 (% CM) r = -.76

Y(ADG) = .592 - 0.0075 (% CM) r = -.88

Y(ADT) = 16.93 + 0.3200 (% CM) r = .90

Results of the combined periods, 6 to 10 kg and 10 to 20 kg liveweight (Table 3.4) irrespective of protein levels, indicated that pigs fed diets in which more than 25 percent of the SBM protein was replaced by CM protein had depressed ADF and ADG. The level of CM in the diet did not affect the FCE.

2. Experiment Two

Results from pigs fed diets containing 20 percent crude protein from 6 to 20 kg liveweight indicated that replacement of more than 25 percent of the SBM protein by CM protein resulted in a significant reduction in ADF and ADG (Table 3.5). Feed conversion efficiency was not affected by the level of CM in the diet. Regression analyses of the results showed that for each percent increase of CM in the diet, there was a linear (P<0.001) decrease in ADF and ADG

Table 3.4 The average performance[1] of pigs(6-10-20 kg) fed diets supplemented with soybean meal(SBM) and canola meal(CM)

SBM/CM RATIO	100%SBM ---	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	100%CM	SE[2]	SIG[3]
<u>Period 1(6-10kg)</u>							
Level of CM in diet(%)	0.0	8.2	16.8	25.7	35.4		
Days on test	20	19	21	23	25	.84	*
Daily feed (g)	376.0	364.0	359.0	329.0	305.0	16.08	*
Daily gain (g)	203.0	198.0	191.0	172.0	156.0	7.07	*
Feed: gain	1.86	1.83	1.87	1.91	1.96	0.11	NS
<u>Period 2(10-20kg)</u>							
Level of CM in diet(%)	0.0	6.3	12.7	19.5	27		
Days on test	17	18	21	23	26	.63	*
Daily feed (g)	1000.0	937.0	866.0	796.0	745.0	34.10	*
Daily gain (g)	592.0	557.0	483.0	437.0	397.0	16.89	*
Feed: gain	1.70	1.69	1.80	1.83	1.88	0.09	NS
<u>Overall(6-20kg)</u>							
Days on test	38	37	42	46	51	0.64	*
Daily feed(g)	662.0	641.0	600.0	562.0	532.0	12.90	*
Daily gain(g)	385.0	378.0	341.0	317.0	290.0	5.05	*
Feed:Gain	1.72	1.70	1.76	1.78	1.78	0.04	NS

[1] 12 pigs per treatment individually fed.
[2] SE- Standard error of means
[3] *-Statistical significance at $p<0.05$; NS = nonsignificant ($p>0.05$)

Table 3.5 The performance [1] of pigs(8-20kg) fed diets supplemented with soybean meal(SBM) and canola meal(CM)

SBM/CM RATIO	100%SBM ---	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	100%CM	SE[2]	SIG[3]
Levels of CM in the diet(%)	0.0	8.2	16.8	25.7	35.4		
Days on test	36	37	41	44	48	1.83	*
Daily feed(g)	660.0	630.0	584.0	560.0	535.0	25.15	*
Daily gain(g)	392.0	378.0	349.0	333.0	303.0	15.06	*
Feed:Gain	1.69	1.67	1.68	1.68	1.77	0.01	NS

[1] 12 pigs per treatment individually fed
[2] Standard error of means
[3] *-Statistical significance at $p<0.05$; NS = nonsignificant ($p>.05$)

by 3.7 and 2.5g respectively and an increase in ADT by 0.30.

$$Y(ADF) = .658 - 0.0037\ (\%\ CM)\quad r = -.76$$

$$Y(ADG) = .395 - 0.0025\ (\%\ CM)\quad r = -.87$$

$$Y(ADT) = 35.25 + 0.3000\ (\%\ CM)\quad r = .84$$

2. Experiment Three

Feed intake and ADG were significantly depressed when CM protein replaced more than 25 percent of the SBM protein (Table 3.6). Feed conversion efficiency was not significantly depressed until CM replaced 75 percent or more of the SBM supplement. The following regression analyses of the results indicated that each percent inclusion of CM to the diet resulted in a linear ($P<0.001$) decrease in ADF and ADG by 4.6 and 4.2g respectively and an increase in ADT by .24

$$Y(ADF) = .825 - 0.0046\ (\%\ CM)\quad r = -.56$$

$$Y(ADG) = .457 - 0.0042\ (\%\ CM)\quad r = -.78$$

$$Y(ADT) = 22.89 + 0.2400\ (\%\ CM)\quad r = .72$$

The results of this study showed that CM protein can replace 25 percent of the SBM protein without significantly reducing ADG or FCE of pigs weaned at 5 weeks and fed 18% CP diet from weaning to 20kg liveweight.

3.3.4 Discussion

The regression analyses of the results of the three experiments indicates that every percent addition of CM to the diet would result in reduction in feed intake and growth rate. The performance data indicates that when CM completely

Table 3.6 The average performance[1] of 5-wk-old weaned pigs fed diets supplemented with soybean meal(SBM) and canola meal(CM)

SBM/CM RATIO	100%SBM ---	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	100%CM	SE[2]	SIG[3]
Levels of CM in the diet(%)	0.0	6.3	12.7	19.5	27.0		
Initial weight(kg)	9.8	9.8	9.9	9.8	9.8	0.01	
Final weight(kg)	20.4	20.2	20.0	20.0	20.0	0.07	
Days on test	23	24	26	28	30	0.93	*
Daily feed(g)	841.0	780.0	760.0	740.0	700.0	23.06	*
Daily gain(g)	460.0	440.0	400.0	370.0	350.0	15.01	*
Feed:Gain	1.86	1.78	1.92	2.01	2.02	0.06	NS

[1] 12 pigs per treatment individually fed
[2] Standard error of means
[3] *Statistical significance at $p<0.05$; NS = nonsignificant ($p>0.05$)

replaced SBM a significant reduction in performance was observed. This does not agree with results of Bowland (1975) who reported that complete replacement of SBM protein by CM protein (20% CM in the diet) did not affect performance of pigs fed the CM supplemented diets. These experiments indicate that 25 percent replacement of SBM protein by CM protein did not affect pig performance. The results of McKinnon and Bowland (1977) suggest that CM may be included in starter diets at levels as high as 25 percent of the diet, with no significant reduction in pig performance. However, Castell (1977), Ochetim, et al,(1980) and McIntosh (1983) suggest that levels of 17 to 20 percent CM in the diet of starter (5 to 20 kg) pigs will significantly reduce pig performance. Castell (1977) included CM at 7.5 percent in the diet of starter pigs and observed a significant decrease in pig performance. This observation agrees with the results obtained with pigs fed the 18 percent crude protein diet from 10 to 20 kg where more than 6.3 percent CM in the diet caused a significant decrease in performance. McIntosh (1983) concluded from two starting pig experiments that CM (approximately 17 percent in the diet) can replace 50 percent of the protein supplied by SBM without significantly affecting the growth rate or the FCE of starter pigs. This observation is consistent with data obtained in this study using pigs from 3 weeks of age to 10 kg (Experiment 1). However, the overall results indicated that 50 percent replacement of SBM protein by CM protein caused a depression in performance.

The slower rate of growth of pigs fed CM supplemented diets compared with pigs fed SBM control diet appears to be related to a significant reduction in ADF. Possible reasons for the reduction in ADF may be due to the influence of the hydrolytic products of the glucosinolates in the CM (McKinnon and Bowland, 1979; Ochetim et al, 1980; Bell, 1984), the palatability of the meal (Singam and Lawrence, 1979; McIntosh and Aherne, 1981), the higher fiber levels of CM supplemented diets (Kennelly et al, (1978). Rundgren (1983) in a review indicated that the substances in CM associated with low palatability are the breakdown products of glucosinolates, tannins and sinapine but the products of glucosinolates seemed most likely to be associated with reduced feed intake.

The results of these starting pig experiments would suggest that CM can safely be included at a level of 8 percent in the diet of starting pigs (6 to 20 kg liveweight) without affecting performance.

3.4 SECTION B

3.4.1 Effect of flavor additives in canola meal diets

3.4.2 Materials and Methods

1. Experiment One

Thirty-six 4-wk-old crossbred pigs were randomly allotted within sex to one of six diets shown in Table 3.7. This experiment was designed as a 3 X 2 factorial with diets containing 0, 50 and 100 CM percent replacing equal amounts of protein from SBM with or without the addition of two feed flavors. The flavor additives (Hy Sugr ADE and Pig Krave) obtained from Feed flavors International Incorporated, Illinios, U.S.A., were added at levels recommended by the manufacturers. The pigs were individually housed in 1.2m X 1.2m slatted floor pens for the 28 day duration of the experiment.

2. Experiment Two

Thirty 5-wk-old crossbred pigs were individually housed in 0.6m X 1.2m flat decks. This feed preference experiment employed the Single Stimulus method first described by Aldinger and Fitzgerald(1966). With this procedure pigs were alternately given access to two of the six diets shown in Table 3.7. Each pig was exposed to one of two diets with or without flavor but containing the same CM level. For example, a non-flavored diet was placed in the pen for a 4hr period followed by a second 4hr period of access to a,

Table 3.7 Formulation and chemical composition of starter diets supplemented with soybean meal(SBM) and canola meal(CM) and flavor additives.

SBM/CM RATIO	100%SBM		50%SBM 50%CM		100%CM	
Level of CM in the diets(%)	0.0		17.6		35.3	
Flavor additive	-	+	-	+	-	+
Ingredients						
Wheat	20.0	20.0	20.0	20.0	20.0	20.0
Barley	49.6	49.4	41.4	41.4	33.0	33.0
Soybean meal	25.4	25.4	12.7	12.7	35.3	35.5
Canola meal	0.0	0.0	17.6	17.6	6.7	6.7
Blended animal fat	0.0	0.0	3.3	3.3	0.4	0.4
Iodized salt	0.4	0.4	0.4	0.4	2.0	2.0
dicalcium phosphate	2.0	2.0	2.0	2.0	1.5	1.5
Ground limestone	1.5	1.5	1.5	1.5	1.0	1.0
Starter premix[1]	1.0	1.0	1.0	1.0	0.0	0.23
Pig Krave[2]	0.0	0.23	0.0	0.23	0.0	0.90
Hy Sugr ADE[2]	0.0	0.90	0.0	0.90	0.10	0.10
L-lysine(HCl)	0.10	0.10	0.10	0.10	93	97
Relative cost	100	103	97	100		
Chemical analysis						
Dry matter(%)	86.9	86.9	88.3	87.8	86.5	88.1
Crude protein(%)	20.3	20.4	19.9	19.9	20	19.7
Gross energy(MJ/Kg)	15.7	15.6	16.7	16.5	17.6	17.6
Ether extract(%)	1.4	1.3	5.0	4.8	9.1	9.0
Crude fiber(%)	3.9	4.1	4.9	5.0	6.3	6.1
Ash(%)	5.9	6.2	6.5	6.8	7.1	7.2

[1]Starter premix provided the following per kg of diet: 120mg zinc, 12mg manganese, 150mg iron, 12mg copper, 0.1mg selenium, 500mg choline chloride, 5000IU vitamin A, 22IU vitamin E, 200ug biotin, 12mg riboflavin, 45mg niacin, 25mg calcium pantothenate, 30ug vitamin B , 275mg ASP250

[2]Feed flavor additives

flavored diet. This feeding pattern was maintained from 0800hr to 2400hr and repeated for 28 day duration of the experiment.The feeder was, however, not changed from 2400hr to 0800hr.

3.4.3 Results

1. Experiment One

Feed intake and weight gain were reduced($P<0.05$) as the level of CM in the diet increased with or without added flavor (Table 3.8). Pigs offered flavored feed containing CM as a complete replacement for SBM ate (8%) more ($P<0.05$) than pigs offered the non-flavored feed with the same level of CM. Although, the feed intake and growth rate of pigs fed the flavored 50:50 SBM:CM diets increased, the difference relative to a similar non-flavored diet was not significant. Feed conversion efficiency was not affected($P>0.05$) by the level of CM in the diet or by the addition of flavor, however, pigs fed CM supplemented diets without flavor had poorer FCE.

2.Experiment Two

The preference of starter pigs for flavored or non-flavored diets was investigated in expriment two and the results are summarized in Table 3.8. The pigs' preference for the flavored diet was shown by the increase in the feed intake of all the flavored diets compared with the non-flavored diets. The increase in feed intake of the flavored diets decreased as the level of CM in the diet increased. The corresponding increase in feed intake of flavored diets containing 0, 17.6 and 35 percent CM in the diet were 29, 26 and 21%.

3.4.4 Discussion

These results indicate that the flavored subtances (Hy Sugr ADE and Pig Krave) did influence feed intake of pigs fed CM supplemented diets. However, the increase in feed intake of flavored CM supplemented diets decreased as the level of CM increased. Several studies have indicated possible reasons for the low palatability of CM supplemented diets. Singam and Lawrence(1979) suggest that the poorer acceptability of CM relative to SBM for pigs might be due to tannins. Chubb(1982) concluded that the reduced palatability of the CM may be due to the presence of tannins, phytic acid, sinapine, glucosinolates and their breakdown products and fiber.

McIntosh(1983) suggested that pigs were able to detect 5% CM in the diet and consequently reduced feed intake. McIntosh(1983) reported that there was no influence of supplementary mono-sodium glutamate, dextrose or corn oil on the consumption of CM diets in which CM replaced 50 or 100 percent of the protein supplied by SBM. The addition of flavored subtances in the current experiment did increase feed intake of pigs fed CM supplemented diets, however, the performance of these pigs was below the performance of pigs fed the SBM control diet. Thus, the flavor additives did not

Table 3.8 Effect of flavor additives on utilization of canola meal(CM) by starter pigs

Flavor addition	No Flavor			Flavor				
SBM/CM RATIO	100%SBM ---	50%SBM 50%CM	--- 100%CM	100%SBM ---	50%SBM 50%CM	100%CM		
Level of CM in diets(%)	0.0	17.6	35.3	0.0	17.6	35.3	SE[1]	SIG[2]
Experiment 1								
Initial weight(kg)	7.4	7.4	7.5	7.6	[illegible].4	7.4	.05	
Final weight(kg)	17.5	16.8	14.5	18.7	[illegible].0	15.4	.51	
Avg. daily feed(g)	593.0	554.0	464.0	647.0	575.0	510.0	28.86	*
Relative feed intake(%)	100.0	93.0	78.0	109.0	[illegible]	86.0		
Avg. daily gain(g)	361.0	332.0	250.0	397.0	34[illegible].0	285.0	22.36	*
Feed:Gain	1.64	1.67	1.88	1.63	1.67	1.80	0.07	NS
Experiment 2								
Avg. daily feed(g)	508.0	435.0	391.0	655.0	574.0	501.0		*
Relative feed intake(%)	100.0	86.0	77.0	129.0	112.0	98.0		

[1]Standard error of means
[2]*-Statistical significance at p<0.05; NS = nonsignificant (p<0.05).

completely mask the effects of the subtances responsible for low feed intake of the CM supplemented diets.

3.5 SECTION C

3.5.1 Canola meal as protein supplement for growing-finishing pigs

3.5.2 Materials and Methods

1. Experiment One

Thirty six crossbred (Yorkshire X Landrace) pigs with an average initial weight of 20.3kg were used in this experiment. Eighteen of the 36 pigs had been previously fed a 50:50 SBM:CM supplemented diet and the remaining 18 were fed a SBM supplemented diet during the starter phase(10-20kg liveweight). Nine pigs from each of these groups continued on the diet they were fed during the starter phase whereas the other 9 pigs were changed to a SBM or 50:50 SBM:CM diet. The composition of the diets is shown in Table 3.9. Pigs were housed individually in 1.2m X 1.2m slatted floor pens. The experiment was terminated when pigs weighed 40kg.

2. Experiment Two

Seventy crossbred (Yorkshire X Landrace) pigs with an average initial weight of 20.1kg were allotted on the basis of sex and weight to one of the five dietary treatment shown in Table 3.10. Diets were formulated to contain 16% crude protein, but were not equalized for energy. The pigs were individually penned in 1.2m X 1.2m partially slatted floor pens from 20 to 60kg liveweght. The pigs were bled by anterior vena cava puncture at 45kg liveweight Serum was

Table 3.9 Formulation and chemical composition of diets for growing(20-40kg) pigs supplemented with soybean meal(SBM) and canola meal(CM)

SBM:CM RATIO	100%SBM ---	50%SBM 50%CM
<u>Ingredient(%)</u>		
Wheat	41.7	39.5
Barley	40.0	40.0
Soybean meal	13.0	6.5
Canola meal	0.0	8.2
Blended animal fat	1.5	2.0
Iodized salt	0.4	0.4
dicalcium phosphate	1.2	1.2
Ground limestone	1.2	1.2
Grower premix[1]	1.0	1.0
L-lysine(HCl)	0.0	0.02
Relative cost	100	94
<u>Chemical Analysis</u>		
Dry matter(%)	86.8	87.2
Crude protein(%)	16.3	16.9
Gross energy(MJ/Kg)	16.3	16.6
Ether extract(%)	2.2	3.2
Crude fiber(%)	4.3	4.9
Ash(%)	4.1	4.9

[1]Grower premix provided the following per kg of diet: 120mg zinc, 12mg maganese, 150mg iron, 12mg copper, 5000IU vitamin A, 500IU vitamin D_3, 22IU vitamin E, 12mg riboflavin, 45mg niacin, 25mg calcium pantothenate, 30ug vitamin B_{12}

Table 3.10 Formulation and chemical composition of non-isoenergetic diets for growing pigs supplemented with soybean meal(SBM) and canola meal(CM)

SBM/CM RATIO	100%SBM ---	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	100%CM
Level of CM in diets(%)	0.0	3.6	7.3	10.9	16.8
Ingredients(%)					
Wheat	40.0	40.0	40.0	40.0	40.0
Barley	44.8	43.8	42.6	41.4	39.4
Soybean meal	11.4	8.8	6.4	3.9	0.0
Canola meal	0.0	3.6	7.3	10.9	16.8
Iodized salt	0.4	0.4	0.4	0.4	0.4
dicalcium phosphate	1.2	1.2	1.2	1.2	1.2
Ground limestone	1.2	1.2	1.2	1.2	1.2
Grower premix[1]	1.0	1.0	1.0	1.0	1.0
L-lysine(HCl)		0.01	0.02	0.03	0.04
Relative cost	100	97	95	92	88
Chemical Analysis					
Dry matter(%)	86.6	86.9	87.3	88.2	88.1
Crude protein(%)	15.6	16.0	16.0	16.0	16.0
Gross energy(MJ/KG)	15.7	15.4	15.2	14.9	14.8
Ether extract(%)	1.0	1.1	1.1	1.4	1.1
Crude fiber(%)	4.3	4.4	4.9	5.1	5.7
Ash(%)	4.2	4.4	4.8	4.9	5.2

[1]Grower premix provided the following per kg of diet: 120mg zinc, 12mg manganese, 150mg iron, 12mg copper, 5000IU vitamin A 500IU vitamin D_3, 22IU vitamin E, 12mg riboflavin, 45mg niacin, 25mg calcium pantothenate, 30ug vitamin B_{12}, 500mg choline chloride.

separated and divided into two portions, for analysis of triiodothyronine(T_3) and thyroxine(T_4) respectively. Samples were stored at -20°C until analyzed. The T_3 was determined by radioimmounoassay with a kit of reagents(T_3 RIA (PEG) Diagnostic Kit, Abbott Labs. Illinois, U.S.A) and the T_4 by a competitive binding method also using a kit of reagents (T_4 RIA (PEG) Diagnostic Kit, Abbott Labs. Illinois). Dysprosium($DyCl_3 6H_2o$) was added to each diet at a level of 10ppm as an inert marker according to procedures described by Kennelly et al,(1980). The digestibility coefficients for dry matter, energy and protein were determined using the instrumental neutron activation analysis (INAA) procedure described by Kennelly et al.(1980). Fecal grab samples were collected from each pig on days 30, 31 and 32 of the test period. The fecal samples were frozen, freeze-dried, ground and stored for analysis.

3. Experiment Three

Two hundred and forty crossbred pigs with an initial weight of 20.7kg were randomly allotted on the basis of sex and weight to one of five experimental diets shown in Table 3.11. The pigs were housed in groups of four(two barrows,two gilts) in concrete floored pens measuring 1.5m X 3.9m from 20 to 60kg liveweight.

One hundred and twenty of the growing pigs when they attained 60kg liveweight continued on the same experimental diets but the crude protein level was reduced to 14%. The growing-finishing pigs were kept in the same pens from 60 to

Table 3.11 Formulation and chemical composition of growing-finishing pig diets

TYPE OF DIET	GROWER					FINISHER				
SBM/CM	100%SBM ---	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	--- 100%CM	100%SBM ---	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	100%CM
Wheat	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Barley	43.0	41.2	39.0	37.0	33.2	48.6	47.0	45.1	44.1	41.0
Soybean meal	13.2	10.0	7.1	4.2	0.0	7.0	5.3	4.0	2.0	0.0
Canola meal	0.0	4.6	9.1	13.2	19.6	0.0	2.8	5.5	8.0	12.0
Blended animal fat	0.0	0.5	1.0	1.8	3.0	0.5	1.0	1.5	2.0	3.0
L-lysine(HCl)	0.0	0.01	0.02	0.03	0.04	0.0	0.01	0.02	0.03	0.04
Relative cost	100	98	97	97	96	100	99	98	98	97
Chemical Analysis										
Dry matter(%)	87.8	88.2	88.1	89.5	85.7	85.7	86.4	86.0	86.8	86.4
Crude protein(%)	16.1	16.0	16.2	16.0	16.0	14.2	14.1	14.2	14.2	14.1
Gross energy(MJ/Kg)	15.5	15.6	15.5	16.2	16.7	15.6	15.8	16.3	16.7	17.0
Crude fiber(%)	4.3	4.5	4.9	5.3	5.7	4.3	4.5	4.7	4.8	4.9
Ether extract(%)	1.2	1.9	2.7	3.8	4.2	1.3	2.1	3.0	4.5	5.5
Ash(%)	4.1	4.4	5.0	5.1	5.3	4.6	4.9	5.0	5.0	5.1

[1] All growing-finishing diets contained 0.5% iodized salt. 1.2% limestone, 1.2% calcium phosphate, and 1% of a vitamin-mineral premix[2]

[2] Vitamin-mineral premix provided the following per kg of diet 120mg zinc, 12mg manganese, 150mg iron, 12mg copper, 5000 vitamin A, 500IU vitamin D, 22IU vitamin E, 12mg riboflavin, 45mg niacin, 25mg calcium pantothenate, 30ug vitamin B, 500mg choline chloride

90kg liveweight. Pigs were marketed through a commercial slaughtering plant as the average weight in the pen approached 90kg liveweight at the weekly weighing. Canadian grade index and record of performance (ROP) measurements (Canada Department of Agriculture,1971) were recorded for each carcass. The ROP yield, which is an estimate of the percentage yield of wholesale cuts, was calculated from the formula:

$$Y=51.68-1.273TBF+.161LEA+48.5HW/SW+.827HLA/HW$$

where TBF=The sum of three backfat depth (shoulder, midback, and loin)

LEA=Loin eye area, in cm^2

HW=Ham weight, in kg

SW=Side weight,in kg

HLA=Area of lean in the ham face in cm^2.

3.5.3 Results

1. Experiment One

No significant effect of CM supplementation on pig performance was observed(Table 3.12). However, pigs fed the SBM supplemented diet grew faster ($p>0.05$) than pigs fed CM supplemented diets during the growing period. Previous exposure to CM supplemented diets or lack of it did not influence ADF or pig performance during the experimental period.

2. Experiment Two

When diets were not isoenergetic ADF tended to increase as level of CM in diet increased (Table 3.13). Growth rate was depressed ($P<0.05$) when CM replaced more than 75% of the SBM supplement. However, FCE was not significantly affected by an increase in the level of CM in the diet. The following regression equations indicate that every percent addition of CM to the diets would result in 5.6g increase in feed intake and 6.8g reduction in growth rate.

$$Y(ADF)=2.02+0.0056(\%CM) \quad r=.17$$

$$Y(ADG)=0.80-0.0068(\%CM) \quad r=-.45$$

A linear ($P<0.001$) increase in the number of days on test(ADT) was observed as the level of CM in the diet increased as indicated by the following regression equation:

$$Y(ADT)=51.79+.4418\ (\%CM) \quad r=.45$$

Although the pigs fed the CM supplemented diets had lower apparent digestibility coefficients for energy, protein and dry matter than those of pigs fed the SBM control diet, the differences were not significant (Table 3.13). Serum T_3 and T_4 concentration of pigs at 45kg liveweight were not significantly affected by the level of CM in the diet(Table 3.13). However, there was a tendency for plasma thyroid hormone levels to decrease with an increase in CM in the diets.

Table 3.12 The average perfomance of grower pigs fed diets supplemented with soybean meal(SBM) and canola meal(CM)

Diets						
Starter phase	100%SBM		50%SBM/50%CM			
Grower phase[1]	100%SBM ---	50%SBM 50%CM	100%SBM ---	50%SBM 50%CM		
Level of CM (%)	0.0	8.2	0.0	8.2	SE[2]	SIG[3]
Performance[1]						
Init. weight(kg)	20.3	20.4	20.1	20.2	0.31	
Final weight(kg)	40.3	39.7	40.2	39.7	0.27	
Daily feed intake(kg)	1.64	1.64	1.77	1.80	0.06	NS
Daily gain(kg)	0.71	0.69	0.72	0.70	0.02	NS
Feed:Gain (kg)	2.31	2.39	2.47	2.58	0.09	NS

[1]9 pigs per treatment individually fed
[2]Standard error of means
[3]NS = nonignificant ($p>0.05$)

Table 3.13 The average performance of grower pigs fed non-isoenergetic diets supplemented with soybean meal (SBM) and canola meal (CM) as protein supplements

SBM/CM RATIO	100%SBM ---	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	100%CM	SE[1]	SIG[2]
Level of CM in diets(%)	0.0	4.4	9.0	13.0	18.5		
Performance							
Initial weight(kg)	20.0	20.6	20.1	20.0	20.0	0.51	
Final weight(kg)	60.9	61.5	61.4	60.7	60.0	0.54	
Days on test	52	53	55	58	60.0	1.57	*
Daily feed(kg)	1.98	2.09	2.09	2.09	2.11	0.06	NS
Daily gain(kg)	0.79	0.78	0.75	0.71	0.67	0.02	*
Feed:Gain	2.51	2.71	2.80	2.95	3.19	0.05	NS
Digestion coefficients(%)							
Dry matter	81.0	79.3	79.3	79.1	78.9	0.53	NS
Energy	82.0	81.6	80.6	80.2	79.2	0.54	NS
Protein	78.5	77.4	76.3	76.1	76.2	0.85	NS
T3(ug/100ml)[3]	82.9	80.4	80.3	80.8	79.8	2.38	NS
T4(ug/100ml)[4]	4.2	4.0	4.0	3.9	3.8	0.20	NS

[1] Standard error of means
[2] *-Statistical significance at $p<0.05$; NS = nonsignificant ($p>0.05$)
[3] Triiodothyronine
[4] Thyroxine

3. Experiment Three

Grower Period

No significant differences in ADF and FCE were observed with inclusion of CM in the diet, though there was the tendency for each of these criteria to deteriorate with the increase in CM in the diets (Table 3.14). Daily gain was lower ($P<0.05$) for pigs fed diets in which 75 percent or more of the SBM protein was replaced by CM protein (13.2 percent CM in the diet). Regression analyses of the results indicate that for each percent addition of CM in the diet there was a 3.2g reduction in ADF, a 4.4g depression in ADG and an increase of .23 days to grow from from 20 to 60 kg.

$$Y(ADF) = 1.86 - 0.0032 \ (\% \ CM) \quad r = -.12$$

$$Y(ADG) = .77 - 0.0044 \ (\% \ CM) \quad r = -.49$$

$$Y(ADT) = 53.01 + 0.2360 \ (\% \ CM) \quad r = .32$$

Finisher Period

Complete replacement of SBM protein by CM protein in the diets of finisher pigs did not affect ($P>0.05$) any of the parameters studied (Table 3.14). Regression analyses of the results showed that for each percent addition of CM to the diets resulted in 2.3g decrease in ADF and 6g reduction in growth rate. The number of days taken to grow from 60 to 90 kg liveweight increased by 0.25 for every percent addition of CM to the diet.

Y(ADF) = 2.73 - 0.0023 (% CM) r = -.10

Y(ADG) = 0.939 - 0.006 (% CM) r = -.39

Y(ADT) = 32.24 + .253 (% CM) r = .36

Overall period (20 to 90 kg liveweight).

Canola meal supplementation of the [illegible] increased the number of days required by the pigs to re[illegible]n market weight (Table 3.14) and also reduced average daily gain ($P<0.05$). There was a decrease ($P<0.05$) in ADF as the level of CM in the diet increased. Feed conversion efficiency decreased when CM replaced 50 percent of the protein or more of the SBM protein supplement, but the differences were not significant.

A summary of the results of the carcass measurements is presented in Table 3.15. While there were no significant treatment differences in final weight, pigs fed the 100 percent CM supplemented diet had lower killing-out percent and lower carcass weights ($P>0.05$). There was a trend for total backfat (the sum of three measurements: shoulder, back, and loin) to decrease as the level of CM supplementation in the diets increased. Ham weight, area lean in ham, commercial grade index and ROP score showed no significant differences across treatments.

3.5.4 Discussion

Canola meal inclusion at any level from 4.9 percent to 19.6 percent of the diet of growing and finishing pigs did not significantly affect the feed intake. These results are

Table 3.14 The average performance of growing-finishing pigs fed diets supplemented with soybean meal(SBM) and canola meal(CM)

SBM/CM RATIO	100%SBM ---	75%SBM 25%M	50%SBM 50%CM	25% SBM 75% CM	100%CM	SE[1]	SIG[2]
Performance							
Grower period							
Level of CM in diet(%)	0.0	4.6	9.1	13.2	19.6		
Intial weight(kg)	20.5	20.8	20.8	20.7	20.8	0.14	
Final weight(kg)	61.5	61.4	61.1	60.5	60.4	0.21	
Days on test	53	55	55	56	58	0.70	*
Daily feed(kg)	1.86	1.83	1.80	1.79	1.79	0.03	NS
Daily gain(kg)	0.78	0.74	0.74	0.71	0.69	0.01	*
Feed:Gain	2.40	2.58	2.47	2.54	2.61	0.05	NS
Finisher period							
Level of CM in diet(%)	0.0	2.8	5.5	8.0	12.0		
Initial weight(kg)	61.9	61.6	61.3	60.8	60.8	0.25	
Final weight(kg)	92.4	91.6	91.5	91.1	90.6	0.47	
Days on test	34	33	35	37	38	0.98	NS
Daily feed intake(kg)	2.73	2.72	2.72	2.69	2.69	0.04	NS
Daily gain(kg)	0.90	0.91	0.88	0.85	0.83	0.02	NS
Feed:Gain	3.03	2.99	3.09	3.16	3.24	0.06	NS
Overall period							
Days on test	85	87	90	93	97	0.90	*
Daily feed(kg)	2.19	2.09	2.08	2.05	2.05	0.02	NS
Daily gain(kg)	0.85	0.81	0.78	0.76	0.73	0.01	*
Feed:Gain	2.59	2.58	2.65	2.72	2.84	0.03	NS

[1]Standard error of means
[2]*-Statistical significance at $p<0.05$; NS = nonsignificant ($p>0.05$)

Table 3.15 Effect of diets supplemented with soybean meal(SBM) and canola meal(CM) on carcass quality

SBM/CM RATIO	100%SBM ---	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	100%CM	SE[1]	Sig[4]
Final weight(kg)	92.6	91.8	92.1	91.5	91.0	1.1	NS
Carcass weight(kg)	71.3	68.3	70.4	69.7	68.2	1.2	NS
Dressing(%)	77.0	75.0	76.0	76.0	75.0	0.57	NS
Total backfat[2](cm)	8.6a	8.2ab	8.1ab	7.6b	7.7ab	.23	*
Loin eye area(cm²)	31.2a	28.6bc	29.9ab	27.0c	28.5ab	0.68	*
Ham weight(kg)	8.3	8.1	8.1	8.4	8.2	0.16	NS
Area Lean in ham(cm²)	120.6	127.2	121.7	120.0	127.5	3.56	NS
Grade index	102.9	102.7	102.5	103.0	101.6	0.72	NS
ROP score[3]	69.3	70.4	70.0	70.1	70.1	0.45	NS

[1]Standard error of means
[2]Measurement of three backfat depths (shoulder, midback, and loin).
[3]Predicted percent yield of trimmed cuts
[4]*-Statistical significance at $p<0.05$;NS=nonsignificant

consistent with those of other experiments (Bell, 1975; Castell, 1977; McKinnon and Bowland, 1977; Aherne and Lewis, 1978). The regression analyses of the results indicated that for every percent addition of CM to the diet of grower pigs fed isonitrogenous and isoenergetic diets, ADF and ADG decreased by 3.3 percent and 4.4 percent respectively. Pigs fed the CM supplemented diets, however, had lower growth rates and poorer FCE.

Petersen and Schulz (1978) observed that feed intake of pigs fed isonitrogenous but not isoenergetic diets increased with decreasing energy content, making the energy comsumption between treatments equal. The results of experiment two confirms this observation. Several studies have shown that all of the supplemental protein in growing pig diets can be provided by CM without significantly reducing performance (Omole and Bowland, 1974; Bowland, 1975; Bell et al. 1981). However, Aherne and Lewis (1978), and McKinnon and Bowland(1977) observed a significant reduction in feed intake when CM completely replaced SBM supplement in diets of growing pigs. The results of the current experiments also indicated that complete replacement of SBM protein by CM protein produced a reduction ($P<0.05$) in growth rates of the pigs. Bell et al, (1981) reported that poorer growth rate and FCE resulted as the CM level increased in the diets from zero to 15 percent. Kennelly et al, (1978) and Aherne and Lewis (1978) reported that growth rate and FCE may be significantly reduced when CM constitutes levels as low as 9 to 10 percent of the diets of growing pigs (20 to 60 kg). The present work suggests that 13 percent CM or more in the diets of growing pigs may significantly depress their growth rate.

Aherne and Lewis (1978) reported that CM could serve as a complete replacement for SBM in diets of finishing pigs. In the present study moderate depression ($P>0.05$) in ADF, ADG, and poorer FCE's were noted when CM totally replaced SBM in the diet of finishing hogs, but the effects were not significant.

Canola meal supplementation to diets of finishing pigs did not affect carcass measurements (McKinnon and Bowland, 1977; Aherne and Lewis, 1978). These observations agree with the results reported in this experiment where no significant differences were found in carcass weight, dressing percentage, ham weight, area of lean in ham, commercial grade index and ROP score. However, total backfat and loin eye area decreased ($P<0.05$) as the level of CM in the diet increased. Aherne et al.(1977) concluded that for finishing pigs (60 to 90 kg) CM can be used effectively to provide all of the supplemented protein without significantly reducing ADF, ADG, FCE or carcass quality of hogs.

The results of experiments reported herein indicate that CM protein can replace 75 percent (13 percent CM in the diet) of the SBM protein in the diets of growing pigs (20 to 60 kg liveweight) and total (12 percent CM in the diet) replacement in the diets of finishing pigs (60 to 90 kg liveweight) without affecting performance or carcass quality.

4. GENERAL SUMMARY AND CONCLUSIONS

The experiments reported herein indicated that canola meal (CM) as the only protein supplement in diets based on wheat and barley for starting, growing and finishing pigs resulted in reduced feed intake and pig performance compared with pigs fed soybean meal(SBM) supplemented diets. Generally feed conversion efficiencies (FCE) were not affected by the level of CM in the diet for all phases of pig growth.

Regression analyses of the results of 3wk-weaned pigs fed a 20% CP diet to 10kg liveweight indicated that for every percent addition of CM to the diet resulted in reduction in ADF and ADG of 1.9g and 1.3g respectively. However,there was no significant difference in performance when CM protein (16.8% CM in the diet) replaced 50% of the SBM protein. When the protein level of the diets was reduced to 18% CP and fed to the pigs from 10kg to 20kg liveweight, performance deteriorated when CM protein replaced more than 25 percent of the SBM protein. The results of the experiments in which pigs were fed from 6 to 20kg liveweight with CM supplemented diets containing 20% CP indicated that replacing 25% or more of SBM protein with CM protein resulted in a significant reduction in performance.

There was no advantage in feeding the pigs a 20% CP diet from 6 to 20kg liveweight over feeding them two levels of protein in the diet(20% CP from 6 to 10kg and 18% CP from 10 to 20kg liveweight). This confirms the recommendation by

NAS-NRC(1979) to feed two levels of protein to starting pigs. The performance of 3wk-weaned pigs fed CM supplemented diets to 10kg and 20kg liveweight, was better ($p>0.05$) than pigs weaned at five weeks and fed CM supplemented diets to 20kg liveweight. This observation may suggest that the young pig requires a period of time, after weaning, to adapt to its new environment before it exhibits complete acceptance to its new diet. Generally,the starter experiments indicated that CM can be included in the diets of starting pigs (6 to 20kg liveweight) at a level of 8 percent without affecting performance.

Although flavor additives did increase the feed intake of CM supplemented diets, the increase in feed intake decreased as CM level in the diets increased. The usage of the flavor additives increases the cost of the feed by 4 percent. The flavor additives did not improve the performance of pigs fed CM supplemented diets, compared with the SBM control with no flavor additives. Thus the relatively high cost of the flavored diets seem to indicate that not much benefit may be accrued from supplementing CM diets with flavor additives.

The grower experiments would indicate that CM can be included in the diets of growing pigs (20 to 60kg) at a level of 13 percent without affecting performance. The low digestible energy of CM compared with SBM increases the cost of CM diets due to the supplementation of CM diets with blended animal fat. The growth rate of growing pigs fed isoenergetic diets was similar to pigs fed diets not supplemented with blended animal fat. Apparent digestibility coefficients of dry matter, protein and energy in diets with CM supplementation was similar to SBM control diet. However, a trend towards lower digestibility coefficients with increase in CM in the diets was apparent. This trend could be due to the high fiber levels of the CM supplemented diets.

Complete replacement of SBM protein supplement by CM (12 percent CM) in the diets of finishing pigs (60 to 90kg liveweight) had no significant effect on performance. However, the number of days to attain market weight increased (P>0.05) with the level of CM in the diet. Average total backfat and loin eye area decreased with increase in CM in the diets. This observation may be attributed to the slower growth of pigs fed the CM supplemented diets.

These studies would suggest that the current recommended level of 12 percent CM in the diet of starter pigs (6 to 20kg liveweight) may be high. However, the optimum level of inclusion of 13 percent CM for grower pigs (20 to 60kg liveweight) and 12 percent CM for finisher pigs (60 to 90kg liveweight) does not negate the current recommended levels of 10 to 15 percent CM for grower and complete substitution for finisher pigs.

The feed intake and growth rate of the starter pig are suppressed when fed diets with increasing levels of CM, however, the FCE's are affected to a lesser extent. It seems that the problem of feed intake is not associated with bitterness per se but may be as a result of metabolic disorders due to the anti-nutritive factors in CM. Further studies could be performed to determine precisely what causes the low feed intake of canola meal supplemented diets and how to overcome those depressing effects.

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5. APPENDICES

Appendix 1. Amino Acid (AA) Composition of Protein Sources

Protein source	SBM[1]		CM	
	as fed	in protein	as fed	in protein
	%	%	%	%
Essential AA				
Arginine	3.01	6.51	2.20	6.26
Histidine	1.15	2.48	1.01	2.86
Isoleucine	1.85	4.00	1.47	4.16
Leucine	3.35	7.23	2.65	7.49
Lysine	2.84	6.12	2.18	6.16
Methionine	0.60	1.30	0.62	1.75
Phenylalanine	2.39	5.15	1.38	3.92
Threonine	1.70	3.68	1.67	4.73
Valine	2.06	4.45	1.45	4.11
Non-Essential AA				
Alanine	1.94	4.20	1.61	4.57
Aspartic Acid	5.43	11.72	2.89	8.18
Cystine	0.45	0.97	0.29	0.84
Glutamic Acid	7.96	17.18	6.71	18.96
Glycine	1.88	4.06	1.92	5.45
Proline	2.49	5.38	2.23	6.31
Serine	2.37	5.11	1.68	4.77
Tyrosine	1.26	2.72	0.90	2.55
AA Nitrogen Recovery[2]	86.48		[illegible]1.63	

[1] SBM - Soyaben Meal; CM - Canola Meal
[2] Nitrogen contained in AA expressed as a percentage of total nitrogen in diets

Appendix 2. Amino Acids (AA)[1] Analyses of Starter Diets and Amino Acid Requirements of 5-10 kg Pigs

Diets	100% SBM ----	75% SBM 25% CM	50% SBM 50% CM	25% SBM 75% CM	--- 100% CM	NAS-NRC (1979) Requirements
Essential AA (%)						
Arginine	1.26	1.26	1.26	1.17	1.18	0.25
Histidine	0.50	0.49	0.43	0.45	0.30	0.23
Isoleucine	0.86	0.81	0.87	0.80	0.79	0.63
Leucine	1.58	1.58	1.56	1.53	1.52	0.75
Lysine	1.25	1.25	1.24	1.24	1.24	0.95
Methionine	0.39	0.38	0.37	0.37	0.37	0.56[2]
Phenylalanine	1.04	0.99	1.04	0.94	0.89	0.88[3]
Threonine	0.80	0.74	0.77	0.77	0.78	0.56
Valine	1.02	0.97	0.99	1.07	1.05	0.63
Non-Essential AA						
Alanine	0.69	0.62	0.82	0.6[illegible]	0.99	
Aspartic Acid	1.80	1.83	1.79	1.65	1.71	
Cystine	0.20	0.21	0.22	0.22	0.22	
Glutamic Acid	4.39	4.39	4.38	4.29	4.27	
Glycine	0.96	0.96	0.93	0.99	0.92	
Proline	1.35	1.27	1.26	1.35	1.33	
Serine	1.13	1.07	1.10	1.02	1.02	
Tyrosine	0.53	0.47	0.48	0.49	0.51	
AA Nitrogen Recovery[4]	94.88	92.99	95.79	92.08	95.16	

[1]Estimated on dry matter basis
[2]Value of methionine and cystine
[3]Value of phenylalanine and tyrosine
[4]Nitrogen contained in AA expressed as a percentage of total nitrogen in diets

Appendix 3. Amino Acids (AA)[1] Analyses of Starter Diets and Amino Acid Requirements of 10-20 kg Pigs

Diets	100% SBM	75% SBM 25% CM	50% SBM 50% CM	25% SBM 75% CM	--- 100% CM	NAS-NRC (1979) Requirements
Essential AA (%)						
Arginine	1.03	1.04	1.04	0.98	1.01	0.23
Histidine	0.46	0.46	0.45	0.47	0.49	0.20
Isolencine	0.77	0.67	0.69	0.70	0.69	0.56
Leucine	1.52	1.46	1.46	1.46	1.44	0.68
Lysine	0.98	1.01	1.00	1.03	1.03	0.79
Methionine	0.36	0.34	0.37	0.35	0.38	0.51[2]
Phenylalanine	0.87	0.94	0.94	0.91	0.93	0.79[3]
Threonine	0.65	0.60	0.64	0.65	0.67	0.51
Valine	0.95	0.86	0.94	0.99	0.95	0.56
Non-Essential AA						
Alanine	0.61	0.60	0.68	0.57	0.61	
Aspartic Acid	1.72	1.70	1.66	1.54	1.59	
Cystine	0.31	0.22	0.25	0.20	0.24	
Glutamic Acid	4.08	3.96	3.92	4.01	1.36	
Glycine	0.91	0.91	0.90	0.95	0.94	
Proline	1.46	1.26	1.33	1.37	1.36	
Serine	0.96	0.97	0.94	0.92	0.98	
Tyrosine	0.48	0.57	0.57	0.50	0.48	
AA Nitrogen Recovery[4]	85.67	83.78	83.92	83.30	84.67	

[1]Estimated on dry matter basis
[2]Value of methionine and cystine
[3]Value of phenylalanine and tyrosine
[4]Nitrogen contained in AA expressed as a percentage of total nitrogen in diets

Appendix 4. Amino Acids (AA)[1] Analyses of Starter Diets and Amino Acid Requirements of 20-60 kg Pigs

Diets	100% SBM ----	75% SBM 25% CM	50% SBM 50% CM	25% SBM 75% CM	--- 100% CM	NAS-NRC (1979) Requirements
Essential AA (%)						
Arginine	0.87	0.82	0.76	0.77	0.80	0.20
Histidine	0.40	0.37	0.37	0.38	0.40	0.18
Isolencine	0.67	0.60	0.60	0.63	0.64	0.50
Leucine	1.20	1.11	1.10	0.64	1.17	0.60
Lysine	0.73	0.74	0.74	0.75	0.77	0.70
Methionine	0.27	0.25	0.28	0.26	0.25	0.45[2]
Phenylalanine	0.89	0.83	0.72	0.72	0.72	0.70[3]
Threonine	0.52	0.52	0.53	0.53	0.53	0.45
Valine	0.90	0.87	0.87	0.80	0.83	0.50
Non-Essential AA						
Alanine	0.67	0.62	0.62	0.63	0.64	
Aspartic Acid	1.72	1.70	1.66	1.54	1.59	
Cystine	0.31	0.22	0.25	0.20	0.24	
Glutamic Acid	4.08	3.96	3.92	4.01	1.36	
Glycine	0.91	0.91	0.90	0.95	0.94	
Proline	1.46	1.26	1.33	1.37	1.36	
Serine	0.96	0.97	0.94	0.92	0.98	
Tyrosine	0.48	0.57	0.57	0.50	0.48	
AA Nitrogen Recovery[4]	85.67	83.78	83.92	83.30	84.67	

[1]Estimated on dry matter basis
[2]Value of methionine and cystine
[3]Value of phenylalanine and tyrosine
[4]Nitrogen contained in AA expressed as a percentage of total nitrogen in diets

Appendix 5. Amino Acids (AA)[1] Analyses of Starter Diets and Amino Acid Requirements of 80-90 kg Pigs

Diets	100% SBM ----	75% SBM 25% CM	50% SBM 50% CM	25% SBM 75% CM	--- 100% CM	NAS-NRC (1979) Requirements
Essential AA (%)						
Arginine	0.81	0.64	0.58	0.48	0.57	0.18
Histidine	0.40	0.32	0.39	0.34	0.40	0.16
Isolencine	0.62	0.61	0.62	0.64	0.60	0.44
Leucine	1.17	1.15	1.16	1.20	1.15	0.52
Lysine	0.67	0.65	0.67	0.66	0.66	0.61
Methionine	0.22	0.21	0.21	0.25	0.23	0.40[2]
Phenylalanine	0.88	0.85	0.86	0.87	0.82	0.61[3]
Threonine	0.55	0.54	0.59	0.57	0.58	0.39
Valine	0.74	0.76	0.81	0.83	0.84	0.44
Non-Essential AA						
Alanine	0.73	0.71	0.71	0.72	0.71	
Aspartic Acid	1.33	1.25	1.26	1.28	1.14	
Cystine	0.18	0.16	0.19	0.15	0.15	
Glutamic Acid	4.04	3.92	4.05	4.01	3.92	
Glycine	0.70	0.71	0.75	0.76	0.77	
Proline	1.44	1.38	1.49	1.39	1.40	
Serine	0.78	0.75	0.79	0.79	0.76	
Tyrosine	0.35	0.34	0.32	0.35	0.31	
AA Nitrogen Recovery[4]	89.62	85.50	88.08	86.98	87.53	

[1] Estimated on dry matter basis
[2] Value of methionine and cystine
[3] Value of phenylalanine and tyrosine
[4] Nitrogen contained in AA expressed as a[illegible]ntage of total nitrogen in diets

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