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UTILIZATION OF WHOLE OR EXTRUDED CANOLA SEED BY SHEEP AND DAIRY CATTLE

by

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ABSTRACT

A total of four experiments were conducted to investigate the the potential utilization of (immature) Whole Canola Seed (WCS) by dairy cows.

Experiment 1, manuscript 1, involved 4 ram lambs in a Latin Square design feeding trial to determine the digestibility of WCS. 0, 7, 14 or 21% WCS replaced a basal oat ration. These rations were fed in each of four three week periods. Because of consumption difficulties in the first period a fifth period was conducted. A sixth period was executed in which all lambs received 4.7% Raw Canola Oil replacing an equal amount of the basal ration. The apparent digestibility of WCS was determined to be 77.5% for crude protein, 67.2% for ether extract, 70.1% for gross energy and 78.7% for dry matter.

Experiment 2, manuscript 1, involved 20 multiparous cows in a Lucas design experiment to determine if the WCS would be consumed by dairy cows and what effect the WCS would have on production parameters. Five treatment sequences were conducted, each of three weeks duration in four blocks. Diets treatments consisted of long hay fed at 2.0 Kg./cow/day, concentrate fed according to production at 1 kg of concentrate per day for every 2.0 Kg of milk for cows above 7.5 Kg of milk, and Ad libitum corn silage for blocks 1, 2 and 3 and Ad libitum fababean silage for block four, with either 0.0, 0.5, 1.0, 1.5 or 2.0 Kg of WCS top dressed daily in two equal feedings. The top dressing of WCS had a significant linear effect on dry matter intake (P.<0.01). WCS levels of 1.0 and 1.5 Kg./cow/day showed a trend for improved four percent Fat Corrected Milk yield (FCM) when cows in early lactation only were considered.

Experiment 1, manuscript 2, was a nylon bag trial to determine if WCS was degraded by the rumen bacteria. The WCS was determined to be a potential source of by-pass protein and energy based on the dry matter loss of 23.3% and a crude protein loss of 18.1% from nylon bags incubated in the rumen of a Jersey steer.

Experiment 2, manuscript 2, involved 37 cows blocked into a 3x2x2 factorial design. Three rations were employed to determine the effects of extruded or WCS on the productive parameters of dairy cows in early lactation. Extruded or WCS was incorporated into isonitrogenous rations to obtain 3.2% added fat in the total mixed rations. The experimental period was 12 weeks in duration. The mean (±SE) starting time for all cows was 8 ± 1 days post-calving. Milk production and feed intake were measured daily. Weekly milk samples were analyzed for fat, protein and lactose percents. Polynomial regression equations were fitted to the data and the production and intake profiles were analyzed for differences.

Cows consuming the Extruded Canola rations produced ($P=0.0523$) more milk, lower milk fat% ($p<0.05$) and more milk lactose ($P=0.0526$) than cows consuming the control ration. The control group consumed significantly ($P<.05$) less dry matter than the WCS or extruded rations. The WCS group produced more milk fat ($P.<0.05$) than the control group. Significant differences in the milk fatty acid composition were noted between the control, extruded and whole canola seed groups.

DEDICATION

To my wife, Susan, and my children, Aynsley and Brady. Without their support and understanding I would not have attempted this undertaking.

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INTRODUCTION

Rapeseed and cultivars that are low in glucosinolates and erucic acid (commonly such cultivars are referred to as "Canola" and are the major varieties grown) is the major oilseed crop grown in Canada (Jones 1979, Bell 1982).

This oil seed crop is a major source of income for Canadians as Canada is the leading producer and exporter of rapeseed according to Bell (1982). The oil is extracted from the seed and the remaining meal has become a major source of protein in the rations of cattle and to a lesser extent poultry and swine. An estimated 37% of the domestic usage of Canola meal was used in cattle rations, 33% in poultry diets and 28% in swine diets in 1979 (Bell 1982).

The use of rapeseed meal in the rations of dairy cattle has been extensively investigated and with the advent of Canola varieties the palatability and goitrogenic effects of rapeseed were decreased or eliminated. Bell (1982) reported on the frequency of research pertaining to whole rapeseed or its components for the period 1968 to 1979. The results of his review show the number of research studies on seed at 56, meal at 346, low fiber meal at 9, hulls at 8, gums and soapstocks at 12, flour and concentrate at 37 and oil at 103. These studies included all types of livestock, poultry and other animals. Of 200 research trials that were conducted between 1968 and 1979 only 16 (8%) were conducted with ruminants (Bell 1982).

The inclusion of various types of lipids in the rations of lactating dairy cows has recently received much attention by numerous researchers (Banks et al. 1980, Banks et al.1982, Chalupa et al. 1984, Jenkins and Palmquist 1984, Palmquist 1985, Palmquist and Conrad 1980, Smith et al. 1978, Storry 1981, Steele 1985, Wrenn et al. 1976). The primary reasons for including lipids in dairy rations are to increase the energy density of the ration, decrease the level of starch in the ration, and/or alter the composition of the fatty acid profile of the milk fat. Depending upon the type and level of lipid fed alterations in ration digestibility, milk and fat production and milk fat fatty acid composition have been noted (Banks et al. 1980, Kennelly 1983).

One of the primary reasons for including lipids in the rations of dairy cows in early lactation is to increase the energy density of the ration as these cows are most likely to be in a negative energy balance for the first 6 to 8 weeks of lactation. The use of grains at high levels (generally greater than 60% of the ration) provides high levels of starches that may lead to a low milk fat syndrome.

Whole unprocessed Canola seed has not been extensively researched as a potential source of lipid to high producing dairy cows. There is a general absence of literature regarding the utilization of the whole unprocessed seed by ruminants. It is not known whether the whole unprocessed seed is palatable to ruminants or if it is even digestible by ruminants.

Christensen et al. (1978) reported that protected rapeseed (cv Tower) significantly increased the amount of milk produced and the amount of milk per 100 kg of feed when compared to a low forage (35%) or a high forage (50%) ration, but was not differenet from a protected soy-tallow product. The amount of fat and the 4% Fat Corrected Milk (FCM) produced by the cows fed 8% protected Tower rapeseed was significantly more than all other treatments. Both forms of protected lipid increased blood cholesterol over the control levels with the protected rapeseed being significantly higher than the protected soy-tallow product. In a second experiment Candle rapeseed was added to the concentrate to supply a total of 5% and 8% ether extract in the ration. This was compared to a control ration with 2.2% ether extract and to a ration containing Tower rapeseed at a level adequate to supply 8% ether extract in the ration dry matter. There were no differences in production or in milk constituents.

It is the intent of this study to investigate the utilization of (Immature) Whole Canola Seed (WCS) and an Extruded WCS product by lactating dairy cows. The hypothesis assumes that

WCS can supply high levels of lipid and rumen nondegradeable protein to the small intestine of dairy cows in early lactation to aid in increasing the supply of nutrients necessary to maintain or increase milk production. The Extruded WCS product that was tested was included to compare the effects of WCS that had a greater ruminal available protein and fat than the unprocessed whole seed. In manuscript 1,experiments 1 and 2 were conducted to determine the digestibility of WCS for ruminants and to determine if the whole unprocessed Canola seed was acceptable to dairy cows, respectively. In manuscript 2, experiments 1 and 2 were conducted to determine the degree of ruminal protein and dry matter break down and production response of dairy cows in early lactation to whole unprocessed Canola seed or extruded Canola seed product, respectively.

LITERATURE REVIEW

Use of Whole Canola Seed in livestock and poultry rations.

Whole Canola seed has been used in swine rations to provide protein and energy to growing and finishing animals. Castell and Falk (1980) reported that levels of up to 15% rapeseed (cv Candle) did not affect performance of growing and finishing pigs but did improve the amount of daily gain achieved for every Kg of feed offered. The rapeseed caused alterations in the types of fatty acids found in the backfat of the pigs and generally increased the amount of unsaturated fatty acids (especially linoleic and linolenic).

Summers et al. (1982) reported that rapeseed has been fed to poultry with varying results. They state that there may have been a possible effect of erucic acid that caused a depression in growth and energy utilization while low erucic acid oils had no effect on perfomance. They conducted a series of trials to determine if the Canola seed (low in glucosinolates and erucic acid) could be used in broiler rations at levels of 17.5 and 35%. They concluded that in isonitogenous, isocaloric rations that were formulated to contain equivalent levels of lysine and methionine the Canola seed reduced weight gain and feed intake but the feed:gain ratios were similar to the corn-soy control rations. Apparent fat retention was lower for the Canola seed rations and they could not comment if this was specific to the Canola seed or to the dietary fat level. They comment that palatability of the Canola seed may have been involved in the reduced feed intake problem.

At the initiation of the experiments conducted and reported herein, no direct studies appeared in the literature that were conducted to establish digestibility values, effects on milk production or effects on milk constituents of the whole unprocessed Canola seed when fed to lactating dairy cows.

Christensen et al. (1978) had investigated the effects of Tower and Candle rapeseed in rations for dairy cows to provide 5% and 8% ether extract. The rapeseed cultivars were pelleted through a 0.48 cm die. There were no improvements in milk yield or in milk constituents when compared to the control ration (contained 2.2% ether extract). When the Tower rapeseed was protected with formaldehyde there was a significant improvement in milk yield over high and low forage control rations but not when compared to a soy-tallow protected product. The Tower rapeseed significantly improved the 4% FCM yield and fat yield over all treatments.

During these experiments one study reported that cows did not readily adjust to inclusion levels greater than 6% WCS in the total ration (Kennelly, 1983). At the 6% inclusion level there were no significant differences in dry matter intake, milk constituent or milk production. The stage of lactation was not mentioned in this report and may have been an important factor. The inclusion of graded levels of WCS improved the digestibility coefficients for dry matter, organic matter, crude protein and acid detergent fiber while that for lipid was unchanged or reduced.

Use of Canola meal in lactation rations for dairy cattle

Research with Canola meal in the rations of lactating dairy cattle has received substantially more emphasis than research with whole Canola seed. Canola meal is a by-product of the Canola oil industry and is an economical replacement for soybean meal in the rations of dairy cattle in Canada. Canola meal is derived from the processing of rapeseed cultivars, such as Tower and Candle, that are low in glucosinolates and erucic acid(Jones 1979, Bell 1982).

Bell (1982), in a review, tabulated the progress of rapeseed breeding and research with the various products and by-products of the rapeseed industry. His table of the various rapeseed cultivars developed since 1954 is shown as table 1 and can be referred to to chart the evolution of Canola seed (and meal).

Table 1. Canadian rapeseed development.*

Variety	Type	Year
Golden	Bn a	1954
Arlo	Bc b	1958
Nugget	Bn	1961
Tanka	Bn	1963
Echo	Bc	1964
Target	Bn	1966
Oro c	Bn	1968
Polar c	Bc	1969
Turret c	Bn	1970
Span c	Bc	1971
Zephyr c	Bn	1971
Torch c	Bc	1973
Midas c	Bn	1973
Tower cd	Bn	1974
Regent cd	Bn	1977
Candle cd	Bc	1977
Altex cd	Bn	1978
Andor cd	Bn	1981
Tobin cd	Bc	1981

a Brassica napus.
b Brassica campestis.
c Low erucic acid.
d Low glucosinolate.

* Taken from Bell, 1982.

Ingalls et al.(1968) conducted a series of experiments designed to compare the intake and production parameters of replacing soybean meal with rapeseed meal and or urea. Although there was no difference in production parameters the inclusion 12 and 13% rapeseed meal in place of soybean meal caused a significant reduction in dry matter intake of the grain concentrate. The researchers could not explain the reason for the depressed intake. When urea replaced part of the rapeseed meal in the ration there was no difference in intake from the 12% rapeseed meal ration. Both rapeseed meal rations and the soybean meal control ration supported higher concentrate intakes than the ration containing only urea as the source of supplemental protein.

Ingalls and Seale (1971) reported that rapeseed meal (cv Tanka) could support adequate intake and growth of heifers from birth through to the end of their first lactation. When 13.7% rapeseed meal replaced all the soybean meal in the ration of the heifers there was a tendency for lower milk yield but the effect was not significant. The replacement of one half of the supplemental soybean meal with rapeseed meal showed no differences from the soybean meal control.

Waldern (1973) reports that when rapeseed meal, comprising 11.8% of the total daily dry matter intake of lactating cows, was compared to a similar ration with soybean meal comprising 10.6% of the total daily dry matter intake, the digestibility of the total ration crude protein was lower for the cows fed the rapeseed meal. These cows produced less milk, 4% FCM, percent milk fat, protein and nonfat solids than the cows receiving the soybean meal ration ($P<0.05$). Although not mentioned this adverse affect of the rapeseed meal on production parameters may have been due to high levels of glucosinolates as the rapeseed was from a commercially available source.

Ingalls and Sharma (1975) compared the effect of Bronowski (low glucosinolate) rapeseed meal replacing commercial rapeseed meal (high glucosinolate). Compared to a soybean meal control ration the Bronowski rapeseed meal was consumed at the same level and supported the same level of production. When urea replaced 60% of the Bronowski meal protein the cows consumed significantly less grain mix and was not different than the commercial rapeseed meal in affecting intake. When Bronowski rapeseed meal was included in the ration at 10, 17 and 24% in replacement of soybeal meal there were no differences in ration intake or in production parameters. Digestibility of nutrients of these rations were compared. There were no differences in apparent digestibilities but numerically the Bronowski containing rations had higher digestibility coefficients and higher nitrogen retention than the soybean meal control ration. In a third trial the addition of molasses or feed flavor or pelleting did not improve the consumption of commercial rapeseed meal when compared to soybean meal control ration or to a ration containing Span rapeseed meal.

Sharma et al. (1977) found that dairy rations containing either commerical rapeseed meal or Canola meal (cv.Tower) at levels of 25% of the concentrate or 12.5% of the total rations were consumed as well as a soybean meal control ration. There were no observed differences in any of the production parameters, rumen metabolites, blood serum urea or serum thyroxine levels. The authors concluded that rapeseed meals of the Tower cultivar could be included in the rations of dairy cows at levels up to 12.5% of the total ration without affecting intake or production.

Papas et al.(1978) compared Tower and "1821" canola meals to a soybean-meal-containing control ration. When 1821 canola meal replaced all the soybean meal in the ration the cows gave significantly more milk than cows fed the control or Tower rations. Milk iodine levels were lower as a result of feeding the canola meal rations. Thiocyanate levels were increased by the canola rations, and the Tower canola meal produced higher levels than the 1821 variety. There were no differences in plasma thyroxine levels between rations.

Fisher and Ingalls (1981) reported that Canola meal is extensively used to supplement the protein requirements of all classes of cattle. These include growing calves, beef cattle, especially growing and finishing feedlot cattle and lactating dairy cows. They caution that Canola meal does have a higher fiber content than soybean meal and this may in some cases depress the ration digestibility. But when Canola meal is used in least cost ration formulations the problem of higher fiber levels can easily be overcome.

Satter and Roffler (1975) suggested that there is an upper effective limit to the amount of the soluble protein that can be used in rations fed to high producing cows to limit the level of ruminal ammonia to 5 mg/100ml of rumen fluid. From data provided by Ha and Kennelly (1983a) the amount of Canola meal that can be added to a barley based concentrate and fed in conjunction with alfalfa hay is about 6 to 7% of the total ration if this level of rumen ammonia is not to be exceeded. As graded levels of Canola meal were added to the ration the rumen ammonia concentration, blood urea and duodenal total nitrogen supply were increased. By adding Canola meal to provide dietary protein levels of greater than 14% the rumen ammonia concentration was elevated well above the 5 mg/100 ml level and there was no effect on intake or milk production over that observed when a 14% crude protein ration was fed (Canola meal comprised 12% of the concentrate). However, this experiment was a change over design and may not have been the best design to evaluate the effect of protein level on production. The ruminal ammonia concentrations would be reasonably indicative of what might have been expected in a non change over design experiment. The two week periods may not have left enough time between treatment sequences for the cows to respond to the different protein level, especially a higher protein level.

Laarveld and Christensen (1976) compared Span and "1788" (a Canola cultivar) rapeseed meals against a soybean meal control ration. Eight and one half percent rapeseed replaced 7.0% soybean meal in a pelleted concentrate that was fed in a 50:50 ratio with ground hay. The protein of the total rations were 14%. There were no differences in dry matter intake or production parameters. The cows comsuming the rapeseed meal treatments did have a significantly higher digestible energy intake than the soybean meal control. Digestibility of the dry matter, ether extract, crude fiber and energy were higher for the rapeseed meal rations than for the soybean meal ration. This was determined at maintenance intake levels using Hereford steers weighing about 240 kg. The high level of glucosinolates found in the Span rapeseed meal may have produced symptoms of hypothyroidism.

Fisher and Walsh (1976) conducted a trial comparing "1788" Canola meal at graded levels of 0, 11, 22 and 34% of the concentrate in replacement of soybean meal. The total replacement of soybean meal with 1788 rapeseed meal caused a reduction in the dry matter intake, milk yield, fat yield, protein yield, lactose yield and plasma thyroxine levels. Ration dry matter and nitrogen digestibilites were lower for the 34% rapeseed meal treatment. The experimental 1788 rapeseed was processed under similar conditions as commercial rapeseed meal but the level of ether extra was analyzed to be 11%. This oil contained 5.5% erucic acid and would not be considered as canola meal. This level of erucic acid may have caused the discrepancy between this trial and the one reported by Laarveld and Christensen (1976).

Sharma et al. (1977) compared commercial, Tower and 1788 rapeseed meals (at 25% of the concentrate) in partial replacement of soybean meal. The rations were consumed equally by cows in early lactation in a Lucas switch-back design. There were no differences in milk yield, 4% FCM yield or butterfat %. The 1788 rapeseed meal ration promoted a higher fat yield and lower milk protein % than the soybean meal and commercial rapeseed meal rations. The level of serum thyroxine was significantly lower than the soybean meal control ration but not different from the other rapeseed rations. In a second trial Tower rapeseed meal (at 25% of the concentrate) or Tower (at 15% of the concentrate) with urea were compared to a soybean meal control ration. The urea containing rations were either mixed into the concentrate or extruded prior to incorporation. There were no differences in intake or production parameters on any of the rations. The extruded Tower and urea ration showed a significant increase in the amount of nitrogen retained when compared to the other rations. Although the level of glucosinolates was not mentioned for the 1788 rapeseed, it was likely low as the palatibility of the ration and the production of the cows were good in contrast to the results of Fisher and Walsh (1976).

Laarveld et al. (1981a,b) investigated the effect of replacing soybean meal with Tower or Midas rapeseed meal at inclusion rates of 5.7, 13.2 and 18.9% of the ration. All rations were formulated to be isonitrogenous with protein balanced at 18.9%. Cows fed the Tower rapeseed meal had similar ration intakes and milk yields, fat%, protein% and solids-not-fat%. All Tower containing rations had lower crude protein and energy digestibilities than the soybean meal control ration. There were no differences in the ether extract or crude fiber digestibilities. Both rapeseed cultivars caused decreased levels of milk iodine and increased amounts of unsaturated nitrile and thiocynate when compared to the control ration. The nitrile and thiocynate levels in the milk of cows fed the Tower rations were lower than when Midas rations were fed. When thyrotropin-releasing hormone was used to evaluate the goitrogenic potential of the Tower rapeseed meal it was found that there was no difference when compared to the soybean meal control ration. The cows fed the Midas rations (13.2% and 18.9%) showed a significant response to thyrotropin releasing hormone.

Laarveld et al (1981c) evaluated the effect of increasing the concentration of dietary iodine in rations containing 20% Tower rapeseed meal in the concentrate with 1.2, 2.2, 3.3 and 4.5 mg/kg of iodine. The dietary iodine concentration was fed for three weeks and then elevated to the next higher level. The pre-trial ration (containing 6% Tower in the concentrate) had higher levels of milk iodine (42 ug/100ml) than the rations containing higher levels of Tower rapeseed meal. When dietary iodine concentration was elevated from 1.2 or 2.2 mg/kg the iodine concentration in the milk increased from 9.2 or 11.1 ug/100ml to 14.5 and 18.7 ug/100ml for the rations containing 3.3 or 4.5 mg/kg iodine respectively.

Sanchez and Claypool (1983) compared a commercial blend of Candle and Tower canola meal against cottonseed meal and soybean meal as the sources of supplemental protein in the rations of dairy cows in early lactation. They found no differences in the yield of milk, 4% FCM, fat or protein, or percent butterfat and protein. The cows consuming the canola meal ration ate more feed than cows fed the other two rations. Also cows offered the canola meal ration produced more milk solids not fat and tended to produce more milk and 4% FCM (prob.= .12 and .103, respectively) than cows fed the other rations. There was no effect of canola meal in the ration on the thyroxine level of the cows and the authors concluded that canola meal could adequately supplement the protein requirements of lactating cows.

DePeters and Bath (1985) compared Canola meal versus Cottonseed meal as the only protein supplements of rations for first calf and mature cows. They found no differences in dry matter intake, milk yield or constituent, VFA's or ruminal ammonia concentration or in dry matter or protein dissappearance of the meals from nylon bags. They conclude that Canola meal can replace Cottonseed meal on an equivalent protein basis in the rations of high producing cows in early lactation.

Added lipid to ruminant rations

Banks et al.(1982) reviewed the literature on the amount and types of fat that could be incorporated into rations of lactating cows. When unsaturated and polyunsaturated fats are incorporated into the ration there may be an overloading of the biohydrogenation system which can affect the amount of volatile fatty acids (VFA's) produced and could lead to a low butter fat percent.

Banks et al.(1982) state that when cows received a basal ration that provided 80 g per cow per day of natural dietary fat they noted a significant response in milk yield to added dietary fat. Yet when the basal ration,of similar composition, provided 110 g per cow per day of natural dietary fat there was no response to added dietary fat. The level of production in these cows was about 15 kg/day and may have had a bearing upon the response to added fat in the ration.They recommend that an upper level of about 450 g of added fat, per cow per day, will in most cases be the level at which increases in milk yield and/or fat yield may be seen.

Orskov et al.(1980), Palmquist and Conrad (1980), Palmquist and Jenkins (1980) andPalmquist (1985) comment upon the detrimental effect of unprotected lipid on ruminal fiber digestion. The lipid when fed at a rate of about one pound per cow per day or more decreases the digestibility of the fiber, possibly due to a coating effect. It is believed that the lipid interfers with the microbial population of the rumen and primarily inhibits the population that is most directly involved in fiber digestion and it is postutated that this may be due to a toxic effect of fat upon certain microbial populations. The lipid may be attracted to the microbial cell wall and in some way inhibits cellobiosis. A final effect may be a reduced cation availability from the formation of long chain fatty acid soaps. It is not known if this effect is direct or indirect through a decrease in the rumen pH.

Storry (1981) states that added dietary fat may reduce fiber digestion in the rumen and that there may be a reduction in the milk butter fat percentage. He suggests that these detrimental effects may be reduced or eliminated by supplying the added dietary fat as unextracted seed or in a form that protects the fat from rumen fermentation.

Effects of added lipid on rumen digestion.

When lipid that is high in unsaturated and polyunsaturated fatty acids, such as soya oil, is fed in an unprotected form to dairy cows the lipid undergoes biohydrogenation by the ruminal microbes (Kemp and Lander 1983, Kemp at al. 1984a,b). This biohydrogenation process alters the potential amount of unsaturated or polyunsaturated fatty acids that could be incorporated into the milk fat. When polyunsaturated fatty acids are fed to ruminants the hydrogenation of these fatty acids is accomplished by many different rumen bacteria. Linoleic acid can be hydrogenated to stearic acid as well as its precursors, cis octadeconoic acids and trans-11-octadeconoic acid. This is accomplished by Group A bacteria. Recent work by Kemp and Lander (1984) shows that for complete hydrogenation of linoleic acid to stearic acid two groups of bacteria (Group A and B bacteria) must be present. The Group A bacteria hydrogenate the linoleic acid to trans-11-octadeconoic acid and the Group B bacteria then hydrogenate this end product to stearic acid.

Chalupa et al. (1984) investigated the effects of long chain fatty acids in various forms upon In Vitro VFA production and the ratio of acetate to propionate. They concluded that long chain fatty acids of 14 and 16 carbon atoms and unsaturated long chain fatty acids of 18 carbon atoms decreased VFA production. The melting point of the long chain fatty acids accounted for 93 to 95% of the variation of the VFA production and the acetate to propionate ratio. Calcium soaps of long chain fatty acids had little effect upon the fermentation and this was also noticed with triglycerides. Free tallow fatty acids at 10, 15 or 20% of the test feed dry matter caused increases in propionate, decreases in acetate, butyrate and total VFA production. These effects were not evident when the same acids were incorporated as calcium soaps, and the effects were only minimal when the acids were incorporated as triglycerides.

In contrast, the In Vivo fermentation of long-chain fatty acids with a high melting point (stearic acid, m.p.=69 degrees C) and calcium soaps of long-chain fatty acids decreased the acetate:propionate ration (20%) relative to the control ration. But oleic acid or tallow decreased the acetate:propionate ratio by 50-60% (Chalupa et al. 1986). The authors conclude that long-chain fatty acids or calcium soaps of long-chain fatty acids can protect the rumen microbes from deleterious effects of added fat in the ration.

Jenkins and Palmquist (1984) found similar results to those of Chalupa et al.(1984) when free tallow or soy fatty acids as free oil or calcium soaps were fed to lactating cows. The tallow fatty acids reduced total fiber digestion and rumen fiber and dry matter digestion. The calcium soaps of long chain fatty acids prevented these effects but the digestibility of the fatty acids was reduced by 6%. They conclude that calcium soaps of fatty acids are an effective source of fat for dairy cow rations.

When soya oil, tallow or a palm oil/palmitic acid mixture were fed at 10% of the dairy concentrate to Ayrshire heifers the soya oil ration had no effect on milk fat percent where as the other lipid sources both increased milk fat percent Banks et al. (1980). When compared to the control the palm oil/palmitic acid mixture significantly decreased the solids-not-fat of the milk. The amount of unsaturated fatty acids added to the ration was also reflected in the amount of long-chain fatty acids found in the milk fat. This evidence of incorporation of dietary fat into milk fat can be used to alter the fatty acid composition of the milk fat by the type of dietary fat supplied to the cow.

Alterations of fatty acid composition were noted by other researchers and it is now accepted that the fatty acid composition of the milk fat can be altered by the manipulation of the dietary fat, the amount of dietary fat and the degree of unsaturation of the fat (Wrenn et al. 1975, Smith et al, 1978, MacLeod et al, 1978, Sharma et al, 1978, Clapperton and Steele 1983, Storry et al. 1974, Storry 1981).

Steele (1985) investigated the effects of free oil addition versus the addition of intracellular oil (crushed soybeans) at two levels. The intracellular fat addition at high levels maintained milk fat yield and percent over the addition of free oil at the same level. Both oil types cause significant reductions in dry matter and energy intake and in milk yield (except for the high level soy oil addition). Steele states that in rations containing free oil the concentration of the oil, not the amount of oil, is the primary determinant in the reduction of the milk fat percent. The detrimental effect of the fats in reducing total energy intake were more apparent with the free oil rations. The detrimental effect may be due to a physical effect of the fat preventing the microbes from accessing other dietary constituents (coating) or the fat may exert a bactericidal effect causing changes in the bacterial populations. Czerkawski et al. (1975) found increased bacteria numbers and decreased protozoan numbers when linseed oil was added to the ration of sheep.

Jentsch et al.(1972) fed rape-seed oil at amounts of 700 to 1420 g per cow per day to dairy cows in various stages of lactation. They concluded that feeding rape seed oil caused a decrease in milk yield and milk fat production and that the energy requirement per kg of milk produced was increased. They also noted an increase in the amount of proprionic acid and a decrease in the amount of butyric acid found in the rumen fluid.

The use of oil seeds in lactation rations.

The use of whole seeds that are high in fat has received much attention. Whole cotton seed is one of the most effective sources of added fat as a whole seed (DePeters et al. 1985, Bernard and Amos 1985, Anderson et al. 1979, Anderson et al. 1984). The whole cotton seed repeatedly increases fat%, 4% FCM and in most instances milk yield. When compared to sunflower seeds or extruded soybeans the cotton seed was the most desirable source of fat when all factors were taken into account (Anderson et al. 1984).

Whole sunflower seeds have also been investigated as potential sources of fat (Anderson et al. 1984, Drackley et al. 1985, Finn et al. 1985,). Whole sunflower seeds are not effective in increasing milk yield, milk fat or 4% FCM yield. When limestone was added to rations containing whole sunflower seeds improvements in production parameters were noted over rations containing whole sunflower seeds. But the improvement was not attributable to the formation of calcium soaps of long chain fatty acids.

White (1985) found that whole sunflower seeds improved the milk fat percentage and milk fat yield when compared to a control ration containing 3.1% sunflower oil and a positive control containing 3.1% sunflower oil and 1% sodium bicarbonate. The added sodium bicarbonate resulted in a non-significant trend towards improved fat percent and milk fat yield.

Kennelly (1983) reports a trial in which cows were fed graded levels of WCS (unextracted ground seed) at 6, 12 and 18% of the concentrate. The 18% WCS level resulted in significantly less milk and dry matter intake. All WCS treatments produced significantly less 4% Fat Corrected Milk. Dry matter, organic matter, crude protein and acid detergent fiber digestibilities were significantly higher for the WCS treatments than for the control treatment. The cows receiving the 18% and to some extent the 12% WCS treatments suffered from diarrhea when first introduced to the WCS treatment.

Handy and Kennelly (1983) compared the use of WCS, ground Canola seed and "Protec" to a control ration. The test ingredients were incorporated into the concentrate at 6% or 3.6% of the total ration. There were no significant differences in dry matter intake, milk yield or milk component yield. The fatty acid profile of the milk fat from cows fed the WCS more closely resembled that of the control ration than the ground Canola seed or the "Protec" ration. "Protec" is a protein-lipid source treated with formaldehyde to reduce the rumen degradation of the product. The "Protec" product is produced commercially in Barrhead Alberta by Alta Lipids.

Macleod et al. (1985) reported that a 50:50 mixture of Canola meal and Canola seed had lower dry matter, nitrogen and acid detergent fiber digetibilities than the Canola meal control ration. These effects were similar when the miture or the meal were treated with sodium hydroxide or blood to protect the protein from ruminal degradation. The digestibility studies were conducted on calves. It appears that the combination of Canola meal and seed had lower digestibilities due to a lower digestibility of the Canola seed itself but the authors do not comment upon this. It was not stated whether the Canola seed was processed in any manner.

GENERAL MATERIALS AND METHODS

RATION COLLECTION AND ANALYSIS -MANUSCRIPT 1

Experiment 1 involved four Dorset x Line M ram lambs in a Latin square type digestibility study. Line M line was developed at the University of Manitoba from foundation stock consisting of Devon Closewool (43%), Oxford (30%), Southdown (9%), Shropshire (8%), Minnesota 100 (6%) and Suffolk (4%) breeds. The lambs were group fed the basal oats ration (Table 4) and the daily intakes were recorded for one week. WCS was then introduced at a level of 2% and increased at a rate of 2% every second day until the lambs reached 90% of their initial intake of the basal ration. The level of WCS inclusion that was reached in this manner was 24%, but by visual inspection of the orts there appeared to be an increase in the concentration of WCS. Therefore the inclusion rates of 0, 7, 14 and 21% WCS in replacement of the basal rations were utilized.

The lambs were weighed on day 1 of each period. During the experimental period the lambs were individually housed in 1.5 by 3.7 m pens for the first 11 days of the ration acclimation period. On day 12, at 8 A.M. the lambs were placed in collection crates. On day 13 of the first collection period 16 ml polyethelene collection tubes were glued to the lambs at a distance of approximately 10 cm around the rectum.

These collection tubes were left in place for the duration of the experiment and reglued as required. On day 14 of each period, at 8 A.M., the tubes were tied off at about 25 cm from the rectum. The feces were collected for seven consecutive days at 8:00 A.M. The succeeding period began, after the final fecal collection, with the lambs being weighed, placed in the individual pens and placed on the next experimantal ration.

During the fecal collection period a daily 5.0%, by weight, sub-sample was dried at 60 C for at least 48 h or until there was no further weight loss. The seven sub-samples were then pooled for proximate analysis. The remaining fecal samples were frozen at -20 C until all samples had been collected. Upon completion of the collection period the fecal samples for each animal were thawed, pooled, mixed for 20 min in a Hobart mixer and a composite sample was obtained for drying and proximate analysis. The pooled sub-sample served as the duplicate for the proximate analysis.

During the 14 day adjustment period the Ad Lib. feed intake of the lambs was monitored. During the collection period the lambs were offered the 21% WCS ration at an estimated 2X maintainence level or at 90% Ad Lib. whichever was lower. The remaining rations were fed at the same percent of live body weight as the 21% WCS ration was calculated to be fed at. The daily feed allotment was weighed into air-tight plastic bags at the beginning of each collection period and a sample of the ration was collected for proximate analysis. Daily total orts were collected, dried at 60 C for at least 48 h or until there was no further weight loss. The seven orts samples were then pooled, mixed and ground through a 1 mm screen in a Willie Mill and analysed for 100% dry matter, crude protein, acid detergent fibre, ether extract and gross energy (A.O.A.C. 1980). The same analysis was performed on the fecal and ration samples. The analysis was performed in duplicate on the ration and orts samples.

Experiment 2 involved the use of 20 multi-parous dairy cows in a Lucas design experiment (Lucas, 1955). The standard milking grain ration was fed in two equal daily allotments based on 1 kg of grain ration for every 2 kg of milk above 7.5 kg of milk. The cows received 2 kg of alfalfa hay in one daily A.M. feeding and Ad Lib. corn silage (periods 1, 2 and 3) or faba bean silage (period 4) in two daily feedings. WCS was top-dressed at 0.0, 0.5, 1.0, 1.5 and 2.0 kg per cow in two equal daily feedings. When the cows were fed the faba bean silage the standard grain ration was adjusted to supply the same daily estimated nutrient intake as when the cows were consuming the corn silage ration. One cow in the 4th period was removed from the experiment as she had apparently slipped in her stall and was suffering from the effects of near strangulation. This experiment was initiated in the fall of 1981, prior to my commencing graduate studies. The stage of lactation for these cows varied from over 200 days in lactation to 60 days in lactation.

RATION COLLECTION AND ANALYSIS -MANUSCRIPT 2

A 454 kg Jersey steer was used in experiment 1 to determine the approximate ruminal dry matter and protein digestibilities of the WCS and to estimate the most desirable extrusion temperature for the extruded Canola product using nylon bags incubated in the rumen. The steer was approximateley 5 years old and had been fistulated and fitted with a 10 cm (i.d.) diameter canula.

A mixture of 70% whole Canola seed and 30% rolled barley , by weight, was extruded at various temperatures in a Brady farm P.T.O. type extruder. The grain mixture was extruded at 82, 94, 104, 107, 110, and 113 degrees C.

Prior to initiating the nylon bag experiment various methods of nylon bag attachment had been attempted. When fish line was used to anchor the bags through the canula the bags became entangled and several bags came loose from their mooring. All the bags had to be evacuated at the same time and any bags that required longer incubation had to be re-introduced into the rumen. This proceedure was time consuming and could affect the subsequent dry matter and protein degradation in the rumen. Attaching the bags to a 2 x

2 x 15 cm stick solved some of the tangling problems.

Duplicate 5 g samples of the extruded WCS products and WCS were incubated in the rumen with duplicate empty control bags. The empty control bags were used to adjust for any inherent error in the incubation proceedure. The length of the incubation periods were 1, 2, 4, 6, 8, 10, 12, and 24 h. The incubation bags were constructed of a 50 micron nylon mesh and were approximately 10 cm by 25 cm with a rounded bottom and tied at the top. They were modified from the design of Kempton (1980) in the following manner; the bags had a 0.5 cm split-ring sewn into the top corner opposite the draw string. The bags were then attched by nylon cord to a chain snap which in turn was attched to a metal loop that was welded to a 1.0 kg metal weight. The metal weight and loops were dipped in "Plastisol" and completely coated to prevent rusting and any potential mechanical damage to the rumen. All sharp corners on the weight had been rounded. This weight and attachment method greatly aided in placement and removal of the nylon bags. The weight was anchored in the rumen by a nylon cord that extended through the canula and was kept in place by the canula cap.

Experiment 2 involved 19 multi-parous cows and 18 first calf heifers. They were used in a 3x2x2 factorial arrangement over a 12 week period. The three factors were: 1) 3 treatments of a completely mixed ration;(control), extruded Canola seed treatment (extruded), and a whole Canola seed treatment (WCS); 2) 2 levels of a B-carotene top-dressing B1; no carotene, B2 treatment level of B-carotene (providing 200 - 1000 mg B-carotene/cow/day); 3) 2 levels of a dewormer treatment; T1, no dewormer (Tramisol) and T2, one injection of 0.044 ml/kg body weight of Tramisol at parturition.

Four weeks prior to the expected calving date cows were fed 2 year old hay low in B-carotene and their respective B1 and B2 top dresses. The concentrate portion of the rations were introduced to the cows about 2 weeks prior to parturition and were increased slowly to provide 3 to 5 kg of concentrate at parturition. Post-parturition, faba bean silage was then introduced to the cows (separately) while they were still in the calving pen. Cows were moved to stalls after at least one full day post-parturition in the calving pen. The completely mixed rations (Table 13) were introduced 2 - 3 days post-parturition and data collection commenced 4 - 10 days post parturition. The mean (± SE) for all cows on the ration treatments was 8 ± 1 days post-parturition. Rations were fed Ad Lib. and were adjusted daily to provide approximately 10% orts. Daily milk yield and ration intakes were recorded for the 12 week period. All cows were weighed on two consecutive days prior to commencing the ration treatments, once at 4 weeks and at 8 weeks into the treatment period, and on two consecutive days immediately prior to finishing the treatment period. At 6 weeks all cows were sampled via eosophageal tube at three times relative to feeding (time=0, 2 and 4 h post-feeding). The rumen fluid collected was inactivated by placing it into a bottle containing mercuric oxide upon returning to the lab the pH was recorded and the sample was centrifuged at 10,000xg for 10 min and the supernatant stored at -20 degrees C until all samples had been collected and could be analyzed for VFA's and ammonia.

Milk samples were collected on two consecutive days (morning and evening samples from each day were composited, based on average relative A.M.(60%) and P.M.(40%) yield) and analyzed for fat, protein, and lactose percents. Prior to analysis, an aliquot of milk was removed and stored at -20 degrees C, for analysis of milk iodine levels and for the fatty acid profiles of the milk fat. A weekly sample of the hay, faba bean silage and the concentrates were taken as well as a weekly sample of each cow's orts. These samples were dried in a forced air oven at 60 degrees C for 48 h and the moisture percent was recorded. Samples were stored at room temperature until they were analyzed for protein, fat (ether extract), acid detergent fiber, gross energy and 100% dry matter.

The data was analyzed for differences following the procedure of Allen (1983). To summarize this procedure; the data was arranged as a 3x2x2 factorial split over time (weekly periods). From this, regression co-efficients were obtained and the resulting profiles were analyzed for significant differences. The bulk of the data is displayed as graphs, which were produced from the regression equations.

Three cows that had started the experiment were replaced by other cows of near the same age and previous lactation milk yields after the experiment was initiated. Two of the cows were receiving the extruded ration and one cow was receiving the WCS ration. All cows that were taken off the experiment were suffering from ketosis and were off feed. They had all calved in late July or early August and the heat during this time period may have affected their performance. Animals that were already receiving the experimental rations also appeared to have depressed appetities. One heifer that was scheduled to receive the extruded ration aborted while on spring pasture and was replaced. Due to the number of animals that could not be used throughout the experiment we prepared a total of six additional cows and heifers to start the experiment. They were fed the appropriate forage and grain mix prior to calving. One animal was not used and another animal was started on the control ration when that cow should have received the extruded ration. The data collected from this animal was used in the analysis of variance and therefore the total number of cows used in this experiment was 37 not the original 36.

Manuscript 1.

Digestibility of Whole Canola Seed by Sheep and Acceptibility and Production Responses of Lactating Dairy Cows When fed Top-Dressed Whole Canola Seed.

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Abstract.

In experiment 1 four ram lambs having an initial weight of 16.7 kg were used to determine the apparant digestibility of whole Canola seed (WCS) in a Latin Square design experiment. Four levels of WCS (0, 7, 14, and 21%) were included in a basal oats ration. Four periods each lasting three weeks were employed. The lambs were placed in digestibility crates for the final ten days of each period and total fecal collections were obtained on the final seven days of each period. Due to sorting of the WCS, a fifth period was employed to obtain additional data. The digestibility of WCS for dry matter, crude protein, ether extract, and gross energy were 78.7 ± 33.8, 77.5 ± 17.2, 67.2 ± 17.6, and 70.1 ± 35.6 (% ± SE).

In experiment 2, 20 multiparous Holstein cows were used in a Lucas design experiment with five treatment sequences of three weeks duration in each of four blocks. The rations were: long hay fed at 2.0 kg/cow/day, concentrate fed according to production (1 kg of concentrate for every 2.0 kg of milk above 7.5 kg of milk produced), and Ad Lib. silage (blocks 1, 2 and 3 received corn silage and block 4 recieved faba bean silage). Treatment levels of WCS were top dressed at 0.0, 0.5, 1.0, 1.5 or 2.0 kg/cow/day split over two equal feedings. The top dressing of WCS significantly increased dry matter intake ($P < 0.01$). Four percent fat corrected milk yield showed a non significant tendency towards improved

production at treatment levels of 1.0 and 1.5 kg of top dressed WCS.

Introduction.

WCS is western Canada's fourth leading crop in terms of acreage seeded and tonnes produced. It is Canada's most important oilseed crop. WCS has the potential to serve as a source of energy and protein for dairy cows due to its high lipid and protein content (41.3% lipid, Biely and Daun, 1980 and 25.1% crude protein as determined by this experiment). Due to the crop's sensitivity to frost there is an ever present danger of substantial amounts of the crop being damaged by an early frost. This damaged seed could serve as a potential feed source for dairy cows. Frost damaged WCS was obtained for these experiments as it was felt that this type of seed would be the source of seed most available to the livestock industry.

When the literature was reviewed there were no reported experiments where the apparent digestibility of whole Full Fat Canola seed in its unprocessed state was determined for ruminants.

Gorrill et al.(1976) state that the low erucic acid, low glucosinolate rapeseed (cv Tower) when used to replace 50% of the protein in the milk replacer did not significantly affect nitrogen, dry matter or gross energy digestibilities by the preruminant lambs when compared to a Tower protein concentrate. The Canola seed was dehulled, heated at 60 degrees C and water-extracted and then milled twice through a 0.04mm screen and spray-dried. The authors further stated that when full-fat rapeseed was incorporated into lamb milk replacers it resulted in reduced milk replacer digestibility and poorer animal performance when compared to the Tower protein concentrate or the meal.

Seoane et al. (1976) compared full-fat rapeseed (cv Tower) in a colloid milled form or dehulled, boiled in water for 2 min, leached in 20 degee C water twice for 30 min each and dried at 60 degrees C for 2 h. Inclusion of either form of rapeseed to replace 25 or 50% of the protein in the lamb milk replacer resulted in significantly poorer apparent digestibilities of dry matter, nitrogen and gross energy and poorer nitrogen retention when compared to the control milk replacer. The researchers commented that the poorer nutritive value of the unmilled rapeseed appeared to be due to a physical rather than a chemical protection of the rapeseed particles. This physical property seemed to protect the particles from enzymatic action in the gastrointestinal tract.

Christensen et al. (1978) reported that protected rapeseed (cv Tower) significantly increased the amount of milk produced and the amount of milk per 100 kg of feed. This product was compared to a protected soy-tallow product and significant differences were found between the two products when 4% fat corrected milk (FCM) yield was compared. The protected rapeseed gave more 4% FCM than the protected soy-tallow ration. In a second experiment Candle rapeseed (added at rates to supply 5.0 and 8.0 % ether extract in the ration) and Tower rapeseed (added at a rate to supply 8.0% ether extract in the ration) did not significantly alter milk production or milk constituents. The rapeseeds were added to the concentrate which was then pelleted through a 0.48 cm die, crushing the rapeseed.

There were no significant differences in dry matter intake. (Christensen et al. 1978). But the cows fed the Candle rapeseed treatment supplying 8.0% ether extract consumed on average 0.9 kg less than the control cows. In contrast, when the protected rapeseed product was fed the intake was 0.9 kg/day higher than what was consumed by the cows fed the control ration. But the differences were not significantly different. Various researchers have reported similar intake patterns where free lipid in the ration would result in a lower intake, Steele (1985), Van Horn (1984), Clapperton and Steele (1985), Jenkins and Palmquist (1984) and a protected lipid would increase the intake (this includes whole seed that were not processed, such as whole cottonseed), Horner et al. (1986), DePeters et al.(1987), Fisher (1979), Anderson (1979). Although in most of the examples there were no significant differences there are numerous reports in the literature that indicate this general tendancy.

These experiments were designed to determine the apparent digestibility of whole unprocessed full-fat Canola seed by ruminating sheep and to determine if this seed would be readily consumed as a top dress by lactating dairy cows. The effect of WCS on milk yield and milk constituent when fed as a top dress is of interest as WCS has the potential to serve as an excellent source of protein and energy.

Material and Methods.

In experiment 1 four Dorset x Line M ram lambs were used ina Latin square type digestibility study. Mean initial weight of the lambs was 16.7 kg. Line M was developed at the University of Manitoba from foundation stock consisting of Devon Closewool (43%), Oxford (30%), Southdown (9%), Shropshire (8%), Minnesota 100 (6%), and Suffolk (4%) breeds. The lambs were group-fed a basal oats ration (Table 2) and daily intakes were recorded for one week. WCS was then introduced at 2% of the daily ration and increased at a rate of 2% every second day. This continued until the consumption of the ration decreased to 90% of the initial intake of the basal ration. The 90% intake level was used assuming that 1 kg of WCS would supply as much protein and energy as 2 kg of the basal ration. The level of WCS that was reached by 90% Ad

Lib. intake was 24%. Visual inspection of the orts indicated some increase in the concentration of WCS. The inclusion rates of 0, 7, 14 and 21% WCS in replacement of the basal ration were established as there was no indication of decreased appetite at the 22% WCS inclusion.

The lambs were weighed on day 1 of each period. During the experimental period the lambs were individually housed in 1.5 by 3.6 m pens for the first 11 days of the ration acclimation period. On day 12, at 8 A.M. the lambs were placed in collection crates. On day 13 of the first collection period 16 ml polyethelene collection tubes were glued to the lambs at a distance of approximately 10 cm around the rectum. These collection tubes were left in place for the duration of the experiment and reglued as required. On day 14 of each period the tubes were tied off at about 15 cm from the distal opening at 8 A.M. and the feces were collected each successive day at 8 A.M., for a total of seven consecutive days. On day 1 of the following period, after the final fecal collection for the preceeding period, the lambs were weighed and individually penned and placed on the next experimental ration.

Table 2: Composition of Basal Oat Ration and Whole Canola Seed Rations Fed to Ram Lambs in the Digestibility Study

	Ration			
	0% WCS+ (kg)	7% WCS (kg)	14% WCS (kg)	21% WCS (kg)
Basal Ration	100.0	93.0	86.0	79.0
Whole Canola Seed	-----	7.0	14.0	21.0
Total	100.0	100.0	100.0	100.0

+ The 0% WCS ration consisted of 96.4% oats, 2.0% molasses, 1.0% limestone, 0.5% salt and 0.1% trace mineral premix that provided 70.0 g of ZnO, 40.0 g of MnO, 200g of $FeSO_4.7H_2O$, 1 g of E.D.D.I. and 0.5 g of $CoCO_3$ per tonne.

During the fecal collection period a daily 5.0%, by weight, sub-sample was taken to be dried at 60 C for at least 48 h or until there was no further weight loss. The seven sub-samples were then pooled for proximate analysis. The remaining fecal samples were frozen at -20 C until all samples had been collected. Upon completion of the collection period the fecal samples for each animal were thawed, pooled, mixed for 20 min in a Hubler mixer and a composite sample was obtained for drying and proximate analysis. The pooled 5.0% sub-sample served as the duplicate for the proximate analysis.

During the 14 day adjustment period the Ad Lib. feed intake of the lambs was monitored. During the collection period the lambs were offered the 21% WCS ration at an estimated two times maintainence level or at 90% Ad Lib. (Ad. Lib. was established during each adjustment period) whichever was lower. The remaining rations were fed at the same percent of live body weight as the 21% WCS ration. The daily feed allotment was weighed into air-tight plastic bags at the beginning of each collection period and a sample of the ration was collected for proximate analysis. Daily total orts were collected, dried at 60 C for at least 48 h or until there was no further weight loss. The seven orts samples were then pooled, mixed and,where appropriate sub-sampled, ground through a 1 mm screen in a Willie Mill and analysed for dry matter, crude protein, acid detergent fibre, ether extract and gross energy (A.O.A.C., 1980). The same analyses were performed on the fecal and ration samples. Analyses were performed in duplicate.

A fifth ration was tested in a seperate period to contrast the effect of the digestibility of the WCS. This ration was the basal ration with 4.7% crude Canola oil added to bring the level of added lipid equivalent to the analyzed level found in the 14% WCS test ration. All the ram lambs were fed this ration during the sixth period with the criterion being the same as the digestibility trial.

The data were analyzed using the General Linear Model (GLM) proceedure of SAS (1982). Treatment means were generated and separated for significant effects using Duncan's Multiple Range Test (Snedecor and Cochran, 1980).

In experiment 2,20 multiparous Holstein cows were randomly assigned within a block to one of five treatments of top dressed WCS. The treatments were 0.0, 0.5, 1.0, 1.5, and 2.0 kg of top dressed WCS/cow/day split over two equal feedings. The WCS was top dressed on top of the dairy concentrate. The dairy concentrate was fed in equal AM and PM feedings at a rate of 1 kg concentrate for every 2 kg of milk produced above 7.5 kg. Corn silage was fed Ad Lib. in AM and PM feedings and was adjusted daily to give at least 5% orts the next morning. Due to the length of the trial the fourth block received faba bean silage as corn silage was no longer available. Alfalfa hay was fed at a rate of 2.0 kg/cow/day to all cows prior to the PM milking. All feedings were weighed and the orts were weighed each AM and a pooled orts sample was collected weekly and dried to adjust for the dry matter intake. Weekly samples of the WCS, silage and hay were collected, dried at 60 degrees C for 48 h ,ground through a 1 mm Wiley mill and analyzed for crude protein, gross energy, acid detergent fibre, ether extract and moisture according to A.O.A.C.(1980).

The experimental period within each block was three weeks in duration, the first two weeks were used to equilibrate the cows to the new treatment and the last week was used to collect the data. The data collected was daily milk yield and daily feed intake. On the last two days of each sample period a pooled AM and PM milk sample was collected and analyzed for fat, protein and lactose percentages by infra red spectroscopy (Milkoscan Model 203, Fosselectric, Cornwall, Ont.). Four percent fat corrected milk yield was calculated using the equation 4%FCM=0.4 x MY + 15(MY x fat%/100), where MY is milk yield.

Analysis of the data was performed using the general linear model proceedure (GLM) of the statistical analysis system (SAS, 1982). Least squares means were generated and comparisons were made by the orthogonal polynomials (Snedecor and Cochran, 1980).

Results.

Experiment 1.

The proximate analysis of the added oil ration and the four test rations are given in table 3. The apparent digestibility of the WCS was 77.5 ± 17.2% for crude protein, 67.2 ± 17.6% for ether extract, 70.1 ± 35.6% for gross energy and 78.7 ± 33.8% for dry matter. Tables 4 and 5 give the ration digestibilities for the Latin square and for the five periods. Lambs were adept at sorting the WCS from the rolled oat basal ration which was most evident when the 7% WCS treatment was being fed. Due to the large standard errors for the digestibility means the percent WCS that was actually consumed was calculated. The difference between the ration offered and the orts collected was calculated using the analysis for crude protein, ether extract and gross energy and then averaging the results for each calculation to achieve the actual percent of WCS consumed. Only determinations where the calculated WCS intake was greater than 4% of the total dry matter intake were used to calculate the digestibility of the WCS. The digestibility for each component of WCS investigated was calculated using the equation (Lloyd et al., 1978):

$$\text{Digestibility co-efficient of test ration component} = \frac{\text{Digestibility of basal ration component} - \text{Digestibility of test ration component}}{\text{percent inclussion of test material}}$$

As can be seen in figure 1, the effect of sorting had a large effect upon the apparent digestibility determination of the WCS. This is primarily due to the fact that the standard error of the proximate analysis determination was the main source of error in the calculation and at low levels of WCS intake would contribute over 50% of the variation found in the calculated digestibility. At levels of intake above 10% of the ration this effect becomes less significant and more confidence can be placed in the results. The digestibility of the WCS components is given in table 5 and as shown by the large standard error of the means the effect of low levels of WCS intake had a profound effect on the confidence of the experiment. However, when the mean digestibility of a component is compared to the mean of that component when the WCS intake was greater than 10%, there was little difference and this gave confidence to the apparent mean digestibilities determined for the WCS at levels of intake between 4 and 20% of the basal ration.

Table 3: Proximate Analysis of The Basal and Test Rations Fed to Ram Lambs in the Determination of the Digestibility of Whole Canola Seed. Values are on a 100% Dry Matter Basis.

Ration	Crude Protein (%)	Ether Extract (%)	A.D.F. (%)	Gross Energy (Kcal./kg)
Basal	11.3	5.7	14.8	4578
7%WCS	12.2	8.2	14.2	4715
14%WCS	13.1	10.0	13.9	4835
21%WCS	13.9	11.8	14.3	4955
Added Oil (4.7%)	10.6	10.1	15.3	4840

TABLE 4: Apparent Digestibilities of the Basal and Test Rations When Fed to Ram Lambs in the Latin Square Design Trial.

Digestibilities (%)	Ration Basal	7%WCS	14%WCS	21%WCS	SE*
Dry Matter	64.8	68.7	70.7	67.2	2.4
Crude Protein	71.1	70.5	72.3	88.6	2.1
Ether Extract	88.8	88.6	87.1	87.0	2.4
Acid Detergent Fiber	-5.4	12.8	15.6	12.8	7.9
Gross Energy	64.1	67.2	68.8	65.4	2.4

* standard error.

TABLE 5: Apparent Digestibilities of the Basal and Test Rations Fed to Ram Lambs in the Extended Latin Square (five periods) Trial.

Digestibilities (%)	Ration				
	Basal	7%WCS	14%WCS	21%WCS	SE*
Dry Matter	64.8	69.7	68.7	67.5	2.4
Crude Protein	71.6	71.9	71.5	72.3	2.0
Ether Extract	88.9	88.9	86.5	87.0	1.2
Acid Detergent Fiber	-5.4	14.6	9.7	12.8	7.3
Gross Energy	64.0	67.8	66.6	65.8	2.4

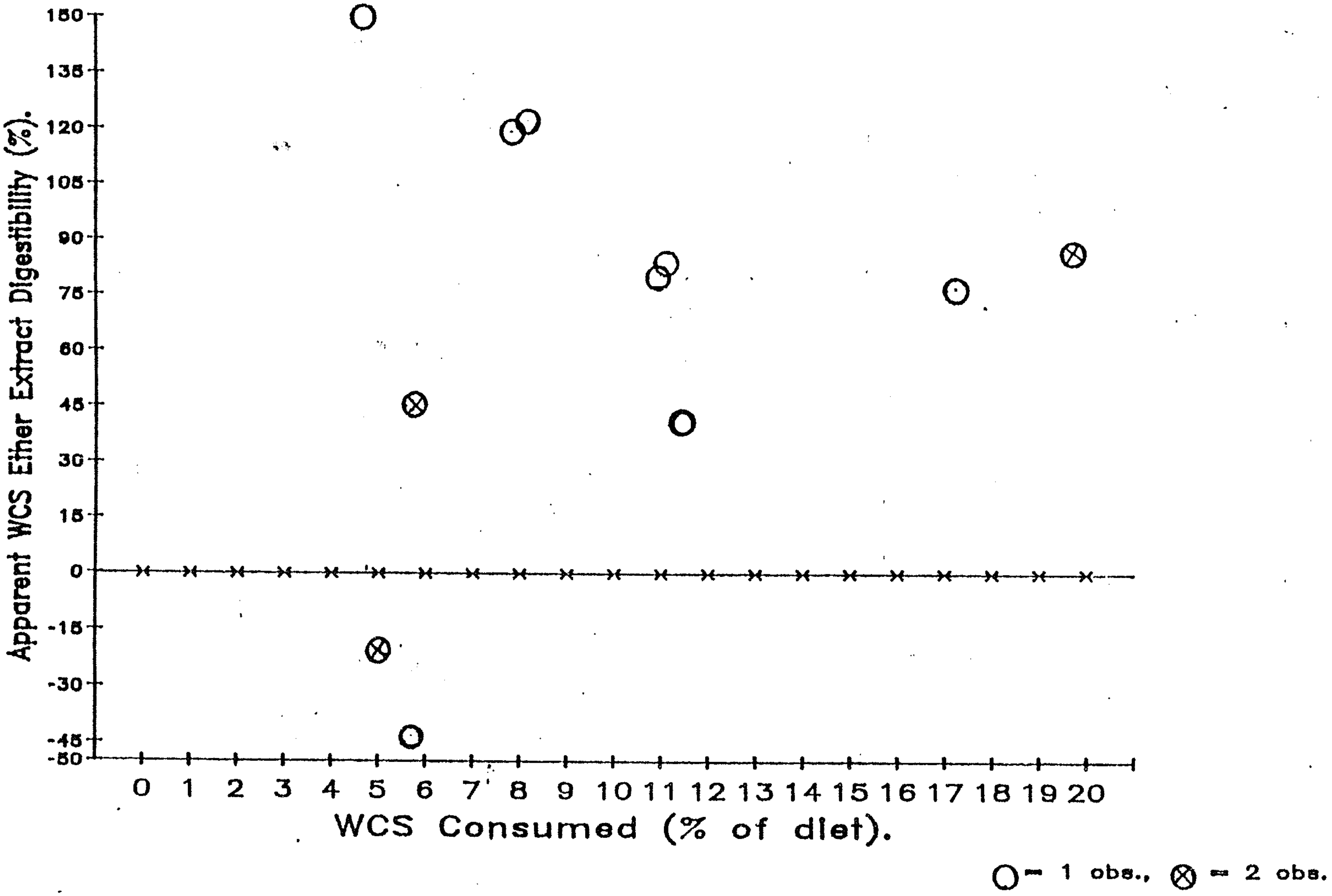
* standard error.

TABLE 6: Digestibility of the Basal Plus Added Oil Ration. (Digestibility of the 14% WCS Ration is Shown for Comparison.)

Digestibilities (%)	Ration		
	14%WCS	Added Oil	SE*
Dry Matter	68.7	69.1	1.1
Crude Protein	71.5	74.6	1.2
Ether Extract	86.5	91.3	0.7
Acid Detergent Fiber	9.7	24.3	3.7
Gross Energy	66.6	68.3	1.0

* standard error (added oil ration only).

Figure 1: Graph of Whole Canola Seed Ether Extract Digestibility by Ram Lambs.



The desired level of added oil was confirmed by ether extract analysis and by the gross energy determination. When compared to the 14% WCS ration the digestibility of the ration with added oil was numerically higher and the standard error of the mean was approximately one half of that for the 14% WCS ration (table 6).

Experiment 2.

The cows consumed the WCS treatments with no apparent refusals.

The analysis of the standard dairy concentrate, corn and fababean silages, alfalfa hay and WCS are given in Table 7. The WCS appeared to increase ($P<0.01$) daily dry matter intake (Table 8). There was no significant effect ($P>0.05$) of top dressing with WCS on milk yield and 4% FCM and on milk composition (Tables 9 and 10 respectively).

TABLE 7: Proximate Analysis of Ration Componets Fed to Dairy Cows to Determine the Effect of Top Dressing Whole Canola Seed at Various Levels. Values Given on a 100% Dry Matter Basis.

Ingredient	Crude Protein (%)	Ether Extract (%)	Acid Detergent Fibre(%)	Gross Energy (Kcal./kg)
Standard Concentrate	21.0	6.0	11.0	4503
Alfalfa Hay	20.3	2.1	35.1	4526
Corn Silage	7.7	2.5	31.8	4339
Fababean Silage	17.7	1.8	37.8	4377
WCS	25.1	36.1	17.2	6433

TABLE 8: Influence of Top Dressed Whole Canola Seed on Dry Matter and Forage Intake of Dairy Cows.

Treatments (WSC kg/day)	Total Intake (kg/day)	Forage Intake (kg/day)	Forage Intake as % of total intake.(%)
0.0	20.0	8.2	41
0.5	21.0	9.1	44
1.0	21.7	9.1	42
1.5	22.6	9.4	42
2.0	22.5	8.9	39
SE*	0.4	0.5	2.0
Orthogonal Polynomials.			
Linear	**	N/S	N/S

* standard error.
** Prob <0.01
N/S not significant

TABLE 9: Effect of Top Dressed Whole Canola Seed on Milk Yield and 4% Fat Corrected Milk Yield.

Treatments (WCS kg/day)	Milk Yield (kg/day)	4% FCM Yield (kg/day)
0.0	27.9	25.4
0.5	28.5	25.4
1.0	28.0	26.0
1.5	28.2	26.1
2.0	28.1	25.2
SE*	0.7	0.9

* standard error.

TABLE 10: Effect of Top Dressed Whole Canola Seed on Milk Constituents of Dairy Cows.

Treatments (WCS kg/day)	Fat (%)	Protein (%)	Lactose (%)
0.0	3.5	3.1	4.6
0.5	3.4	3.0	4.8
1.0	3.7	3.1	4.5
1.5	3.6	3.1	4.6
2.0	3.3	3.0	4.7
SE*	0.2	0.1	0.1

* standard error.

Discussion.

Experiment 1.

A smaller standard error was expected in the digestibility of the added oil ration as there was no period effect involved in the digestibility determination of the ration. There appeared to be no detrimental effect of added oil upon acid detergent fibre digestibility. In fact fiber digestibility was enhanced by the added oil, from a determined average of -5.4% in the basal ration to a level of 24.3% in the added oil ration. One of the observed effects of added oil to the ration of cows can be a decreased fiber digestibility (Palmquist, 1983).

The digestibility of the added oil ration compares well with the digestibility of cottonseed oil found by Shell et al. (1978) in a ground alfalfa and steam processed milo ration. The digestibility of rapeseed oil containing rations as detemined by Jentsch et al. (1972) also compares well with these results. This indicates that the free oil itself is probably not the primary reason for the poorer ether extract digestibility of the WCS. As Seoane et al. (1976) commented it may be that the Canola seed offers a physical protection from enzymatic digestion.

This experiment showed that WCS was digested by sheep when included at graded levels in a basal oats ration. The sheep were able to sort out some of the WCS and therefore the actual percent WCS consumed was generally less than the amount included in the basal ration. Many of the determinations of the apparent digestibilities of the WCS components were conducted at inclusion levels of 4 to 10% and the standard error of the proximate analysis would contribute up to 50% of the standard error of the determination of digestibility. The mean determined digestibility of WCS at inclusion levels greater than 10% was in close agreement with the overall mean and this gives a greater measure of reliability to the observed apparent digestibilities.

Using the apparent digestibilities of the milk replacers reported by Seoane at al. (1976) the apparent digestibility of the rapeseed can be calculated. Using the reported values the mean calculated apparent digestibility of the rapeseed was 36.6% for the dry matter, 18.2% for the nitrogen and 45.5% for the gross energy. The present experiment suggests that WCS is digested to a greater extent by ruminating lambs than by pre-ruminant lambs used by Seoane et al. (1976).

Sharma et al. (1986) determined that the apparent digestibilities of complete calf starter rations containing 12 or 18% WCS were depressed when compared to the control ration. The crude protein, dry matter ether extract and energy digestiblities at 7 weeks of age were all significantly lower in the WCS rations than the control rations but at 15 weeks of age only the crude protein and energy digestibilities were depressed in calves fed the 12% WCS ration. This may have been due to a depression in the amount of crude protein present in the 12% WCS ration, 15.0% compared to 16.2% in the control ration. Ha and Kennelly (1983) showed that urea and canola meal increased microbial nitrogen flow from the rumen when compared to soybean meal and dehydrated alfalfa. This would indicate either an increase in rumen microbial numbers or a faster growth rate which in turn would increase proteolysis and deamination, resulting in a higher ruminal ammonia concentration. The WCS is very slowly degraded in the rumen (Manuscript 2, Experiment 1) and would not significantly contibute protein for the microbial requirements and the microbial population could have been limited by a lack of available free amino acids or peptides. If this were the case then the higher digestibility of the 18% WCS ration diet could be explained by the increase in the amount of protein provided (15.5%).

Experiment 2.

There appeared to be a numeric improvment in the 4% FCM yield when 1.0 and 1.5 kg/day of WCS was top dressed to cows in early lactation (blocks 3 and 4). This was due to improvements in both milk yield and fat% over the control cows. Cow weight was not monitored during this trial and weight gain may have had a significant effect upon the lack of response to the additional energy supplied by the WCS treatments, especially to cows in mid to late lactation.

The effect of additional lipid and/or energy at various stages of lactation was not taken into account in this experiment. Banks et al.(1982) and Storrey (1981) state that due to the higher levels of circulating growth hormone in early lactation as compared to mid and late lactation added lipid will be most efficiently used to support milk and fat production in early lactation. In the first and second block the cows were all in mid to late lactation at the start of the experiment, whereas in the third and fourth blocks the cows were all in early lactation (<100 days post-partum at the start of the first period). The raw data would suggest that the cows in the third and fourth blocks responded more to the WCS treatments than the cows in the first and second blocks when milk yield and 4% FCM yield were considered.

These findings would also be supported by Yang et al. (1978) who found that with long term supplementation of fat the lactation length of the cows was decreased. In this experiment the length of time that fat was supplemented in the ration would not be more than 9 weeks but for cows in mid to late lactation this may be long enough to cause metabolic changes. These may be due to increased lipid deposition and a decrease in lactation length.

One cow in the third period of the fourth block was found in her stall suffering from near strangulation. She had apparently slipped during the night and could not move to relieve the pressure of the stall's head gate on her windpipe. The cow could not be replaced and because of this there was no data collected in the third period for this cow.

Because of the missing data the GLM procedure was employed to analyze the data and to generate the least squares means. This proceedure allows the analysis of experiments based on the Lucas design but can also analyze this type of experiment when there is missing data, which is not easily determined using Lucas's approach.

The WCS when fed as a top dress on the standard dairy concentrate was consumed without refusal by the cows. The WCS significantly increased the dry matter intake of the cows. The results of this experiment warrant further research into the use of WCS in the rations of high producing dairy cows in early lactation to maintain or increase milk yield and/or milk component yield.

Manuscript 2.

Rumen Degradation of Canola Seed and Extruded Canola Seed and Utilization of Whole Canola Seed and an Extruded Canola Seed Product by Dairy Cows in Early Lactation.

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Abstract.

In experiment 1 a 454 kg rumen canulated Jersey steer was used to determine the ruminal dry matter and protein losses of Whole Canola Seed (WCS) and a mixture of 70% WCS and 30% barley, extruded at various temperatures,from nylon bags incubated in the rumen over various time periods. The WCS had significantly lower dry matter and protein losses than the extruded WCS products at the same incubation times ($P< 0.05$).

In the second experiment,37 cows in a 3x2x2 factorial arrangement were used to assess the influence of Whole or Extruded canola seed on intake and production parameters. The cows consuming the WCS and extruded rations ate more than the cows on the control ration ($P<0.05$). Only the cows on the WCS consumed more as a percent of body weight than the control group ($P<0.05$). There was a trend for the cows consuming the extruded ration to produce more milk and milk lactose (g/day) than the control group ($P=0.0523$) and ($P=0.0526$) respectively. The cows fed the extruded ration produced milk with a lower fat percent than the control group ($P<0.05$). The cows fed the WCS had a higher percent of fat than the control group ($P<0.05$).

Introduction.

The method of incubating nylon bags in the rumen of canulated animals can be successfully used to estimate the potential degradability of feedstuffs in the rumen (Kempton 1980, Orskov et al.1980). This method gives reasonably accurate measurements of rumen degradability and has the added feature of being a relatively quick and simple method.

The use of rapeseed meal that was high in glucosinolates and in erucic acid in the diets of lactating cows resulted in decreased dry matter intake, goiterogenic effects and in some cases poorer milk production. Although many researchers found no significant differences when rapeseed meal replaced all or part of the control soybean meal there was a consistent trend throughout the literature indicating a lower production from cows fed rapeseed diets (Waldern 1973, Ingalls and Seale 1971, Ingalls et al. 1968, Ingalls and Sharma 1975, Fisher and Walsh 1976, Wittenberg 1982).

With the genetic improvement that plant breeders have made over the years the Rapeseed cultivars now available are low in erucic acid and glucosinolates. These Rapeseed cultivars are better known as Canola. The effects of the erucic acid and glucosinolates are no longer evident. Many trials have shown that Canola meal can be effectively used to replace soybean meal and other protein sources in the diets of cows and calves (Sharma et al. 1977, Claypool et al. 1985, DePeters and Bath 1986, Wheeler et al. 1980, Sanchez and Claypool 1983, Laarveld and Christensen 1976).

Research with Canola meal in the diets of lactating dairy cattle has received substantially more emphasis than research with whole Canola seed. Canola meal is a by-product of the Canola oil industry and is an economical replacement for soybean meal in the rations of dairy cattle in Canada. Canola meal is derived from the processing of rapeseed cultivars, such as Tower, that are low in glucosinolates and erucic acid.

Satter and Roffler (1975) suggested that there is an upper effective limit to the amount of readily degradable protein that can be used in diets fed to high producing cows to limit the level of ruminal ammonia to 5 mg/100ml of rumen fluid. Other studies suggest maximum microbial protein synthesis at 34 mg/100 ml (Kellaway and Liebholz,1980) and maximum cellulose digestion at 43 mg/100 ml (Hoover,1986) of rumen ammonia. From data provided by Ha and Kennelly (1983b)the amount of Canola meal that can be added to a barley based concentrate and fed in conjunction with alfalfa hay is about 6 to 7% of the total ration based on the data by Satter and Roffler (1975). The addition of graded levels of Canola meal to the ration resulted in a linear increase in the concentration of rumen ammonia.

The inclusion of various types of lipids in the rations of lactating dairy cows has recently received much attention by numerous researchers (Banks et al. 1980, Banks et al. 1982, Chalupa et. al. 1984, Jenkins and Palmquist 1984, Palmquist and Conrad 1980, Smith et al. 1978, Storry 1981, Steele 1985, Wrenn et al. 1975). The primary reasons for including lipids in dairy rations are to increase the energy density of the ration, decrease the level of starch in the ration, and alter the amount and composition of the milk fat. The type and level of lipid fed have causedalterations in ration digestibility, milk and fat production and milk fat fatty acid composition have been noted (Banks et al. 1980, Kennelly 1983).

Banks et al.(1982) reviewed the literature on the amount and types of fat that could be incorporated into diets of lactating cows. When unsaturated and polyunsaturated fats are incorporated into the diet there may be an overloading of the biohydrogenation system which can affect the amount of volatile fatty acids (VFA's) produced and could lead to a low butter fat percent.

Chalupa et al. (1984) investigated the effects of long chain fatty acids in various forms upon In Vitro VFA production and the ratio of acetate to propionate. The authors concluded that long chain fatty acids of less than 18 carbon atoms and unsaturated long chain fatty acids of 18 carbon atoms decreased VFA production. The melting point of the long chain fatty acids accounted for 93 to 95% of the variation of the VFA production and the acetate to propionate ratio. Calcium salts of long chain fatty acids had little effect upon the fermentation and this was also noticed with triglycerides. Free tallow fatty acids at 10, 15 or 20% of the test feed dry matter caused increases in propionate, decreases in acetate, butyrate and total VFA production. These effects were not evident when the same acids were incorporated as calcium soaps, and the effects were only minimal when the acids were incorporated as triglycerides.

Jenkins and Palmquist (1984) found similar results to those of Chalupa et al.(1984) when the effects of free tallow or soy fatty acids as free oil or calcium soaps were fed to lactating cows. The tallow fatty acids reduced total fiber digestion and rumen fiber and dry matter digestion. The calcium soaps of these fatty acids prevented these effects but the digestibility of the fatty acids was reduced by 6%. They conclude that calcium soaps of fatty acids are an effective source of fat for dairy cow rations.

Orskov et al.(1980) and Palmquist and Conrad (1980) comment upon the detrimental effect of unprotected lipid on ruminal fiber digestion. The lipid when fed at a rate of about one pound per cow per day or more decreases the digestibility of the fiber, possibly due to a coating effect. It is believed that the lipid interfers with the microbial population of the rumen and primarily inhibits the population that is most directly involved in fiber digestion and it is posutated that this may be due to a toxic effect of fat upon certain microbial populations. The lipid may be attracted to the microbial cell wall and in some way inhibits cellobiosis. A final effect may be a reduced cation availability from the formation of long chain fatty acid soaps. It is not known if this effect is direct or indirect through a decrease in the rumen pH.

Steele (1985) investigated the effects of free oil addition versus the addition of intracellular oil (crushed soybeans) at two levels. The intracellular fat addition at high levels maintained milk fat yield and percent over the addition of free oil at the same level. Both oil types cause significant reductions in dry matter and energy intake and in milk yield (except for the high level soy oil addition). Steele states that in rations containing free oil, the concentration of the oil and not the amount of oil is the primary determinant in the reduction of the milk fat percent. The detrimental effect of the fats in reducing total energy intake were more apparent with the free oil diets. The detrimental effect may be due to a physical effect of the fat preventing the microbes from accessing other dietary constituents (coating) or the fat may exert a bactericidal effect causing changes in the bacterial populations.

Jentsch et al.(1972) fed rape seed oil at amounts of 700 to 1420 grams per cow per day to dairy cows in various stages of lactation. They concluded that feeding rape seed oil caused a decrease in milk yield and milk fat production and that the energy requirement per kg of milk produced was increased. They also noted an increase in the amount of proprionic acid and a decrease in the amount of butyric acid found in the rumen fluid.

The use of whole seeds that are high in fat has recieved much attention. Whole cotton seed is one of the most effective sources of added fat as a whole seed (DePeters et al. 1985, Bernard and Amos 1985, Anderson et al. 1979, Anderson et al. 1984). The whole cotton seed has consitently increased fat percent, 4% FCM and in most instances milk yield. When compared to sunflower seeds or extruded soybeans the cotton seed was the most desirable source of fat when all factors were taken into account (Anderson et al. 1984).

Whole sunflower seeds have also been investigated as potential sources of fat (Anderson et al. 1984, Finn et al. 1985, White 1985). Whole sunflower seeds are not effective in increasing milk yield, milk fat or 4% FCM yield. When limestone or sodium bicarbonate were added to rations containing whole sunflower seeds improvements in production parameters were noted over rations containing whole sunflower seeds.

Kennelly (1983) reports a trial in which cows were fed ground,unextracted WCS at 6, 12 and 18% of the concentrate. The 18% WCS level resulted in significantly less milk and dry matter intake. All WCS treatments produced significantly less 4% Fat Corrected Milk. Dry matter, organic matter, crude protein and acid detergent fibre digestibilities were significantly higher for the WCS treatments than for the control treatment. The cows receiving the 18% and to some extent the 12% WCS treatments suffered from diarrhea when first introduced to the WCS treatment.

Handy and Kennelly (1983) compared the use of WCS, ground Canola seed and "Protec" to a control ration. The test ingredients were incorporated into the concentrate at 6 or 3.6% of the total diet. There were no significant differences in dry matter intake, milk yield or milk component yield. The fatty acid profile of the milk fat from cows fed the WCS more closely resembled that of the control diet than the ground Canola seed or the "Protec" diet. "Protec" is a protein-lipid source treated with formaldehyde to reduce the rumen degradation of the product. The "Protec" product is produced commercially in Barrhead, Alberta, by Alta Lipids.

The object of these studies was to investigate the utilization of immature and extruded WCS by lactating dairy cows. The hypothesis assumes that WCS can supply high levels of lipid and rumen nondegradeable protein to the small intestine of dairy cows in early lactation to aid in increasing the supply of nutrients necessary to maintain or increase milk production. The extruded WCS product was tested by nylon bag methodology to determine the differences that extrusion temperature may have had upon protein and dry matter losss compared to the raw WCS. The WCS extruded at 107 C was used to compare the effects of WCS that had a greater ruminal available protein and fat.

MATERIALS AND METHODS

One rumen canulated Jersey steer was used in experiment 1 to incubate nylon bags in the rumen. The steer weighed 454 kg and was approximately 5 years old. The bags employed were constructed as described by Kempton (1980). The nylon used had a 52 ± 7 micron pore size. Duplicate 5 gram samples of the feedstuffs were incubated for periods of 1, 2, 4, 8, 12 and 24 h . All bags were removed at the end of each time period. Duplicate empty bags were incubated with the bags containing the feedstuffs to correct for any inherent error in protein or dry matter losses while in the rumen.

The extruded WCS product was a mixture of 70% WCS and 30% ground barley extruded in a farm type Brady P.T.O. extruder at 82, 94, 104, 107, 110 and 113 degrees Celcius. Visual observation as the product was being extruded showed that at the 113 C temperature some oil loss was occuring. The protein content of the WCS and the Extruded Canola seed product is shown in table 11.

All incubation periods started at 8:00 A.M., immediately prior to the once per day feeding of the steer. The diet was a brome grass alfalfa hay mixture fed free choice and 2.5 kg of the standard milking cow ration used at the University of Manitoba (see manuscript, experiment 2, table 7).

Table 11: Crude Protein of the WCS and Extruded Canola Products Incubated in Nylon Bags in the Rumen of a Mature Steer.

	WCS	82 C	94 C	104 C	107 C	110 C	113 C
Crude Protein (%)	24.5	22.0	22.0	22.0	21.6	21.6	21.6

The data were analyzed by the General Linear Model procedure (GLM) using SAS (1982). Treatment means for each incubation were separated using Duncan's multiple range test (Snedecor and Cochran, 1980).

Experiment 2 involved thirty-seven Holstein-Fresian cows. Nineteen multi-parous and eighteen first calf heifers were used in a 3x2x2 factorial arrangement over twelve weekly periods. The three factors were: 1) 3 treatments of a completely mixed ration; A control ration (control), B an extruded Canola seed treatment (extruded),and C WCS. ; 2) 2 levels of a B-carotene top-dressing, B1 no carotene and B2 supplemental B-carotene treatment providing 200 - 1000 mg B-carotene/cow/day ; 3) 2 levels of a dewormer treatment (Anthelmintic), T1 no dewormer (Tramisol) and T2 one injection of 0.044 ml/kg body weight of Tramisol at parturition.

Four weeks prior to the expected calving date cows were fed 2 year old hay low in B-carotene and their respective B1 and B2 top dresses. Table 12 shows the feeding stadegy and levels of vitamins provided by the B1 and B2 (B-carotene) supplements. The concentrate portion of the rations were introduced to the cows about 2 weeks prior to parturition and were increased slowly to provide 3 to 5 kg of concentrate at parturition. Post-parturition, Faba bean silage was then introduced to the cows (separately) while they were still in the calving pen. Cows were moved to individual stalls after at least one full day post-parturition in the calving pen. The completely mixed rations (Table 13) were introduced 2-3 days post-parturition and data collection commenced 4-10 days post parturition. The mean (± SE) starting time for all cows on the ration treatments was 8 ± 1 days post-parturition. Rations were fed Ad Lib., once daily, and were adjusted daily to provide approximately 10% orts. Daily milk yield and ration intakes were recorded for the twelve week period. All cows were weighed on two consecutive days prior to commencing the ration treatments, once at 4 weeks and at 8 weeks into the treatment period, and on two consecutive days immediately prior to finishing the treatment period. At 6 weeks all cows were sampled via eosophageal tube (Ingalls et al., 1980) at three times relative to feeding (time=0, 2 and 4 hours post-feeding). The rumen fluid collected was inactivated by placing it into a bottle containing mercuric oxide. Upon returning to the laboratory the pH was determined and the sample was centrifuged at 10,000xg for 10 min and the supernatant was stored at -20 degrees C until all samples had been collected and could be analyzed for VFA's and ammonia. VFA's in the rumen fluid were determined by gas chromatography (Erwin et al.,1961). Rumen ammonia was determined by an ammonia electrode (Model 95-10, Orion Research, Cambridge, MA).

Table 12: Daily Vitamin Supplementation of Early Lactation Dairy Cows.

	Vitamin Supplement	
	B1	B2
Milk production (L/day)	Vitamin A (I.U.)	B-carotene* (mg)
Dry Cows	80,000	200
Lactating cows:		
<20	160,000	400
20 - 29	240,000	600
30 - 39	320,000	800
>40	400,000	1,000

Vitamins D and E - Similar for both treatments.

Vitamin D - 6,000 I.U.

Vitamin E - 2 I.U. for every 1,000 I.U. of Vitamin A equivalent.

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*Source = Rovimix B-carotene 10% (Roche).

Table 13: Ingredient Composition of Experimental Rations Fed to Dairy Cows in Early Lactation.

Ingredient	Control	Extruded	WCS
	Ration		
	kg/tonne		
Barley	360.5	419.5	419.5
Corn	97.0	-	-
Canola meal	125.6	85.3	85.3
Canola seed(extruded)	-	79.0	-
Canola seed(whole)	-	-	79.0
Molasses	15.7	15.0	15.0
Urea (feed grade)	5.0	5.0	5.0
Trace mineral premix*	4.5	4.5	4.5
Salt (cobalt-iodized)	3.0	3.0	3.0
Limestone	9.2	9.2	9.2
Phosphorus supplement (biophos)	7.5	7.5	7.5
Hay	176.0	176.0	176.0
Fababean silage	196.0	196.0	196.0

*Trace mineral premix supplied per kg of diet:110 mg of Cu as CuSO4, 202 mg Zn as ZnO, 168 mg of Mn as MnO2-H2O and 6 g of Mg as MgO.

Weekly milk samples were collected on two consecutive days and analyzed for fat, protein, and lactose percent by infra red spectroscopy (Milkoscan Model 203, Fosselectric, Cornwall, Ont.). Morning and evening samples from each day were composited. An aliquot of milk was removed, and stored at -20 degrees C, for analysis of milk iodine levels and for the fatty acid profiles of the milk fat. Milk fat was extracted from the samples according to Lambert (1964) and the molar ratios of fatty acids of milk fat were determined by injections of a methylated sample (Metcalfe et al, 1966) onto a GP 3% SP 2310/2% SP 2300 on 100/120 Chromsorb WAW 2.44 m by 0.635 cm packed column. Peak areas for each fatty acid were analyzed using a Varian 402 Data System and values were expressed as a percent of the total fatty acids. A weekly sample of the hay, faba bean silage and the concentrates were taken as well as a weekly sample of each cow's orts. These samples were dried in a forced air oven at 60 degrees C for 48 hours and the percent moisture was determined. Samples were stored at room temperature until they were analyzed for protein and fat (ether extract) according to Association of Official Analytical Chemist (1980), acid detergent fiber according to Goering and Van Soest (1970), gross energy determined by Parr Adiabatic Oxygen Bomb Calorimiter and dry matter. Total mixed ration proximate analysis is shown in table 14.

Table 14: Proximate Anlysis of the Experimental Rations Fed to Dairy Cows in Early Lactation.

Nutrients (dry matter basis)	Control	Extruded	WCS	SE
Crude protein,%	19.1	18.8	18.8	0.1
Ether extract,%	2.3	5.5	5.7	0.3
Acid detergent fibre,%	20.3	20.7	21.0	0.1
Gross energy,Kcal/kg	4467	4545	4542	17
Calcium,%	0.94	0.95	0.94	0.05
Phosphorus,%	0.62	0.60	0.63	0.03

Solids corrected milk (SCM) was calculated using the equation: $SCM (kg) = 12.3(F) + 6.56(SNF) - 0.072(M)$ where F=fat, SNF=solids-not-fat and M=milk, Maynard et.al (1979).

The data was analyzed for differences following the procedure of Allen (1983) and Allen et al. (1983). To summarize this procedure; the data was arranged as a 3x2x2 factorial split over time (weekly periods). From this, regression co-efficients were obtained and the resulting profiles were analyzed for significant differences. To reduce the effects of cows in their first lactation the cows were grouped into a first lactation group and a multiparous group and the data was analyzed with age as a class effect. The bulk of the data is displayed as graphs, which were produced from the regression equations.

Three cows that had started the trial were replaced by cows having a similar age and previous lactation milk yields after the trial was initiated. Two of the replaced cows were receiving the extruded ration and one cow was receiving the WCS ration. All cows that were taken off the trial were suffering from ketosis and were "off-feed". They had all calved in late July or early August and the heat during this time period may have affected their performance. Animals that were already receiving the experimental rations also appeared to have depressed appetities. One heifer that was scheduled to receive the extruded ration aborted while on spring pasture and was replaced. Due to the number of animals that were leaving the trial we prepared a total of six animals to start the trial by feeding them the forage and grain mix prior to calving. One animal was not used and another animal was started on the control ration when she was required to receive the extruded ration. The data collected from this animal was used in the analysis of variance and therefore the total number of animals used in this experiment was 37 not the original 36.

RESULTS.

Experiment 1.

The effect of rumen incubation upon dry matter and protein disappearance from WCS and extruded Canola seed are shown in Tables 15 and 16, respectively.

Experiment 2.

The profiles for dry matter intake, milk yield, 4% FCM, SCM, fat percentage, protein percentage, lactose percentage, fat yield, protein yield, lactose yield, dry matter intake as a percentage of body weight and body weight were generated using the following equation:

$$X = C0 + C1 \times (\text{week}) + C2 \times (\text{week} \times \text{week}) + C3 \times (\text{week} \times \text{week} \times \text{week}) + C4 \times (\text{week} \times \text{week} \times \text{week} \times \text{week}).$$

Where C0, C1, C2, C3 and C4 are the generated regression equation co-efficients.(For further details see Appendix).

Table 15: Dry Matter Disapearance of WCS and Extruded WCS When Incubated in the Rumen in Nylon Bags.+

Product	Incubation Length (hours)					
	1	2	4	8	12	24
WCS	0.4a*	4.7a	7.1a	8.0a	9.3a	23.3a
82 C	12.3b	19.5b	35.8b	52.7b	57.6b	65.0b
94 C	14.4b	24.4bc	38.0b	54.4b	60.7b	69.7b
103 C	19.0b	25.9bc	39.4b	58.3b	60.8b	68.3b
107 C	16.6b	32.0 c	36.4b	53.4b	58.3b	67.5b
110 C	17.9b	31.3 c	38.2b	55.8b	57.7b	71.4b
113 C	18.1b	25.8bc	39.2b	52.9b	61.8b	68.7b

* a,b,c Means within a column with different superscripts are different ($P<0.05$).

+ Expressed as Percent of Initial Dry Matter.

Table 16: Crude Protein Disappearance of WCS and Extruded WCS When Incubated in the Rumen in Nylon Bags.+

Product	Time (hours)					
	1	2	4	8	12	24
WCS	-1.5a*	3.9a	5.7a	4.8a	6.8a	18.1a
82 C	21.9b	39.8b	36.6bc	61.3b	61.5b	70.9bc
94 C	25.0b	33.4b	42.4 c	61.8b	62.3b	69.1bc
103 C	31.7b	34.1b	40.7bc	58.1b	61.4b	74.5 c
107 C	25.4b	37.3b	33.2b	62.3b	54.9b	67.2bc
110 C	25.2b	36.3b	40.5bc	56.6b	51.3b	65.3b
113 C	23.0b	30.2b	37.2bc	58.1b	59.8b	64.5b

* a,b,c Means within a column with different superscripts are different ($P<0.05$).

\+ Expressed as Percent of Initial Crude Protein.

The dry matter intake of the cows consuming the extruded and WCS were significantly different ($P<0.05$) from those consuming the control ration. The dry matter intake profiles are shown in Figure 2. The intake of the cows fed the control ration approximated a normal intake curve. The cows fed the extruded ration showed a rapid increase in DMI (dry matter intake) from the start of the experiment to the end of the second week, leveled off for 6 weeks and then gradually increased to the end of the experiment. The DMI of cows fed the WCS ration was significantly ($P<0.05$) higher than the control ration at the start of the experiment but the shape of the curve was not significantly different after 2 weeks.

Figure 3 shows the effects of the treatments when DMI is expressed as a percent of live body weight. The shape of the three curves doesn't change but the positition of the curve for the extruded ration was increased relative to the control and WCS rations. The extruded ration was consumed at a higher percentage of the cows body weight ($P<0.05$) and the WCS ration tended to be consumed at a greater percentage of body wieght ($P=0.115$).

The body weight of the cows over the experimental period is shown in Figure 4. There were no significant differences in live body weight, but the cows assigned to the extruded ration did show a numerically lighter body weight which accounts for the shift of the DMI as a percent of body weight curve for the WCS and extruded rations.Although there was no significant differences it is noteworthy that the cows on the extruded ration did not lose body weight throughout the experiment, while the cows on the control and WCS rations lost body weight during the first weighing period. This loss of body weight would indicate a negative energy balance.

The statistical analysis of the data showed a strong trend for differences in the milk yield of the cows receiving the experimental rations. The cows receiving the extruded ration tended to give more milk than cows receiving the control ration (P=0.0523) Figure 5 shows the profile of the milk yield as expressed by the co-efficients that were calculated. The cows receiving the control ration had a lower peak milk yield and reached that peak earlier in the trial than cows receiving the extruded ration.The profile of the milk yield of the cows receiving WCS was similar to the extruded ration but not significantly different from the control ration.

The milk fat percent of the cows fed the extruded ration was significantly lower (P<0.05) than the control ration. The control ration milk fat percent showed a much sharper decline over the first three weeks of the trial than WCS. The extruded ration had a similar decline as the control ration but after the initial decline the milk fat percent of the cows receiving the control ration gradually increased and the milk fat percentage of the cows receiving the extruded ration continued to gradually decline. The profiles of the extruded ration and WCS were significantly different from the control ration. Figure 6 illustrates the effect of ration on milk fat percent.

The milk fat yields were also significantly different among treatments (P<0.05). WCS had the greatest yield at any given time period and the decline in yield over time was less than for the control ration. The extruded ration had a similar profile to the control ration but with a greater intercept. The profiles of milk fat yield are shown in figure 7.

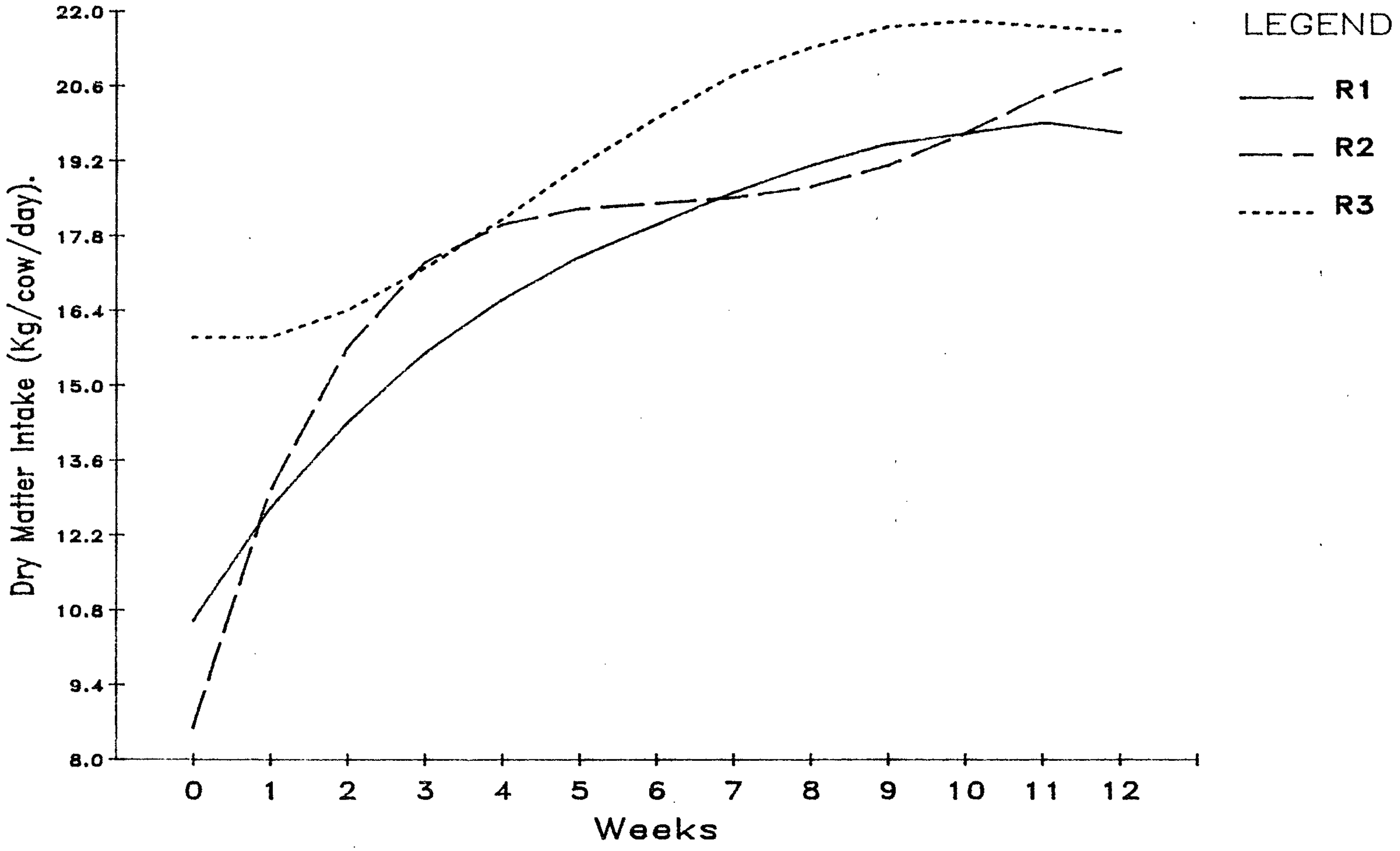
Figure 8 illustrates the effcet of the rations on the 4% FCM yield. There were no significant differences. There was a non-significant trend towards an interaction between the WCS and the control ration with and without the supplemental B-carotene (P=0.1005).

Figure 9 shows the SCM yield response to the rations. The SCM yield was not significantly affected by the dietary treatments and resembled the 4% FCM profiles.

Figure 10 illustrates the effect of ration on the milk protein percent. The profiles were all parallel with no significant ration effect on milk protein percent. The milk protein yields, g per day, were not different but the slope of the extruded ration protein yield profile was different from the control ration (Figure 12).

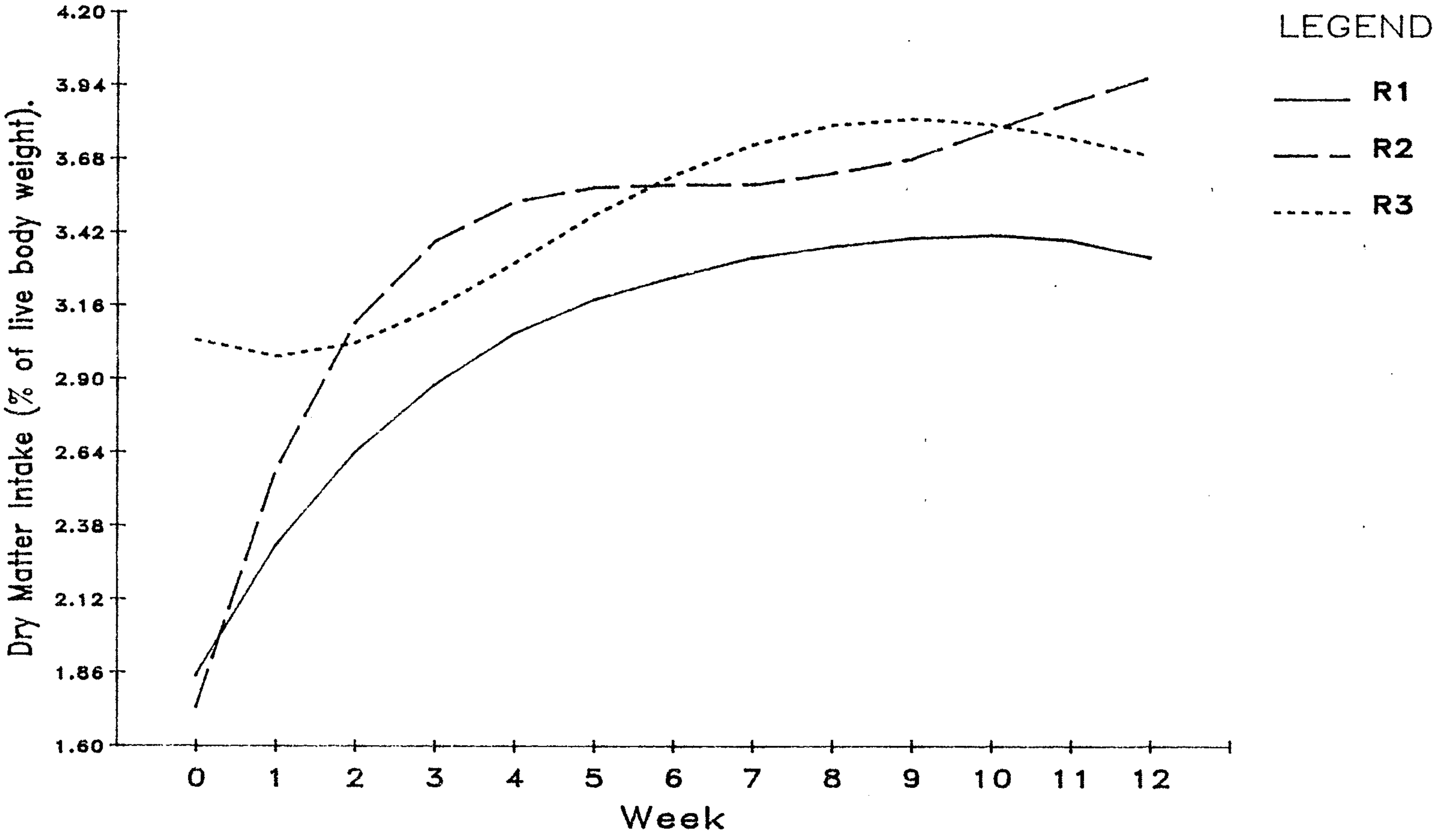
There were no significant diferences between rations in milk lactose percent (Figure 11). The yield of milk lactose, in g per day (Figure 13) tended to be higher for the extruded ration when compared to the control ration (P=0.056) and resembled the milk yield profiles.

Figure 2: Effect of Whole or Extruded Canola Seed on Dry Matter Intake of Dairy Cows in Early Lactation.
(Pooled Residual Standard Deviation = 3.1)



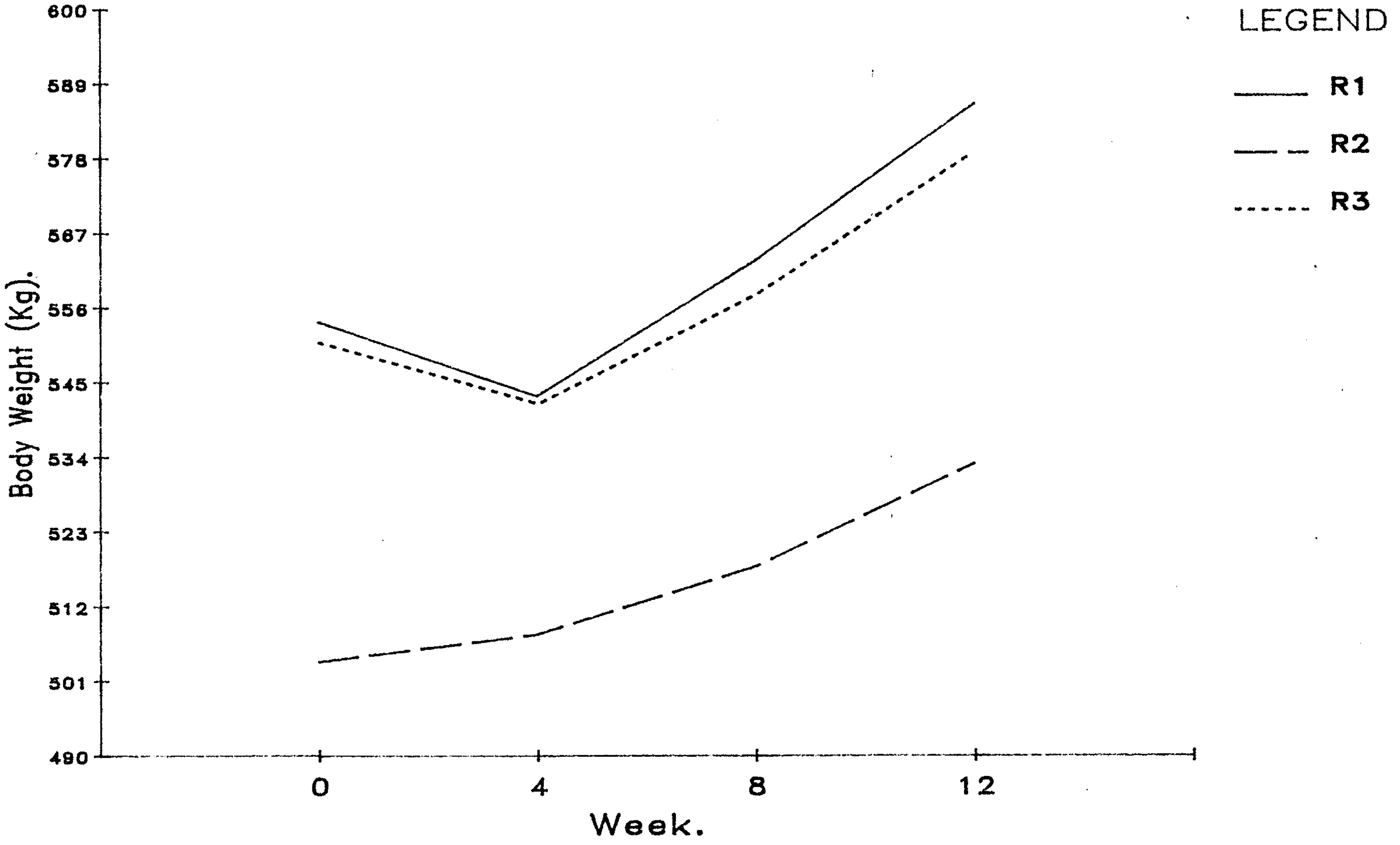
R1 = Control. R2 = Extruded Canola Seed. R3 = Whole Canola Seed.

Figure 3: Effect of Whole or Extruded Canola Seed on Dry Matter Intake of Dairy Cows in Early Lactation, Expressed as a Percentage of Live Body Weight. (Pooled residual Standard Deviation = 0.53)



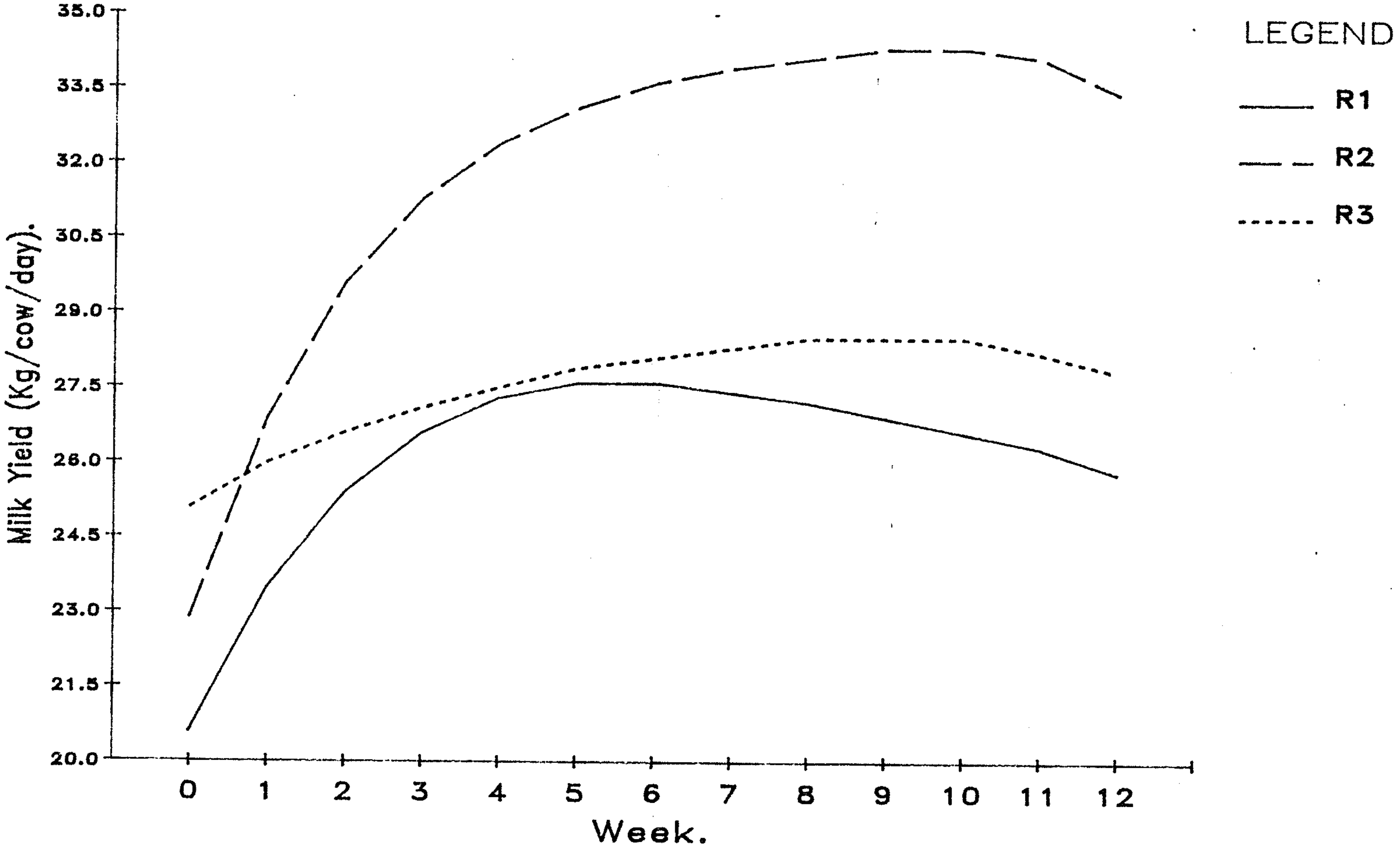
R1 = Control. R2 = Extruded Canola Seed. R3 = Whole Canola Seed.

Figure 4: Effect of Whole or Extrude Canola Seed on the Live Body Weight of Dairy Cows in Early Lactation. (Pooled Residual Standard Deviation = 39)



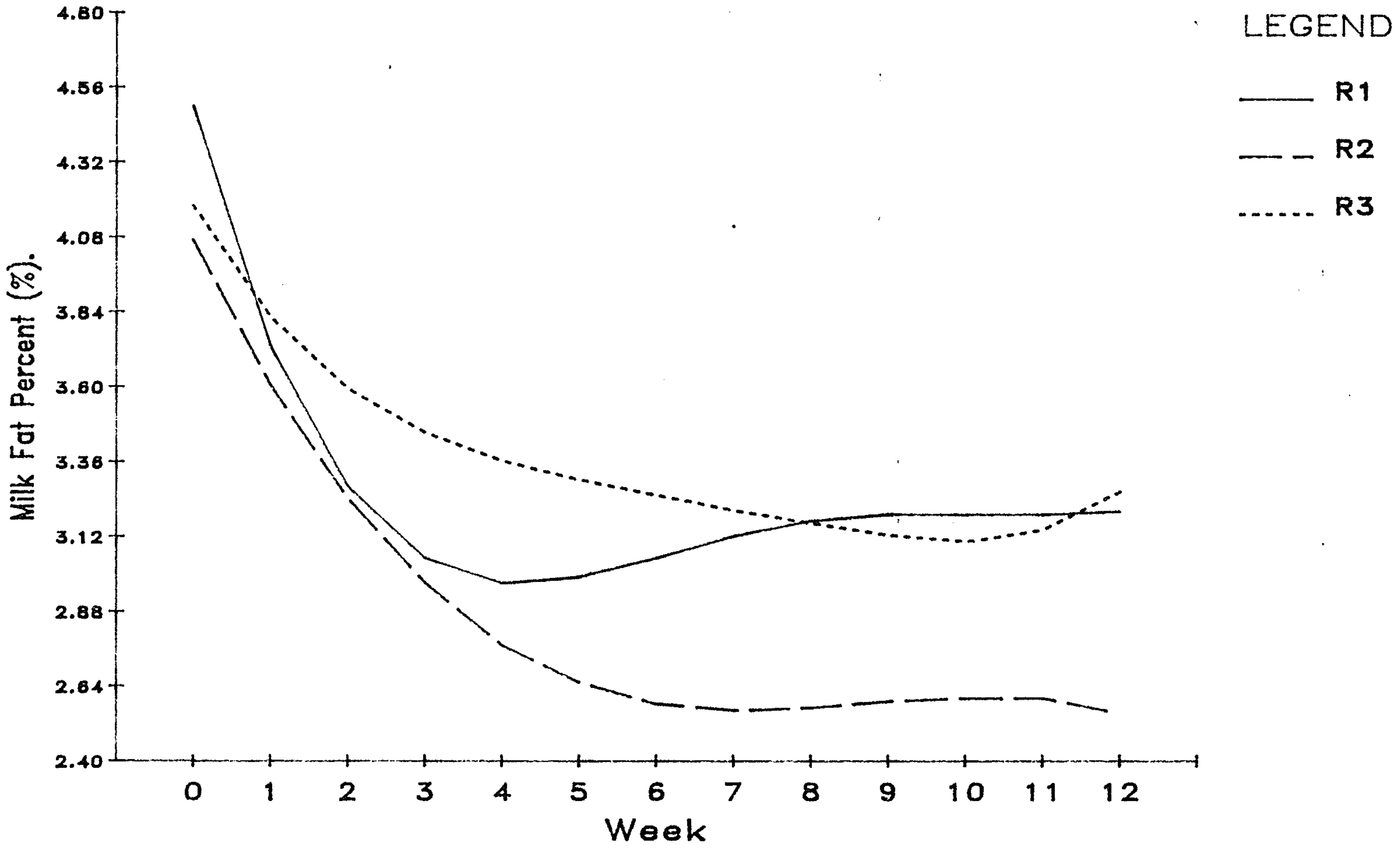
R1 = Control. R2 = Extruded Canola Seed. R3 = Whole Canola Seed.

Figure 5: Effect of Whole or Extruded Canola Seed on the Milk Yield of Dairy Cows in Early Lactation.
(Pooled Residual Standard Deviation = 4.9)



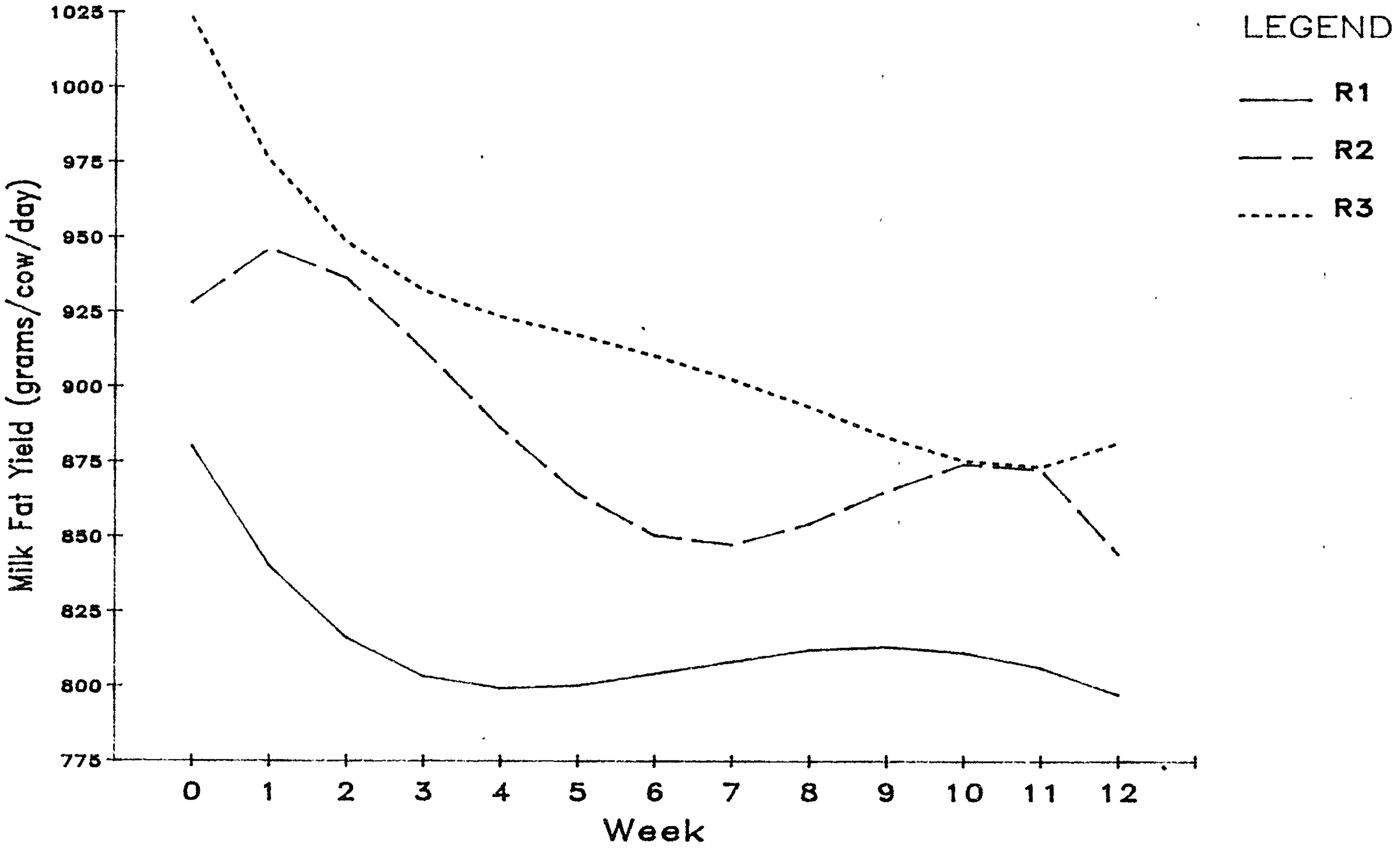
R1 = Control. R2 = Extruded Canola Seed. R3 = Whole Canola Seed.

Figure 6: Effect of Whole or Extruded Canola Seed on Milk Fat Percentage of Dairy Cows in Early Lactation.
(Pooled Residual Standard Deviation = 0.61)



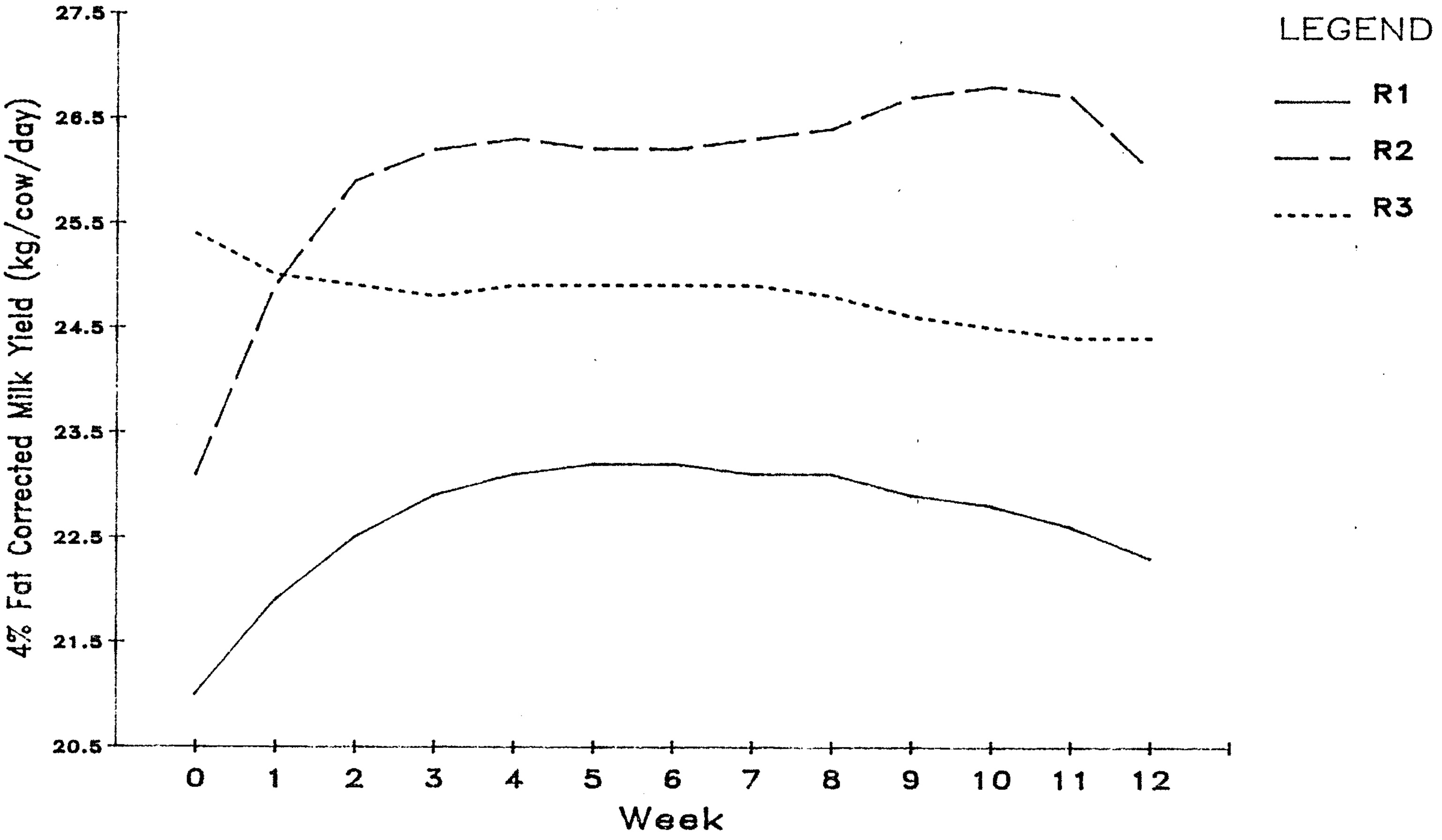
R1 = Control. R2 = Extruded Canola Seed. R3 = Whole Canola Seed:

Figure 7: Effect of Whole or Extruded Canola Seed on Milk Fat Yield of Dairy Cows in Early Lactation.
(Pooled Residual Standard Deviation = 211)



R1 = Control, R2 = Extruded Canola Seed, R3 = Whole Canola Seed

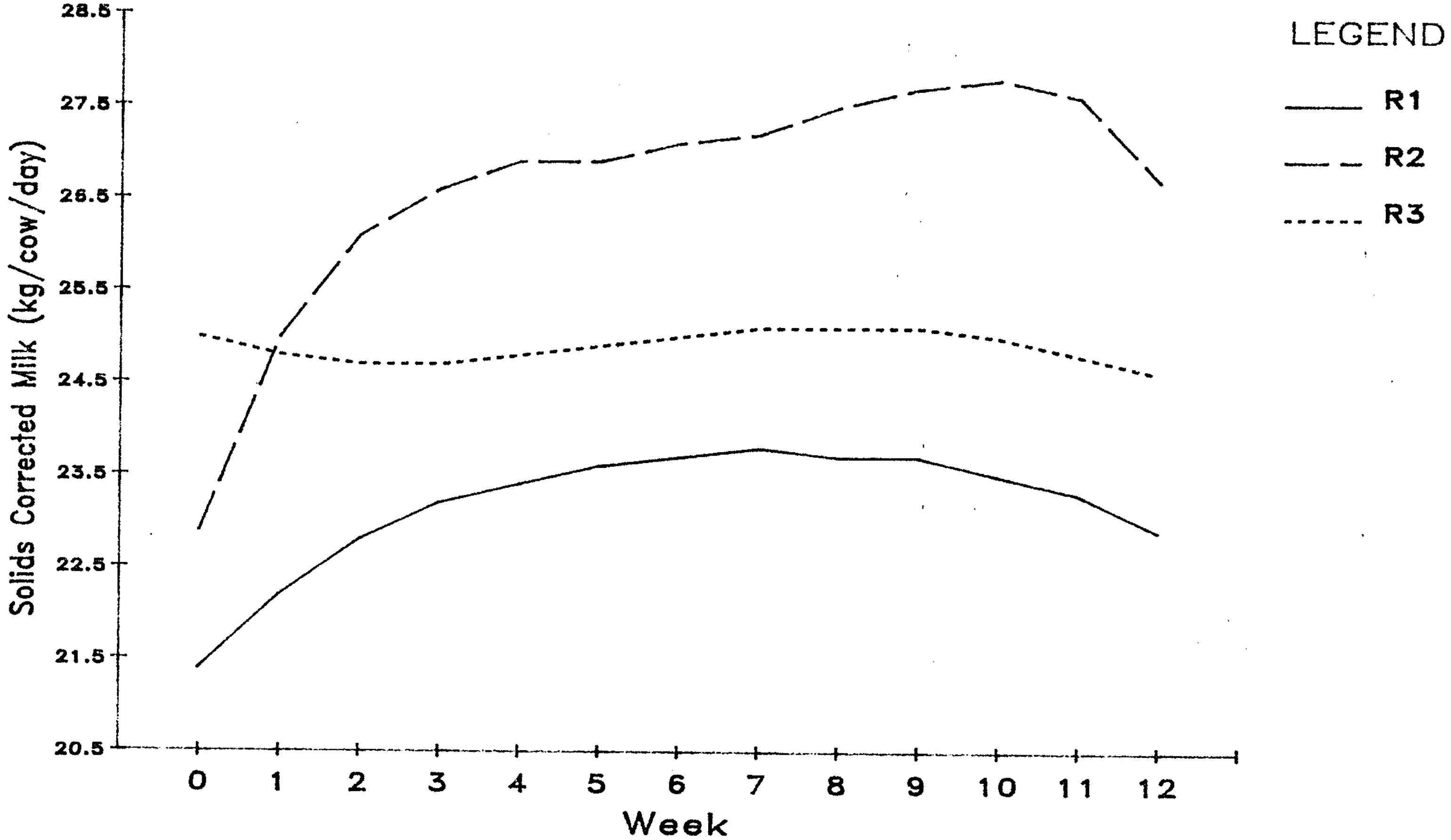
Figure 8: Effect of Whole or Extruded Canola Seed on 4% Fat Corrected Milk Yield of Dairy Cows in Early Lactation.
(Pooled Residual Standard Deviation = 4.6)



R1 = Control, R2 = Extruded Canola Seed, R3 = Whole Canola Seed

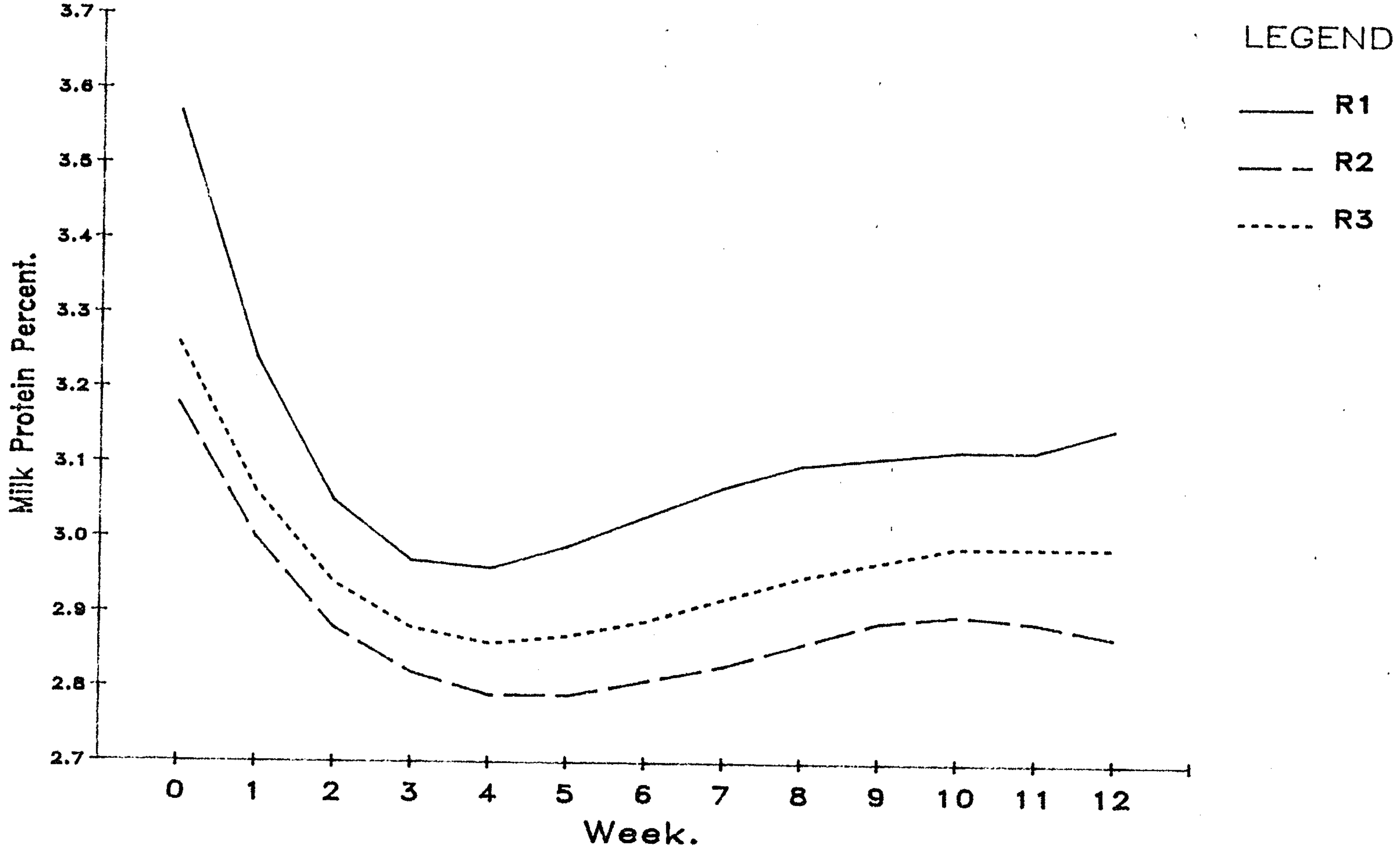
Figure 9: Effect of Whole or Extruded Canola Seed on Solids Corrected Milk Yield of Dairy Cows in Early Lactation.

(Pooled Residual Standard Deviation = 4.5)



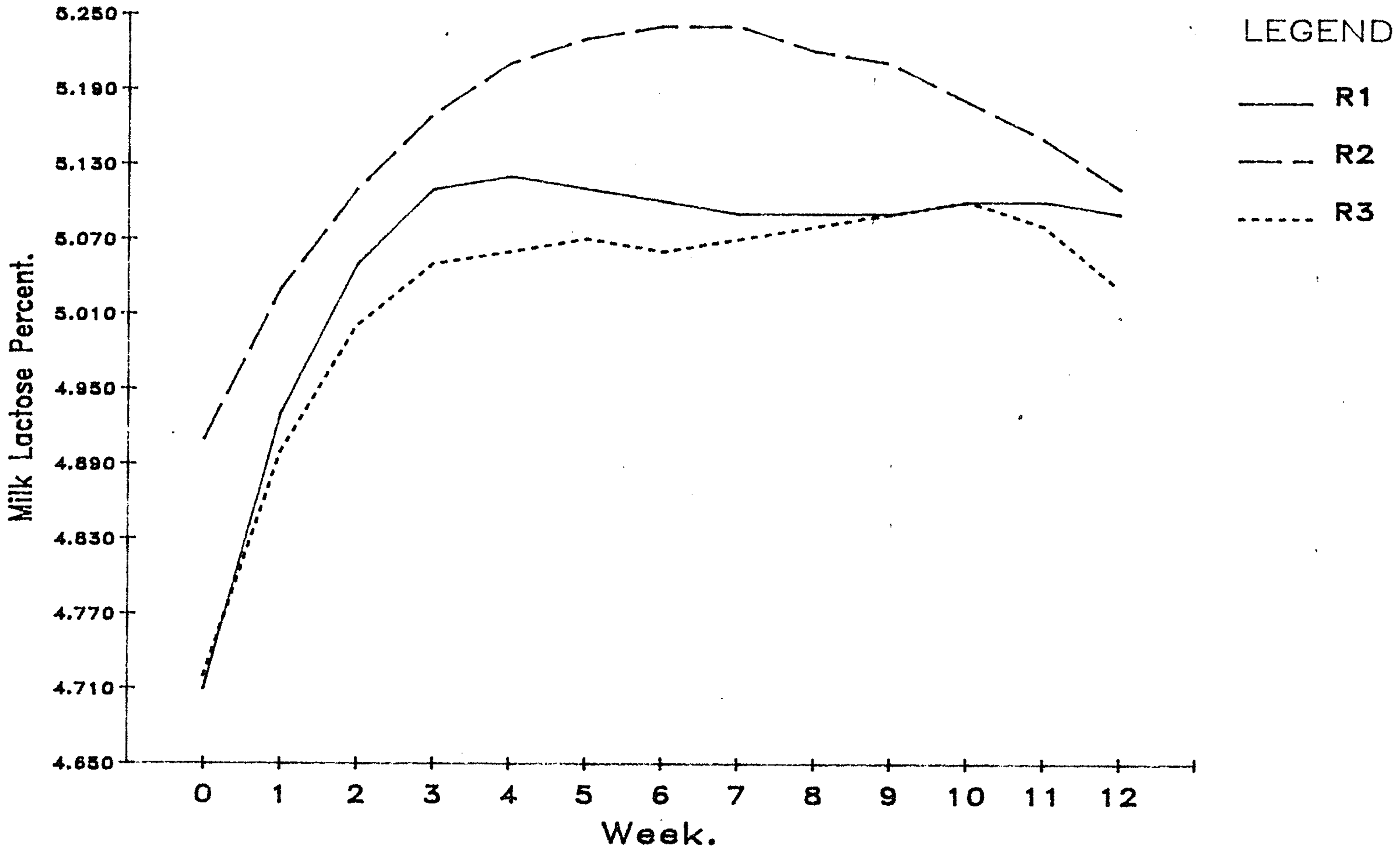
R1 = Control, R2 = Extruded Canola Seed, R3 = Whole Canola Seed

Figure 10: The Effect of Whole or Extruded Canola Seed on Milk Protein Percent of Dairy Cows in Early Lactation.
(Pooled Residual Standard Deviation = 0.21)



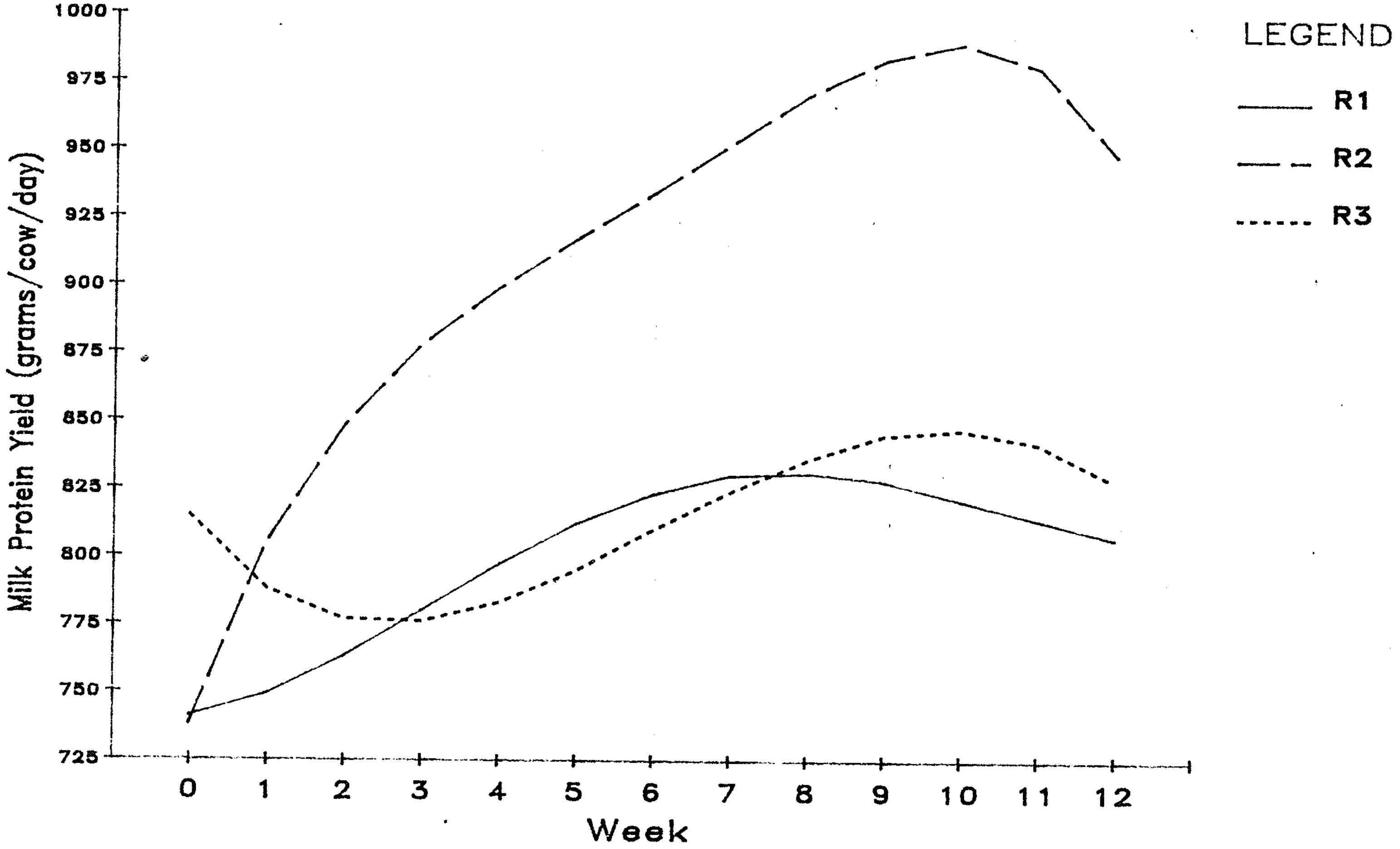
R1 = Control. R2 = Extruded Canola Seed. R3 = Whole Canola Seed.

Figure 11: Effect of Whole or Extruded Canola Seed on Milk Lactose Percent of Dairy Cows in Early Lactation.
(Pooled Residual Standard Deviation = 0.28)



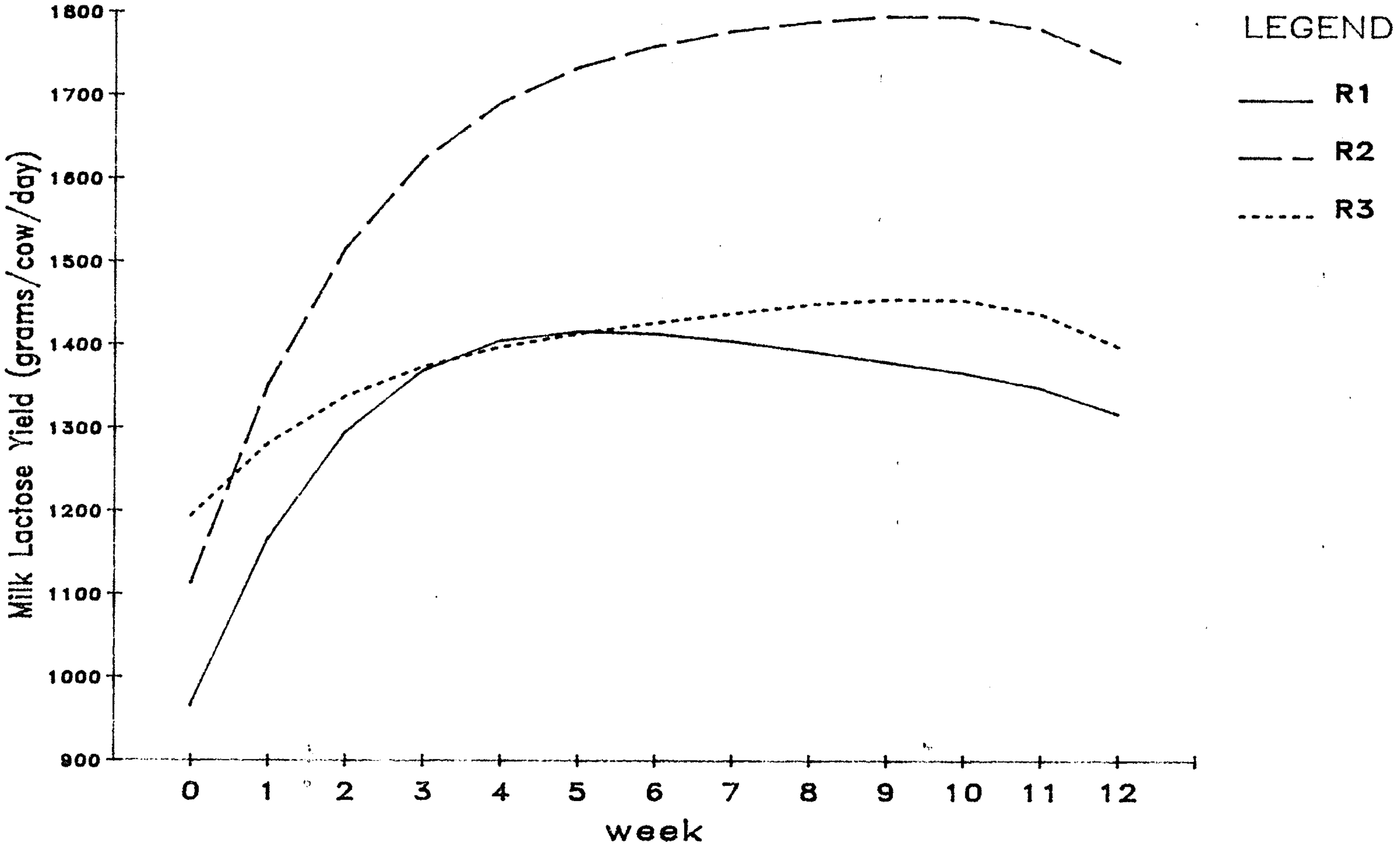
R1 = Control. R2 = Extruded Canola Seed. R3 = Whole Canola Seed.

Figure 12: Effect of Whole or Extruded Canola Seed on Milk Protein Yield of Dairy cows in Early Lactation.
(Pooled Residual Standard Deviation = 146)



R1 = Ration 1, R2 = Extruded Canola Seed, R3 = Whole Canola Seed

Figure 13: Effect of Whole or Extruded Canola Seed on Milk Lactose Yield of Dairy Cows in Early Lactation.
(Pooled Residual Standard Deviation = 276)



R1 = Ration 1, R2 = Extruded Canola Seed, R3 = Whole Canola Seed

The effects of rations, B-carotene and Tramisol on ruminal VFA's, ammonia concentration and milk iodine was analyzed using the general linear models (GLM) proceedure of SAS. The data was analyzed as a split-plot over time model and the main treatment effects and interactions were separated and analyzed using cow(ration x B-carotene x Tramisol) as the error term.

The ration treatments showed no significant effects on ruminal ammonia concentration but there was a significant time effect (Table 18). The concentration was lowest at time 0, peaked at time 2 h and slightly ($P>0.05$) declined at the 4 h sampling period. The pH of the rumen fluid was not different over the ration treatments nor was there a significant effect of sampling time.

VFA concentrations, rumen fluid pH values and milk iodine concentrations were not affected by dietary treatments ($P>0.05$) or sampling time ($P>0.05$) (Tables 17 and 18).

Table 17: The Effect of Whole or Extruded Canola Seed on Ruminal VFA's.

	Rations			
Substrate	CONTROL	EXTRUDED	WCS	SE*
Acetic acid (molar %)	62.0	63.1	59.8	0.006
Propionic acid (molar %)	24.6	24.9	23.4	0.005
Iso-butyric acid (molar %)	0.9	0.9	1.4	0.001
N-butyric acid (molar %)	9.3	8.5	12.0	0.003
Iso-valeric acid (molar %)	1.6	1.3	1.8	0.001
N-valeric acid (molar %)	1.6	1.3	1.6	0.001
Total VFA's (mmole/100ml)	69.6	61.4	64.7	2.950
Ratio of Acetic to Propionic	2.73	2.79	2.66	0.095

* SE, standard error.

Table 18: Effect of time and ration on rumen ammonia and pH and of time on milk iodine concentration.

Sampling time. (hours relative to feeding)	Rumen Ammonia (mg/100ml)	SE*	Rumen pH	SE*	Milk Iodine (ug/ L.)	SE
0	7.4a**	0.7	7.17	0.05		
2	15.9b		6.98			
4	13.1b		6.80			
Ration						
CONTROL	11.5	0.7	7.01	0.05	50.8	1.4
EXTRUDED	12.9		6.97		47.6	
WCS	12.0		6.90		54.1	

* standard error.

** means within a column that have a different superscript are different (P. <0.05).

The fatty acid composition of the milk fat showed that the effect of the extruded canola seed was more pronounced than that of the WCS (Table 19). Both canola seed treatments caused a higher level of total unsaturated fatty acids than what was seen in the control diet. The profile of the milk fatty acids in this experiment compare well with those observed by Cadden et al. (1984) and Handy and Kennelly (1983).

Table 20 shows the means and standard error of the production parameters measured. The numbers tabulated are the means of the raw data and are shown as a quick reference of the data.

Table 19: Effect of Rations on the Fatty Acid Composition of Milk Fat.

Fatty Acid (weight %)	CONTROL	EXTRUDED	WCS
C 4:0*	0.67 a**	0.72ab	0.74 b
C 6:0	1.56 b	1.37 a	1.52 b
C 8:0	1.32 b	0.95 a	1.27 b
C10:0	3.52 c	2.38 a	3.02 b
C12:0	4.41 c	2.88 a	3.67 b
C14:0	12.70 c	9.72 a	11.44 b
C14:1	1.31 c	1.09 a	1.15 b
C16:0	33.36 c	23.08 a	28.46 b
C16:1	2.02 b	2.07 b	1.68 a
C18:0	10.47 a	14.28 c	13.73 b
C18:1	24.80 a	35.89 c	29.19 b
C18:2	2.36 a	2.75 b	2.39 a
C18:3	0.27 a	0.34 c	0.29 b
C20:0	0.63 a	1.10 c	0.74 b
C20:1	0.40 a	0.96 c	0.55 b
C22:0	0.18	0.16	0.15
C22:1	0.14 a	0.22 b	0.15 a
Total saturated	68.94 a	56.58 c	64.72 b
Total unsaturated	31.06 a	43.42 c	36.28 b

* first number denoted the number of carbon atoms, the number after the colon denotes the number of double bonds.

**a,b,c Means within the same row with different superscripts are different $P<0.05$.

Table 20: Summary of Production Responses of Cows Fed the Control, Extruded or Whole Canola Seed Rations in Early Lactation.

	Ration			
Production Parameter	Control	Extruded	WCS	SE*
Milk Yield (kg)	26.5	32.6	27.8	0.4
4% F.C.M. (kg)	22.8	26.2	24.7	0.1
Solids Corrected Milk Yield (kg)	23.3	26.9	24.9	0.1
Dry Matter Intake (kg)	17.6	18.2	19.6	0.6
Fat %	3.18	2.77	3.31	0.07
Protein %	3.08	2.86	2.94	0.02
Lactose %	5.08	5.18	5.05	0.02
Fat Yield (g)	809	879	909	10
Protein Yield (g)	805	925	813	11
Lactose Yield (g)	1356	1696	1405	25

* standard error.

Discussion.

Experiment 1.

The highest two extrusion temperatures showed some oil leakage from the stored material and because of this these two products were not considered for use in experiment 2, manuscript 2.

Significant differences (P<0.05) between the extruded Canola seed product extruded at different temperatures were noted only at the 2 h incubation time period in the amount of dry matter leaving the nylon bag. At this incubation time the material extruded at 107 and 110 C had more dry matter loss than the product extruded at 82 C. The WCS had significantly less dry matter loss at all incubation times than all the extruded products (P<0.05).

Significant differences (P<0.05) between the extruded Canola seed product extruded at different temperatures werenoted at the 4 and 24 h incubation time periods for the amount of crude protein leaving the nylon bag. At the 2 h incubation time the material extruded at 107 C had less crude protein loss than the product extruded at 94 C. The product extruded at the other temperatures were not different from either. At the 24 h incubation time the product extruded at 104 C had a higher crude protein loss than the products extruded at 110 and 113 C. The product extruded at the other temperatures were not different from those extruded at 110 and 113 C. The WCS had significantly less crude protein loss at all incubation times than all the extruded products ($P<0.05$).

The dry matter losses from the nylon bags of the extruded Canola product extruded at 107 C resembled that of Tower Canola meal for the 1 and 2 h incubation periods but appeared to be faster at the 4, 8, 12 and 24 h incubation periods, Sharma (unpublished, 1983). This may have been due to the barley that was used as a carrier for the Canola seed. Barley has a low acid detergent fiber level and would under go ruminal bacterial degradation faster than Canola meal which has a higher fiber level. Mehrez and Orskov (1977) estimated a dry matter disappeareance of rolled barley from nylon bags at 3 h of rumen incubation at about 15%, and a 73% dissapearance after 24 hours. With Canola meal there appears to be a soluble pool that quickly disappears and then a larger more slowly degraded pool (Ha and Kennelly, 1983). The crude protein losses of this product were higher than what was observed for the Canola meal. This may have been due to the barley carrier as well. Mehrez and Orskov (1977) found the crude protein dissapearance of rolled barley to be about 80% after a 24 h incubation period.

The protein dissappearance of Tower Canola meal from nylon bags found by Sharma (unpublished 1983) was 63.5% at 24 hours. This compares well with that found by Ha and Kennelly (1983) who determined that the degadability of canola meal was 67.7% using nylon bags.

When allowances are made for the barley carrier, the protein and dry matter disappearance from the extruded Canola seed product did not appear to be different than that of untreated Canola meal. There did not appear to be an effect of the oil hindering dry matter or protein loss of the extruded product from nylon bags incubated in the rumen of a steer.

From the nylon bag tests the 107 degree C product was chosen for use in experiment 2 because it was the highest temperature that we were able to reach without leakage from the stored product after extrusion. We wanted to be sure that the seed coat was disrupted so that the product would be able to under go rumen bacterial degradation. From the nylon bag experiment the WCS appeared to under go limited ruminal degradation but appeared to be able to serve as a potential source of thru-pass protein. By inference, the WCS was estimated to be able to serve as a potential source of thru-pass fat due to the low crude protein and dry matter losses from the nylon bags. However extent of digestion in the lower gut is not known.

Experiment 2.

The production of milk, fat percent, protein percent, lactose percent and 4% FCM from cows fed the WCS ration was not significantly different from the cows fed the control ration. This compares well with the findings of Meilke and Schingoethe (1981) and Stern et al. (1985). Meilke and Schingoethe (1981) found no differences in production when cows were fed whole or heat treated soybeans (extruded at 160 C). Stern et al.(1985) used unheated whole soybeans and whole soybeans extruded at 132 and 149 C, and found no differences in production when compared to a soybean meal control diet. The cows in the whole soybean studies were 7 weeks post-partum or mid to late lactation, respectively.

There appeared to be no effect of the WCS on milk protein percent. As has been noted in trials with whole cotton seed (Anderson et al. 1979, DePeters et al. 1985, Smith et al. 1981), protected tallow (with soybean meal as the protein carrier) (Dunkley et al. 1977, Vincente et al. 1984),and soybean oil (Steele 1985) there can be a significant decrease in the milk protein percent when lipid is added to the ration. In contrast this experiment agrees well with the findings of Beaulieu (1986), Handy and Kennelly (1983), Kennelly (1983) and Vincente et al., (1979) when whole or ground canola seed or protected tallow (with canola meal as the carrier) were fed there was no depression in milk protein percent. DePeters et al. (1985) determined that the casein fraction of the milk protein was depressed when whole cottonseed was fed and that the nonprotein nitrogen as a percent of the total milk nitrogen increased as the amount of whole cottonseed in the ration inceased. This contrasts the findings of Dunkley et al. (1977) who found that both the whey and nonprotein fractions of the milk nitrogen were increased (as a % of total milk N). With the differences between protected tallow with soybean meal or canola meal as a carrier and the lack of milk protein percent depression when whole or ground canola seed or crushed soybeans (Steele 1985) are fed, the milk protein depression found when certain types of lipid and protein may be more complex than simple lipid-protein interaction and cannot be explained by this experiment.

The milk protein percent of the cows fed the extruded ration was similar to the control and WCS rations. The responce is comparable to that noted by Steele (1985) when crushed soybeans were added to the diet. Yet when soybean oil was added to the diet to provide the same level of added oil as the crushed soybeans there was a depression in the milk protien percent.

The milk fat percent of the cows fed the WCS ration was not significantly different from that of the control group although the profile was. This was also seen by Beaulieu (1986), Handy and Kennelly (1983) and Kennelly (1983). These researchers found that WCS did not influence milk fat percent when added to the diets. The response of the cows fed the WCS ration, when compared to the control ration is similar to that of low levels of protected tallow added to the diet (between a 2 to 4% increase in the total dietary lipid) as found by Handy and Kennelly (1983) and Sharma et al. (1978). But Fisher (1979) and Vincente et al.(1984) found increases in milk fat percent, milk and 4% FCM yields when protected tallow was fed at these levels.

The lower ($P<0.05$) milk fat percent from the cows fed the extruded ration could have been due to the processing of the canola seed, allowing the oil access to the rumen environment where it could exert a deterimental effect upon the microbial population. This response was similar to that noted by Beaulieu (1986) where canola oil was added to the diet and caused a significantly lower milk fat percent than the control or canola presscake diet. It is unusual that extrussion would cause a depression in milk fat and the presscake did not. The canola presscake is the product of pressed canola seed prior to hexane extraction (Beaulieu, 1986). The amount of oil remaining in the presscake was 21%. The amount of oil from the presscake added 1.7% lipid to the total diet and the amount of added canola oil added 1.9% lipid to the total diet. In this experiment the amount of added lipid was higher, at 2.9% for the extruded ration. Because of the higher level of oil, more free oil may have been available to influence the microbial population in this experiment. Steele (1985) observed that the concentration of extracellular oil, not the total amount of oil, caused the decrease in milk fat percent.

Finn et al. (1985) compared the addition of limestone to whole rolled sunflower seeds to a control ration of soybean meal and corn or sunflower seeds without added limestone. They found that the addition of the limestone improved the 4% FCM, milk fat percent and total solids percent when compared to the sunflower seeds alone. They attributed this improvement to the effects of limestone post-ruminally possibly preventing a postabsorptive effect of the oil. In this experiment the amount of limestone added was 0.92% and in Finn's experiement the amount of limestone added to the total ration dry matter was 0.99%. The effect of the limestone as a source of calcium for the formation of insoluble salts of fatty acids would have been similar. The rations used in experiment 2 were formulated to contain 0.9% calcium which is the lower level of calcium suggested by Palmquist (1983).

The use of added limestone in this experiment contrasts that of Beaulieu (1986), who only added biophos (mono-dicalcium phosphate) primarily as a source of supplemental phosphorous.

Kennelly (1983) and Handy and Kennelly (1983) added calcium carbonate at 1.4% of the concentrate (about 0.7 to 0.8% of total feed) but did not report the final calcium level in the feed. The addition of the limestone to achieve a calcium level of approximately 0.9% of the dry matter may have been beneficial in increasing the total dry matter intake of the rations with the added oil. This was noticed by Finn et al. (1985) who saw an improvement in dry matter intake by adding limestone to the whole sunflower seeds, but both whole sunflower seed rations were not consumed as well as the control ration.

White (1985) noted an improvement in milk fat percent and no decrease in protein percent when whole sunflowers were compared to a control ration containing sunflower oil (with or without added sodium bicarbonate). Similar to this experiment increases in milk fatty acids of 18 carbons was noted with a decrease in the short chain fatty acids (C 4 to 10).

Selner and Schultz (1980) found that trans fatty acids of C 18:1 were the primary cause of fat depression in milk when these acids were fed to lactating dairy cows. They also observed that the fat depression started about 2 weeks after the fat source was incorporated into the ration and that the effect was not noted 2 weeks after the fat source was removed. In this experiment the fat percentages of the control and extruded rations started diverging after 3 weeks into the experiment and may have been due to the trans C 18:1 in the WCS. This is only speculation as the positional isomers of the fatty acids were not determined in this experiment. Kennelly (1983) and Handy and Kennelly (1983) determined that WCS increased the C 18:1 content of the rations and that trans C 18:1 was increased in the milk of cows fed ground or protected canola seed, respectively.

The reduction in the milk fatty acids between C 6:0 and C 16:0 is likely due to the inhibition of acetyl-coenzyme A carboxylase (Palmquist and Jenkins, 1980), and is consistent with results found by others including Clapperton and Steele (1985), DePeters et al. (1987), Dunkley et al. (1977), Drackley and Schingoethe (1986), Handy and Kennelly (1983) and Palmquist and Conrad (1978).

It appears that WCS had no detrimental effects on any of the production parameters or on weight loss when compared to the control ration. The extruded WCS product had significant effects upon milk production, milk fat percent and milk protein percent. Because of this profiles for other parameters were also significantly affected. The WCS treatment produced an effect that can be best generalized as intermediate, falling between the control ration and the extruded ration.

Milk iodine concentrations, rumen VFA, pH and ammonia concentrations were not significantly affected by the rations, and the iodine values are similar to those found by Laarveld et. al. (1983c) when iodine was added to the ration.

The profile of the weight loss of the cows receiving the extruded canola product was intersting. The cows did not lose weight during the trial period. This would indicate that they were not in a serious negative energy balance. They may have been in a negative energy balance at the tissue level and the weight gain may have been fluid. Assuming that the composition of the weight loss or gain was equal across all treatments the group of cows receiving the extruded ration were not in a negative energy while the cows on the other treatments were in a negative energy balance for the first 4 weeks of the experiment.

The cows consuming the WCS ration consumed significantly more dry matter than the cows receiving the control and extruded rations. The cows fed the extruded ration produced significantly more milk ($P=0.0523$) and lower milk fat percent ($P<0.05$) than cows fed the control and WCS rations. There were no significant effects of ration on milk iodine, rumen VFA's or rumen ammonia concentrations. The cows receiving the WCS responed to the fat in a manner typical of a protected fat fed at low levels, this may be due to incomplete post-ruminal digestion. The cows receiving the extruded canola product responded in a manner typical of the response when free oil is fed at levels of 400 to 600 grams per cow per day.

The WCS can be used in the rations of dairy cows in early lactation at levels up to 7.9% of the ration dry matter with no adverse effects upon milk production parameters or weight loss. The extruded canola seed product could be used to improve the milk yield of cows in early lactation but the lower milk fat percent may not be of economic advantage.

GENERAL RESULTS AND DISCUSSION.

Manuscript 1.Results.

In experiment 1 two of the sheep became quite adept at sorting the WCS out of the basal oat ration. This contributed to the large number of observations between 4 and 10% WCS inclussion in the diet actually consumed. In one period one of the lambs effectively sorted out virtually all of the WCS, the calculated intake of this lamb in the period was -1.4% and prompted the use of data only above the 4% WCS inclusion rate.

One of the sheep developed diarrhea which continued for the last three days of the fifth collection period. He was diagnosed as having pnuemonia but was not treated. After leaving the collection crate he recovered from the diarrhea and was used in the sixth period. On the last two days of the sixth period this animal again developed diarrhea. There were no animal differences in the analysis of variance and therefore the data collected from this animal was used in the digestibility trial.

Experiment 2 was initiated prior to my involvment with two of the three blocks being completed. There were no abnormal findings or behavior reported to me concerning the cows in the first two blocks.

The intent of this experiment was to determine the palatability of the WCS when fed as a top-dress to lactating dairy cows and there appeared to be no problems encountered with the consumption of the WCS. After about 7 to 10 days the cows being fed the highest level of WCS top-dress (2 kg) appeared to have a mild case of scours and this was attributed to the oil from the WCS.

During the fourth period we started to collect milk samples to compare the infra-red milk fat analysis versus the Babcock and Gerber proceedure. We had analyzed 12 samples when one of the cows left the experiment due to an accident in her stall. As the data was incomplete for this animal we did not statisically analyze this data but there did appear to be a numerical difference in the infra-red results when compared to the Babcock and Gerber proceedures. The infra-red analysis appeared to be lower than the other fat percent determinations and this was most evident for the cows receiving the WCS. But there was only enough time to analyze the milk of one cow receiving the control treatment.

The silage was fed in both the morning and the evening with the hay being fed at noon. The orts were weighed in the morning prior to the silage being fed. It is not known whether there were differences between treatments as to the composition of the orts as they were not analyzed. The concentrate and WCS treatments were fed seperately and there were no reported instances of these feeds being refused.

Manuscript 2.Results.

The intent of the nylon bag trial was to compare the differences between the WCS and the extruded canola seed products. This was accomplished by removing all the bags from the rumen at the same time and analyzing the results for differences at that time. This type of trial would not allow for the development of rate of dry matter or crude protein leaving the bags over the entire 24 h incubations.

A trial was started to determine the dry matter and protein losses of the completely mixed rarions used in experiment 2 from nylon bags incubated in the rumen of a steer but only one determination was completed. The steer was able to remove the cannula cap, it is suspected from rubbing on the side of the pen. At this time the steer was kept in a 3.6 by 3.6 m pen. The rumen contents found on the floor of the pen with the cannula cap led to the conclussion that he had been rubbing on the pen. The steer was being fed the control ration fed to the cows in experiment 2. He was placed on an ad lib. hay diet for 4 days, then fed 7 kg of the completely mixed control ration fed to the cows with ad lib. hay for 4 days and then fed 12.3 kg of the control ration for 4 days.

On the evening of the fourth day the steer had again removed the cannula and the rumen contents were again almost completely evacuated. He was placed on an ad lib. hay diet to recover. This trial was not completed as he was required for another trial. The results of the single determination of the three completely mixed rations fed in experiment 2 are shown in table 21. Although the data are limited, the protein degradation rate of the extruded canola seed ration appears less than that of the control (canola meal) ration.

During experiment 2 the cows fed the extruded and the WCS rations did not show signs of scouring as cows had when fed the highest level of top-dressed WCS in manuscript 1, experiment 2. This is surprising as cows fed the WCS would have been consuming as much or more added oil per day than the cows in the previously mentioned experiment. The greatest difference was that in this experiment the cows were fed a totally mixed ration and the intake of the WCS would have been consumed over a longer period throughout the day.

Table 21: The Crude Protein and Dry Matter Losses of the Control, Extruded and WCS Rations From Nylon Bags Incubated in the Rumen of a Fistulated Steer.

Time (h)	Dry Matter Losses (%)			Crude Protein Losses (%)		
	Ration			Ration		
	Control	Extruded	WCS	Control	Extruded	WCS
2	12.6	14.1	16.7	15.3	6.9	6.9
4	16.4	21.7	20.0	20.7	7.9	8.9
6	29.6	28.2	25.0	21.6	10.0	19.4
8	40.1	38.5	36.2	30.9	11.6	22.0
12	46.7	50.8	49.1	43.4	35.7	42.6
24	71.8	62.2	62.1	76.9	51.5	60.2

The summary of the crude protein, acid detergent fiber, dry matter, ether extract and gross energy intakes are summarized in table 22. These values are corrected actual intakes using the proximate orts analysis. As with the dry matter intakes, the intakes of crude protein and acid detergent fiber were different ($P<0.05$). As expected the intake of ether extract and gross energy were different ($P<0.05$) with both extruded and WCS rations supplying more ether extract and gross energy than the control ration. The fatty acid composition of the oil from the whole canola seed used in the experiments described in manuscripts 1 and 2 is shown in table 23.

When compared to the proximate analysis of the rations fed the actual intakes by the cows showed that the orts were random and little or no sorting of feed occurred. This is evidenced when reviewing the crude protein, A.D.F. and ether extract percentages of the dry matter consumed.

Table 22: Summary of Daily Dry Matter, Crude Protein, Ether Extract, Acid Detergent Fiber and Gross Energy Intakes of Cows Fed the Control, Extruded or WCS Rations. (Values are on a 100% D.M. basis).

Nutrient	Ration			
	Control	Extruded	WCS	SE**
Dry matter (kg/day)	17.1	18.4	19.9	0.03
Crude protein (g/day)	3230	3446	3730	38
Crude protein (%)	18.8	18.8	18.7	0.03
Acid detergent fiber (g/day)	3416a*	3769ab	4115b	44
A.D.F. (%)	19.9	20.4	20.7	0.05
Ether extract (g/day)	380a	1012b	1143b	18
Ether extract (%)	2.2a	5.5b	5.8b	0.08
Gross energy (Mcal/day)	74.4a	83.2ab	89.0b	0.9

*Means within a row with different superscripts are different $P < 0.05$.
** standard error

Table 23: Fatty Acid Composition of the Whole Canola Seed Used in the Experiments Decribed in Manuscripts 1 and 2.

Fatty Acid	Weight Percent of Whole Canola Seed Oil.
C 16:0*	8.418
C 16:1	0.689
C 18:0	2.607
C 18:1	44.703
C 18:2	24.670
C 18:3	11.744
C 20:0	1.371
C 20:1	3.467
C 22:0	0.695
C 22:1	1.295
C 24:0	0.347

* first number denotes the number of carbon atoms, the number after the colon denotes the number of double bonds.

Manuscript 1.Discussion.

The digestibility of the WCS could have been affected by the age (stage of maturity) of the lambs. Schneider and Flatt (1975) suggest that young adult animals or growing animals reaching maturity be used in digestibility trials. It should be noted that the results of this digestibilty trial are applicable to sheep and could only be used to give an indication as to whether WCS is digestible, in its unprocessed form, by other ruminants. These data may not apply to cattle as suggested by the performance of the cows fed the WCS in experiment 2, Manuscript 2 where the fatty acid profile shows that there was a change, probably due to the added WCS, but this change was not a large as that seen with the extruded ration. Also the data of Sharma et al.(1986) show that WCS is poorly, if at all, digested by calves.

In experiment 2 the cows used in the first and second blocks were in mid to late lactation. There appeared to be no respocne to the top-dressed canola seed in these blocks. Because cows were not weighed on this experiment it is difficult to determine if the increased energy that could be supplied by the WCS was used to increase weight gains or if the WCS was not well digested and simply passed through the cows. Washing of several wet fecal samples of cows fed the high level of top-dressed WCS showed some WCS had passed through the cows. Upon inspection of the seeds they were small and shrivaled and appeared the same as the frost damaged seeds prior to feeding.

When cows in the first trimester of lactation, past peak milk yield, were used in blocks 3 and 4 there appeared to be a production response to the top-dressed WCS diet. This was evidenced by a significant difference in the blocks in the analysis of variance determination.

Manuscript 2.Discussion.

The use of nylon bags to determine the relative degadability between feedstuffs is a quick and reasonably accurate method. In this experiment it was the intent to rank the WCS and the extruded products as to theeffect of processing and the suitability of the extruded product. The limitation of animal numbers and time hampered any further investigations. The replication of the limited data obtained for the dry matter and crude protein losses of the three rations used in experiment 2 would have added valuable insight to the results.

In experiment 2 the cows received the rations as total mixed rations. The rations were formulated to contain at least 21% A.D.F. on a 100% D.M. basis. The discepancy between the actual results and those formulated are probably due to the use of the 1981 crop year A.D.F. value for the fababean silage, which was 1.4% higher than the 1982 crop year A.D.F. which was actually used. Also the hay was core sampled and this core sample was used in formulating the rations. The average determined value of the A.D.F. in the hay used was 1.1% lower than the core sample. These two findings are the largest causes for the lower A.D.F. values found. This did not appear to affect the fat percent as the control and WCS rations had an average of about 3.3% fat. The average fat percent for the herd was 3.7% from the 1981 R.O.P. test.

The amount of added oil supplied by the extruded ration was on average 632 grams per day while the WCS ration supplied an average of 763 grams more per day.The amount of oil added by the WCS is comparable to the amount fed by Jentsch et al. (1972) in his first series where approximately 5% rapeseed oil was added to the ration and suppied 700-800 grams of oil. The digestibility of the oil ranged between 91.6 and 95.8% in the diets fed. But even at the 5% inclusion rate the added oil depressed feed intake, milk yield and energy corrected milk yield. The results of this experiment contrast that of Jentsch et al. (1972) because we saw a significant increase in dry matter intake of the WCS ration.

This experiment would support the findings of Steele (1985) when he suggests that it is the free oil that causes the milk fat percent depression and that intracellular oil does not have this effect. The WCS oil could be considered as truly intra-cellular but whether the extruded canola is intra-cellular is difficult to ascertain. Steele (1985) only commented that crushed soybeans provided the intracellular oil, but did not indicate how the soybeans were crushed.

The increase in dry matter intake of the WCS in its unprocessed form in both this experiment and experiment 2 of manuscript 1 have not been noticed in other trials where lipid has been added to the diet. The general consensus is that added lipid in the free form will decrease dry matter intake but that energy intake will remain constant or be slightly improved. Even when protected lipids are fed there is no general increase in dry matter intake but an increase in energy intake will be observed. From experiment 1 it can be seen that the WCS is relatively poorly digested in the rumen. The WCS by being virtually inert in the rumen may enhance intake as it is not bulky (bushel weight =60 pounds). This could partially explain the improvement in dry matter intake. But if the WCS were truely inert, it would be reasonable to expect an increase of no more than 7.9% in dry matter intake (WCS inclussion of the ration) when the observed increase was approximately 16.3% or more than double the amount of WCS that were included in the ration. This is also noted when the dry matter intake of the rations is viewed as a percentage of live body weight. Both added oil rations increased (P<0.05) the amount of feed consumed, by approximately 0.4% of the live body weight.

Both the WCS and the extruded canola seed can be used in the rations of lactating dairy cows in early lactation. The extruded canola seed would decrease the milk fat percent, but both forms of canola seed increased dry matter intake which can be beneficial in early lactation.

The WCS would warrant further investigation. If the seed coat could be softened, perhaps by soaking or other process that would not damage it, to allow for better post-ruminal degradation it could be a potentially more usefull product. The extruded seed was most probably ruminally available and this could have been the reason for the detrimental effect upon milk fat percent. With less processing this effect could be overcome.

GENERAL SUMMARY.

1. The WCS in both experiments conducted with dairy cows caused an increase in the dry matter intake.

2. The WCS was found to be digestible by ruminating ram lambs but this may not be applicable to dairy cows.

3. The canola seed extruded at 107 C caused a depression in

the milk fat percent and an increase in milk yield and milk lactose yield.

4. The WCS showed lower dry matter and crude protein losses from nylon bags incubated in the rumen of a steer than that obsreved for the canola seed-barley mixture extruded at various temperatures.

5. Neither the WCS nor the extruded canola seed had any detrimental effects upon animal health.

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APPENDIX

Multivariate Analysis of Variance, Raw milk yield data and regression co-efficients generated, Manuscript 2, Experiment 2.

Table 1: Raw Milk Yield Data.

OBS	COW	RAT	DCAR	TRAM	AGE	MY1	MY2	MY3	MY4	MY5	MY6	MY7	MY8	MY9	MY10	MY11	MY12	CONTRST1	CONTRST2	CONTRST3	CONTRST4	CONTRST5
1	1	1	1	1	2	16.72	20.19	24.58	26.10	27.82	27.37	28.70	28.73	29.45	28.80	29.12	28.83	1	1	1	1	1
2	2	1	1	1	1	16.40	18.31	18.93	20.55	18.86	18.54	17.99	18.05	17.34	16.92	16.98	16.85	1	1	1	1	1
3	3	1	1	1	1	15.26	21.23	21.59	24.35	24.61	23.54	23.57	25.26	21.92	21.20	21.69	21.95	1	1	1	1	1
4	4	1	1	2	2	19.87	22.66	22.50	21.85	22.08	23.08	23.25	22.40	20.00	20.55	20.71	19.74	1	1	1	1	1
5	5	1	1	2	1	18.57	20.58	21.33	22.01	23.25	24.54	26.01	25.46	25.52	24.84	22.60	24.94	1	1	1	1	1
6	6	1	1	2	2	37.80	39.19	40.55	39.35	40.58	40.01	39.09	38.99	38.21	38.02	33.47	30.81	1	1	1	1	1
7	7	1	2	1	2	25.36	24.38	25.32	24.90	24.35	24.03	24.42	25.39	26.20	24.84	27.05	27.73	1	1	-1	-1	-1
8	8	1	2	2	1	18.70	19.06	19.22	20.23	19.80	20.58	19.84	19.64	19.68	20.46	20.68	19.90	1	1	-1	-1	-1
9	9	1	2	1	2	34.71	35.78	36.40	36.98	36.10	35.75	34.58	31.90	31.46	30.23	29.03	28.38	1	1	-1	-1	-1
10	10	1	2	1	1	19.42	21.69	22.44	23.08	23.93	23.86	23.54	23.31	23.86	24.06	23.57	24.19	1	1	-1	-1	-1
11	11	1	2	1	1	15.81	17.30	17.86	17.04	18.47	17.73	17.92	17.53	17.34	17.89	17.89	17.63	1	1	-1	-1	-1
12	12	1	2	2	2	36.62	38.41	40.26	41.36	41.27	42.24	41.95	42.08	41.75	41.66	40.80	39.38	1	1	-1	-1	-1
13	37	1	1	2	1	15.49	17.99	19.16	18.67	17.79	19.29	19.42	18.34	19.03	18.31	19.51	19.06	1	1	1	1	1
14	13	2	1	1	1	24.71	26.98	26.53	27.04	26.92	25.29	26.27	27.70	27.99	25.26	27.60	28.93	-1	0	1	-1	0
15	14	2	1	1	1	15.84	18.06	20.03	20.68	21.75	20.55	22.83	23.47	22.53	23.96	21.79	22.66	-1	0	1	-1	0
16	15	2	1	1	2	25.20	28.44	32.53	35.81	36.20	35.88	36.14	35.52	37.24	38.57	37.01	35.10	-1	0	1	-1	0
17	16	2	1	2	2	29.29	33.67	37.40	44.58	43.31	40.68	44.29	44.87	43.99	44.22	43.28	44.32	-1	0	1	-1	0
18	17	2	1	2	1	27.70	29.06	31.07	33.64	34.58	33.34	33.54	33.54	33.21	32.44	32.66	30.42	-1	0	1	-1	0
19	18	2	1	2	2	32.53	32.70	33.96	35.10	34.48	35.75	35.62	34.38	36.23	35.26	28.80	31.46	-1	0	1	-1	0
20	19	2	2	1	2	30.03	35.55	40.23	38.18	39.32	40.03	41.20	41.14	42.56	42.79	42.18	38.99	-1	0	-1	1	0
21	20	2	2	1	1	18.38	17.96	19.61	22.37	23.15	23.67	22.73	23.02	23.83	23.08	23.67	23.80	-1	0	-1	1	0
22	21	2	2	1	1	23.25	22.08	23.96	24.94	25.68	26.36	26.98	26.14	28.15	28.41	26.62	27.76	-1	0	-1	1	0
23	22	2	2	2	2	34.54	39.32	39.54	38.38	42.21	43.34	41.56	41.46	43.47	43.70	42.53	41.08	-1	0	-1	1	0
24	23	2	2	2	2	40.13	42.30	43.12	43.60	42.44	41.95	43.93	45.13	44.03	43.83	43.83	42.66	-1	0	-1	1	0
25	24	2	2	2	2	27.01	30.78	34.03	33.51	35.91	36.56	35.94	37.92	37.37	36.40	39.25	39.16	-1	0	-1	1	0
26	25	3	1	1	2	32.04	34.38	33.93	34.03	31.53	35.46	36.49	36.79	34.19	35.10	33.54	31.72	0	-1	1	0	-1
27	26	3	1	1	2	25.39	24.06	23.64	28.77	30.71	30.55	31.36	30.65	28.28	29.54	28.93	27.96	0	-1	1	0	-1
28	27	3	1	1	1	29.68	32.66	26.14	21.20	27.56	29.22	30.91	30.29	30.71	30.80	30.16	31.36	0	-1	1	0	-1
29	28	3	1	2	1	21.59	23.25	24.68	24.35	24.84	22.79	23.12	24.68	25.39	25.10	24.35	25.29	0	-1	1	0	-1
30	29	3	1	2	2	27.92	27.60	28.28	28.90	27.96	29.90	29.64	28.90	30.94	31.14	29.16	29.16	0	-1	1	0	-1
31	30	3	1	2	2	29.16	31.40	31.46	30.10	29.97	28.86	28.34	28.38	28.67	28.38	24.61	25.03	0	-1	1	0	-1
32	31	3	2	1	2	30.35	29.25	27.56	29.32	25.32	27.14	26.62	25.88	26.20	23.15	25.68	26.53	0	-1	-1	0	1
33	32	3	2	1	2	34.74	29.45	36.36	36.59	37.47	37.27	35.39	36.20	35.97	35.97	37.04	35.20	0	-1	-1	0	1
34	33	3	2	1	1	11.07	11.90	13.38	14.19	14.64	13.54	14.40	14.16	13.41	14.22	14.12	13.38	0	-1	-1	0	1
35	34	3	2	2	1	14.71	20.36	20.13	22.56	23.12	24.54	24.35	24.48	25.46	26.17	27.18	25.91	0	-1	-1	0	1
36	35	3	2	2	2	39.94	41.42	43.25	43.99	41.17	42.21	40.32	41.72	43.44	42.73	41.66	41.92	0	-1	-1	0	1
37	36	3	2	2	1	19.06	21.40	22.63	22.04	22.18	24.71	23.96	25.20	26.17	24.61	25.49	26.01	0	-1	-1	0	1

Table 2: Regression Co-efficients Generated from Raw Data.

OBS	B0	B1	B2	B3	B4	B5	C0	C1	C2	C3	C4
1	11.0836	5.976	-0.4972	-0.0415	0.00817	-0.0003225	10.1334	7.3877	-1.1436	0.08251	-0.002307
2	12.8886	4.260	-0.8702	0.0579	-0.00028	-0.0000647	12.6981	4.5434	-0.9998	0.08276	-0.002383
3	5.2850	13.690	-4.1463	0.6464	-0.05045	0.0015222	9.7703	7.0267	-1.0957	0.06125	-0.000982
4	15.5955	6.545	-2.3743	0.4128	-0.03411	0.0010524	18.6966	1.9373	-0.2651	0.00824	0.000089
5	12.7368	8.874	-3.7673	0.7824	-0.07185	0.0023547	19.6754	-1.4347	0.9520	-0.12282	0.004676
6	34.8086	3.885	-1.0405	0.1296	-0.00728	0.0001044	35.1164	3.4279	-0.8311	0.08947	-0.003888
7	24.6577	0.936	-0.5409	0.1050	-0.00848	0.0002579	25.4177	-0.1935	-0.0240	0.00587	-0.000100
8	20.6523	-3.437	1.9223	-0.3973	0.03490	-0.0010989	17.4142	1.3738	-0.2801	0.02519	-0.000816
9	34.3768	-0.272	0.8353	-0.2218	0.01926	-0.0005593	32.7288	2.1761	-0.2856	-0.00679	0.001085
10	16.4182	3.715	-0.7168	0.0650	-0.00281	0.0000487	16.5618	3.5015	-0.6191	0.04629	-0.001221
11	13.9855	2.378	-0.4919	0.0384	-0.00063	-0.0000288	13.9005	2.5046	-0.5497	0.04945	-0.001570
12	34.2705	2.348	0.0243	-0.0776	0.00948	-0.0003578	33.2160	3.9141	-0.6929	0.06000	-0.002153
13	9.8741	7.903	-2.6152	0.4042	-0.02940	0.0008132	12.2702	4.3426	-0.9855	0.09154	-0.002969
14	17.2823	11.160	-4.5306	0.8112	-0.06602	0.0019991	23.1728	2.4084	-0.5242	0.04271	-0.001052
15	8.2527	10.653	-3.7143	0.6290	-0.04912	0.0014183	12.4319	4.4437	-0.8719	0.08379	-0.003029
16	23.4127	-0.639	2.9586	-0.7804	0.07616	-0.0025630	15.8605	10.5817	-2.1780	0.20497	-0.007139
17	22.4714	6.642	-0.0722	-0.1684	0.01979	-0.0006719	20.4916	9.5833	-1.4187	0.08985	-0.002042
18	29.2409	-4.162	3.1971	-0.6869	0.05995	-0.0018707	23.7287	4.0278	-0.5521	0.03231	-0.000848
19	27.8509	6.723	-2.9327	0.6013	-0.05448	0.0017483	33.0026	-0.9309	0.5712	-0.07078	0.002342
20	16.9177	17.498	-5.1591	0.7023	-0.04244	0.0008909	19.5430	13.5977	-3.3735	0.35976	-0.013490
21	23.3386	-8.758	4.4791	-0.8288	0.06586	-0.0019010	17.7370	-0.4357	0.6691	-0.09792	0.004072
22	25.7514	-4.473	2.0811	-0.3501	0.02618	-0.0007322	23.5939	-1.2674	0.6137	-0.06862	0.002382
23	29.0118	7.799	-2.1480	0.3018	-0.01989	0.0004798	30.4257	5.6980	-1.1863	0.11736	-0.004291
24	32.5759	10.879	-4.0916	0.6874	-0.05184	0.0014310	36.7926	4.6143	-1.2236	0.13721	-0.005336
25	20.5486	8.201	-1.9644	0.2645	-0.01861	0.0005314	22.1145	5.8742	-0.8994	0.06022	-0.001343
26	24.5350	12.013	-5.3135	1.0148	-0.08474	0.0025399	32.0192	0.8935	-0.2232	0.03836	-0.002192
27	37.7232	-19.203	8.4281	-1.4430	0.10826	-0.0029914	28.9085	-6.1071	2.4328	-0.29291	0.011037
28	24.1645	12.835	-7.9078	1.7380	-0.15672	0.0049784	38.8343	-8.9602	2.0698	-0.17591	0.005082
29	15.1677	8.723	-2.9521	0.4419	-0.02998	0.0007570	17.3983	5.4095	-1.4350	0.15093	-0.005383
30	27.8400	-0.139	0.1259	-0.0217	0.00251	-0.0001201	27.4861	0.3871	-0.1148	0.02443	-0.001392
31	20.6168	12.728	-5.0774	0.8564	-0.06517	0.0018249	25.9943	4.7381	-1.4199	0.15477	-0.005861
32	30.6986	0.267	-0.8693	0.2341	-0.02442	0.0008842	33.3042	-3.6043	0.9029	-0.10589	0.004313
33	47.5377	-22.080	10.4438	-1.9760	0.16322	-0.0049087	33.0733	-0.5905	0.6059	-0.08886	0.003684
34	10.8214	-0.662	1.1128	-0.2752	0.02570	-0.0008327	8.3678	2.9837	-0.5560	0.04492	-0.001358
35	8.7691	7.763	-1.5791	0.1420	-0.00386	-0.0000551	8.6069	8.0037	-1.6895	0.16316	-0.005651
36	33.4064	8.481	-2.5964	0.3307	-0.01778	0.0003114	34.3239	7.1176	-1.9724	0.21097	-0.007656
37	12.1209	10.255	-4.0025	0.7308	-0.06012	0.0018127	17.4623	2.3197	-0.3696	0.03390	-0.001204

Table 3: MANOVA Testing Equivalent Milk Yield Profiles.

```
MANOVA TEST CRITERIA FOR THE HYPOTHESIS OF NO OVERALL RAT EFFECT
H = TYPE III SS&CP MATRIX FOR: RAT
E = ERROR SS&CP MATRIX
P = RANK OF (H+E)         =        5
Q = HYPOTHESIS DF         =        2
NE= DF OF E               =       24
S = MIN(P,Q)              =        2
M = .5(ABS(P-Q)-1)        =      1.0
N = .5(NE-P)              =      9.5
----------------------------------------------------------------------------------------------------------
WILKS' CRITERION        L = DET(E)/DET(H+E) =       0.39620785     (SEE RAO 1973 P 555)
          EXACT F = (1-SQRT(L))/SQRT(L)*(NE+Q-P-1)/P                WITH 2P AND 2(NE+Q-P-1) DF
                F(10,40) =      2.35       PROB > F = 0.0269
----------------------------------------------------------------------------------------------------------
PILLAI'S TRACE          V = TR(H*INV(H+E)) =        0.73308101     (SEE PILLAI'S TABLE #2)
          F APPROXIMATION = (2N+S)/(2M+S+1) * V/(S-V)               WITH S(2M+S+1) AND S(2N+S) DF
                F(10,42) =      2.43       PROB > F = 0.0219
----------------------------------------------------------------------------------------------------------
HOTELLING-LAWLEY TRACE = TR(E**-1*H) =              1.19761202     (SEE PILLAI'S TABLE #3)
          F APPROXIMATION = (2S*N-S+2)*TR(E**-1*H)/(S*S*(2M+S+1)) WITH S(2M+S+1) AND 2S*N-S+2 DF
                F(10,38) =      2.28       PROB > F = 0.0334
----------------------------------------------------------------------------------------------------------
ROY'S MAXIMUM ROOT CRITERION =                      0.77839691     (SEE AMS VOL 31 P 625)
          FIRST CANONICAL VARIABLE YIELDS AN F UPPER BOUND
                F(5,21) =       3.27       (UPPER BOUND)
----------------------------------------------------------------------------------------------------------
```

Table 4: MANOVA Testing Parallel Milk Yield Profiles.

```
MANOVA TEST CRITERIA FOR THE HYPOTHESIS OF NO OVERALL RAT EFFECT

H = TYPE III SS&CP MATRIX FOR: RAT
E = ERROR SS&CP MATRIX
P = RANK OF (H+E)       =       4
Q = HYPOTHESIS DF       =       2
NE= DF OF E             =      24
S = MIN(P,Q)            =       2
M = .5(ABS(P-Q)-1)      =     0.5
N = .5(NE-P)            =    10.0
--------------------------------------------------------------------------------
WILKS' CRITERION       L = DET(E)/DET(H+E) =      0.52448620    (SEE RAO 1973 P 555)
       EXACT F = (1-SQRT(L))/SQRT(L)*(NE+Q-P-1)/P               WITH 2P AND 2(NE+Q-P-1) DF
              F(8,42) =      2.00       PROB > F = 0.0702
--------------------------------------------------------------------------------
PILLAI'S TRACE         V = TR(H*INV(H+E)) =       0.55069027    (SEE PILLAI'S TABLE #2)
       F APPROXIMATION = (2N+S)/(2M+S+1) * V/(S-V)              WITH S(2M+S+1) AND S(2N+S) DF
              F(8,44) =      2.09       PROB > F = 0.0573
--------------------------------------------------------------------------------
HOTELLING-LAWLEY TRACE = TR(E**-1*H) =            0.76329430    (SEE PILLAI'S TABLE #3)
       F APPROXIMATION = (2S*N-S+2)*TR(E**-1*H)/(S*S*(2M+S+1)) WITH S(2M+S+1) AND 2S*N-S+2 DF
              F(8,40) =      1.91       PROB > F = 0.0856
--------------------------------------------------------------------------------
ROY'S MAXIMUM ROOT CRITERION =                    0.42982383    (SEE AMS VOL 31 P 625)
       FIRST CANONICAL VARIABLE YIELDS AN F UPPER BOUND
              F(4,22) =      2.36       (UPPER BOUND)
--------------------------------------------------------------------------------
```

Table 5: MANOVA Testing Equivalent Curvature of Milk Yield Profiles.

```
MANOVA TEST CRITERIA FOR THE HYPOTHESIS OF NO OVERALL RAT EFFECT
H = TYPE III SS&CP MATRIX FOR: RAT
E = ERROR SS&CP MATRIX
P = RANK OF (H+E)          =         2
Q = HYPOTHESIS DF          =         2
NE= DF OF E                =        24
S = MIN(P,Q)               =         2
M = .5(ABS(P-Q)-1)         =      -0.5
N = .5(NE-P)               =      11.0
--------------------------------------------------------------------------------------------------------
WILKS' CRITERION          L = DET(E)/DET(H+E) =         0.73260485      (SEE RAO 1973 P 555)
        EXACT F = (1-SQRT(L))/SQRT(L)*(NE+Q-P-1)/P                      WITH 2P AND 2(NE+Q-P-1) DF
              F(4,46) =       1.94      PROB > F = 0.1205
--------------------------------------------------------------------------------------------------------
PILLAI'S TRACE            V = TR(H*INV(H+E)) =          0.27392790      (SEE PILLAI'S TABLE #2)
        F APPROXIMATION = (2N+S)/(2M+S+1) * V/(S-V)                     WITH S(2M+S+1) AND S(2N+S) DF
              F(4,48) =       1.90      PROB > F = 0.1250
--------------------------------------------------------------------------------------------------------
HOTELLING-LAWLEY TRACE = TR(E**-1*H) =                  0.35607519      (SEE PILLAI'S TABLE #3)
        F APPROXIMATION = (2S*N-S+2)*TR(E**-1*H)/(S*S*(2M+S+1)) WITH S(2M+S+1) AND 2S*N-S+2 DF
              F(4,44) =       1.96      PROB > F = 0.1176
--------------------------------------------------------------------------------------------------------
ROY'S MAXIMUM ROOT CRITERION =
                                                        0.32896883      (SEE AMS VOL 31 P 625)
        FIRST CANONICAL VARIABLE YIELDS AN F UPPER BOUND
              F(2,24) =       3.95      (UPPER BOUND)
--------------------------------------------------------------------------------------------------------
```

Table 6: MANOVA Testing Equivalent Milk Yield Profiles Between Control and Extruded Rations.

```
MANOVA TEST CRITERIA FOR THE HYPOTHESIS OF NO OVERALL CONTRST1 EFFECT

H = TYPE III SS&CP MATRIX FOR: CONTRST1
E = ERROR SS&CP MATRIX
P = RANK OF (H+E)     =        5
Q = HYPOTHESIS DF     =        1
NE= DF OF E           =       31
S = MIN(P,Q)          =        1
M = .5(ABS(P-Q)-1)    =      1.5
N = .5(NE-P)          =     13.0
--------------------------------------------------------------------------------------------------

WILKS' CRITERION        L = DET(E)/DET(H+E) =       0.68012063      (SEE RAO 1973 P 555)

         EXACT F = (1-L)/L*(NE+Q-P)/P                               WITH P AND NE+Q-P DF

                 F(5,27) =      2.54       PROB > F = 0.0523
--------------------------------------------------------------------------------------------------

PILLAI'S TRACE          V = TR(H*INV(H+E)) =        0.31987937      (SEE PILLAI'S TABLE #2)

         F APPROXIMATION = (2N+S)/(2M+S+1) * V/(S-V)                WITH S(2M+S+1) AND S(2N+S) DF

                 F(5,27) =      2.54       PROB > F = 0.0523
--------------------------------------------------------------------------------------------------

HOTELLING-LAWLEY TRACE = TR(E**-1*H) =              0.47032741      (SEE PILLAI'S TABLE #3)

         F APPROXIMATION = (2S*N-S+2)*TR(E**-1*H)/(S*S*(2M+S+1)) WITH S(2M+S+1) AND 2S*N-S+2 DF

                 F(5,27) =      2.54       PROB > F = 0.0523
--------------------------------------------------------------------------------------------------

ROY'S MAXIMUM ROOT CRITERION =                      0.47032741      (SEE AMS VOL 31 P 625)

         FIRST CANONICAL VARIABLE YIELDS AN F UPPER BOUND

                 F(5,27) =      2.54       PROB > F = 0.0523
--------------------------------------------------------------------------------------------------
```

Table 7: MANOVA Testing Equivalent Milk Yield Profiles Between Control and WCS Rations.

```
MANOVA TEST CRITERIA FOR THE HYPOTHESIS OF NO OVERALL CONTRST2 EFFECT
H  = TYPE III SS&CP MATRIX FOR: CONTRST2
E  = ERROR SS&CP MATRIX
P  = RANK OF (H+E)        =        5
Q  = HYPOTHESIS DF        =        1
NE= DF OF E               =       31
S  = MIN(P,Q)             =        1
M  = .5(ABS(P-Q)-1)       =      1.5
N  = .5(NE-P)             =     13.0
--------------------------------------------------------------------------------------------------------
WILKS' CRITERION         L = DET(E)/DET(H+E) =        0.78023852      (SEE RAO 1973 P 555)
        EXACT F = (1-L)/L*(NE+Q-P)/P                                  WITH P AND NE+Q-P DF
               F(5,27) =      1.52      PROB > F = 0.2164
--------------------------------------------------------------------------------------------------------
PILLAI'S TRACE           V = TR(H*INV(H+E)) =         0.21976148      (SEE PILLAI'S TABLE #2)
        F APPROXIMATION = (2N+S)/(2M+S+1) * V/(S-V)                   WITH S(2M+S+1) AND S(2N+S) DF
               F(5,27) =      1.52      PROB > F = 0.2164
--------------------------------------------------------------------------------------------------------
HOTELLING-LAWLEY TRACE = TR(E**-1*H) =                0.28165936      (SEE PILLAI'S TABLE #3)
        F APPROXIMATION = (2S*N-S+2)*TR(E**-1*H)/(S*S*(2M+S+1)) WITH S(2M+S+1) AND 2S*N-S+2 DF
               F(5,27) =      1.52      PROB > F = 0.2164
--------------------------------------------------------------------------------------------------------
ROY'S MAXIMUM ROOT CRITERION =                        0.28165936      (SEE AMS VOL 31 P 625)
        FIRST CANONICAL VARIABLE YIELDS AN F UPPER BOUND
               F(5,27) =      1.52      PROB > F = 0.2164
--------------------------------------------------------------------------------------------------------
```