THE UNIVERSITY OF MANITOBA

GRAIN BASED DIETS FOR PINK VEAL PRODUCTION

BY

ROSARIA CAMPBELL

A THESIS SUBMITTED TO THE FACULTY
OF GRADUATE STUDIES IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

DEPARTMENT OF ANIMAL SCIENCE

WINNIPEG, MANITOBA

MARCH, 1990

ISBN 0-315-71786-6

GRAIN BASED DIETS FOR PINK VEAL PRODUCTION

BY

ROSARIA CAMPBELL

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

ABSTRACT

An experiment was conducted to determine how a barley-based concentrate diet could be manipulated to equal a corn diet for the production of pink veal.

In the growth trial forty-five male Holstein calves aged 7 - 13 d were allotted at random to one of five diets formulated to contain one of the following as the major source of energy: corn, barley, barley + 3.5% canola oil (barley + oil), barley + 9.7% Jet Sploded Canola Seed (barley + JSCS), or a 50-50 mixture of barley + wheat (barley + wheat). Two calves per treatment were slaughtered at 180 kg live weight and 7 calves per treatment were slaughtered at 210 kg live weight.

Average daily gain (ADG) and the number of days from 6 weeks on test to slaughter were similar ($P>0.05$) for diets containing corn, barley, barley + oil and barley + JSCS. ADG was lower on the diet containing barley + wheat than on diets containing barley + canola oil ($P<0.05$) or barley + JSCS ($P<0.10$). The calves fed the diet containing barley + wheat took longer (24 d; $P<0.05$) to reach slaughter weight than did calves fed diets containing barley + oil or barley + JSCS. Daily feed intakes differed among diets ($P<0.05$) and feed efficiency ratios tended to differ among diets ($P<0.10$). Calves consumed 0.2 - 0.3 kg less feed per day on corn and barley + wheat diets than on barley, barley + oil or barley + JSCS diets. Calves fed barley and barley + wheat diets required 10 - 18% more feed kg^{-1} than did calves fed corn, barley + oil or barley + JSCS.

A digestibility trial was conducted at 12 - 13 weeks of age with 6 calves per treatment using partial collection with a Cr_2O_3 marker. The apparent digestibility coefficients for dry matter (DM), gross energy (GE), crude protein (CP) and total lipids (TL) did not differ ($P>0.05$) among diets. The

addition of JSCS to the barley diet increased ($P<0.05$) the digestibility of acid detergent fiber (ADF) above that of the barley diet and the barley + wheat diet and had a higher ($P<0.05$) digestibility of ADF than the corn or barley diets ($P<0.05$). Rumen pH, rumen ammonia nitrogen (RAN), rumen volatile fatty acid (VFA) proportions, total rumen volatile fatty acids, and blood urea nitrogen (BUN) did not differ ($P>0.05$) among diets.

Dry matter and crude protein disappearance from nylon bags was determined by incubating 2 bags per diet containing 5.0 g of ground (1mm) sample in each of 2 steers for 0, 4, 8 and 36 hours. The disappearance of DM and CP was less rapid for corn diets than for any of the barley-based diets. The effective degradability of DM was lower ($P<0.05$) for diets containing corn than for any of the barley diets, and the effective degradability of DM was lower ($P<0.05$) for the barley + oil diet than for the barley or barley + wheat diets. The effective degradability of CP differed ($P<0.01$) among diets and patterns were similar to those for the effective degradability of DM.

Carcass weight, dressing %, kidney fat weight, rib eye area at the 13th rib, the chemical composition of the 12th rib, meat colour at the brisket and 13th rib, pH at the 13th rib and blood hematocrit and hemoglobin 3 d prior to slaughter did not differ ($P>0.05$) among diets. The proportions of C18:3 increased and C16:0 decreased in the extracted fat of the longissimus dorsi muscle at the 12th rib by the addition of and JSCS to the barley diet.

In a sensory evaluation trial roasts were randomly selected from 6 calves in each dietary treatment for comparison to purchased roasts from milk-fed calves. Panelists evaluated the roasts for tenderness, juiciness, flavour pleasantness and flavour intensity and mechanical measurements of meat quality were made on cooked samples from each roast.

Panelists rated the milk fed veal and veal from calves fed barley + wheat

as being most tender ($P<0.05$) and meat from calves fed barley + JSCS was judged to be more tender than meat from calves fed corn ($P<0.05$). Panelists ratings for juiciness, flavour pleasantness and flavour intensity did not differ ($P>0.05$) among diets. The Instron measurement of meat tenderness indicated that the meat from calves fed barley + canola oil was less tender ($P<0.05$) than the meat from milk fed calves but other differences among diets were not significant. Press fluid % and cooking losses did not differ ($P>0.05$) among diets. Meat from milk fed calves was lighter in colour ($P<0.05$) and had more of a grayish tinge ($P<0.05$) than did meat from the grain fed calves.

ACKNOWLEDGEMENTS

I would like to extend a sincere thank you to my advisor, Dr. J.R. Ingalls, for his time, professional advice and encouragement in completing this program. I would also like to thank my committee members, Dr. K.M. Wittenberg, Dr. N.E. Stanger and Ms. R. Diamant for their time and efforts.

Special thanks go to Terri Garner, Laurel Mollison and Wendy Ralley for their help with data and sample collection and to the entire Glenlea dairy barn staff for the day-to-day care of the animals. I would also like to thank the campus barn, implement shed and feed mill staff for their assistance.

Dr. G.H. Crow and Shah Amal provided many hours of computer and statistical advice.

Special thanks to Tom Ward, Ricki Araneda, Peter Mills, Bogdan Slominski and Phil Charles for their expertise in laboratory analysis procedures and to the entire technical staff for their assistance in the lab.

The carcass trial was completed with the help of staff members at East West Packers in Winnipeg, Country Smoke House in St. Adolphe and the Agriculture Canada graders.

The sensory evaluation was conducted by Bev Fyfe (Department of Foods and Nutrition, University of Manitoba) with the help of the Foods and Nutrition graduate students.

Special thanks to Margaret Ann Baker for typing this thesis.

Funding for this project was provided by the Economic Regional Development Agreement (ERDA).

Dedicated to my parents,

Daniel and Sarah,

for their support.

TABLE OF CONTENTS

Page

Page

LIST OF TABLES

Page

Page

LIST OF FIGURES

LIST OF APPENDICES

Page

INTRODUCTION

Veal has traditionally been raised by feeding either high protein, high fat milk replacers or whole milk to young Holstein calves (<200 kg live weight). Recent work in Quebec and Ontario has led to the development of a feeding system whereby calves are raised from weaning at 6 - 8 weeks to slaughter at 200-230 kg on a high energy, corn-soybean meal based grower diet (Beauchemin, 1980; Drevjany, 1986b). This system of feeding produces carcasses that are of acceptable quality (Beauchemin, 1980; Latrille et al., 1983) although meat colour is darker than that of the milk fed calves (Beauchemin, 1980; Gardner and Wallentine, 1972; Bouchard et al., 1980). Feed costs for grain fed calves are about half the feed costs for milk or milk replacer fed calves (Beauchemin, 1980).

When fed with a 36% protein supplement whole corn gave better calf performance than did whole barley or whole oats (Latrille et al., 1983; Guertin et al., 1987a). Rolled barley has been shown to give comparable, but slightly less efficient gains than did whole corn (Beauchemin, 1980 Guertin et al., 1987a). Carcass quality is comparable on corn and barley diets (Beauchemin, 1980; Latrille et al., 1983). To date, no information is available on the use of wheat in grain-based diets for veal production.

Animal fat additions to barley diets for calves <136 kg have not improved live calf performance, but there is some evidence that levels of 3 - 6% added animal fat enhances the degree of carcass fattening (Gardner and Wallentine, 1972: Bouchard et al., 1980). Acidulated fatty acids (from canola oil processing) have improved calf performance on barley-based diets when calves in the above weight range were studied (Fisher, 1980). Work with heavier (200 kg) calves fed corn-based diets has shown added animal fat to be beneficial in improving feed efficiency but not in enhancing carcass fat (Stiles et al.,

1974). However, the effects of adding fats or oils to barley diets for calves slaughtered at the 200-230 kg weight range has not been studied. Furthermore, although extruded, whole fat canola seeds have been successfully incorporated into calf starters (Sharma et al., 1976), the effects of canola oil or heat-treated canola seeds in calf starters on carcass and eating quality has yet to be examined.

Therefore, the objectives of the studies were:

OBJECTIVES

1. To determine if the energy density of barley-based concentrates could be increased to result in calf performance similar to that documented for corn-based diets.
2. To determine if rumen degradability and/or apparent total tract digestibilities differed among the various experimental diets.
3. To determine if feeding the experimental diets had any effect on selected carcass parameters.
4. To compare the organoleptic properties of the meat from calves fed the experimental diets and to that of meat from milk-fed veal.

LITERATURE REVIEW

I. CALF PERFORMANCE

A. Calf Performance on Grain Based Diets as Compared to Milk Based Diets

Veal calves have traditionally been raised as pre-ruminants on milk or milk replacers containing high quality protein plus added fat. The raising of veal calves as ruminants on high energy calf starters is a relatively new concept.

Several authors have reported superior daily gains on milk based diets when compared to grain based diet. Kunz et al. (1969) fed a calf starter containing 10% added animal fat and 10% chopped alfalfa hay to a live weight of 136 kg and found that ADG was only 0.88 kg, compared with 1.11 kg for calves fed whole milk. Bouchard et al. (1980) reported average daily gains (ADG) to 113 kg of 0.553 kg and 0.717 kg for calves fed barley based concentrates and whole milk respectively. Jones et al. (1974) reported inferior daily gains on corn-based concentrates as compared to milk replacer, even when the crude protein (CP) level in the concentrate was as high as 22.8%.

Other authors have not found superior ADG on milk based diets. Jones et al. (1972) showed no difference in daily gains for calves fed either corn based calf starters containing 5% added fat and 19% CP or a 21% CP 21% crude fat commercial vealer ration to 104-110 kg live weight. Gardner and Wallentine (1972) showed inferior ADG for milk fed animals (0.77 kg/d vs. 0.87-1.09 kg/d) relative to grain fed animals. In a second trial, when calves were slaughtered at 125 kg and milk was fed to appetite, grain fed animals gained as well (1.12-1.26 kg/d) as milk fed (1.11 kg/d) calves. Burnside et al. (1972) showed no difference in daily gains when calves were raised to 128 kg on either a 23% CP milk replacer or a 25% CP calf concentrate.

Beauchemin (1980) fed calves to a constant carcass weight of 88 kg on milk replacer, whole corn plus a protein supplement or a barley based concentrate and

found no difference in daily gains (0.86, 0.80, 0.82 kg/d). When slaughtered to give a carcass weight of 108 kg, ADG on the milk replacer diet were slightly inferior to those on the diet of corn plus protein supplement (0.82 vs. 0.93 kg/d) with daily gains for calves on the barley based concentrate similar to those on the milk replacer diet. Similarly, Lachance et al. (1984) reported ADG of 1.0 kg/d regardless of whether milk replacer was offered for 6 wk, 12 wk or to slaughter at 90 kg live weight.

Even though similar daily gains can be obtained by feeding grain diets, more dry matter (DM) is required to produce a kilogram of live weight gain than is required with milk feeding. Grain DM consumption was 2.6-3.0 kg/d to a live weight of 110 kg and 2.9-3.7 kg/d to a live weight of 125 kg (Gardner and Wallentine 1972). Milk consumption by the milk fed controls was 8.0 and 12.8 kg/d to 110 and 125 kg live weight. Feed to gain ratios were 2.27-2.60 kg DM/kg gain for the grain fed and 1.24-1.38 kg DM/kg gain for the milk fed calves. When slaughter weights were less than 136 kg a similar range of feed efficiency ratios (2.5-3.0) has been reported by other authors for grain fed calves (Kunz et al. 1969; Burnside et al. 1972; Jones et al. 1972, 1974; Bouchard et al. 1980;). The range for milk fed animals in these trials was 1.37 to 2.0 kg DM/kg of live weight gain.

Work with calves slaughtered at heavier weights has also shown an increased requirement of feed per unit of gain when grain rather than milk was fed. Beauchemin (1980) obtained feed conversion ratios of 2.76-2.97 for grain fed calves at 167 kg live weight and these figures were 6% higher when animals were slaughtered at 204 kg live weight. The feeding of a milk replacer to live weights that yielded carcass weights that were comparable to those of the grain fed calves at 167 and 204 kg live weight resulted in feed to gain ratios of 1.65 and 1.86 kg DM/kg live weight gain. Lachance et al. (1984) found that when an

acidified milk replacer was offered from birth to either 6 wk, 12 wk or slaughter at 90 kg, the feed efficiency ratio was reduced from 2.64 to 2.54 to 2.42. They calculated that the consumption of 1 kg of milk replacer reduced by 1.24-1.34 kg the intake of free-choice concentrate without changing daily gains.

B. Effect of Cereal Source

Cereals most commonly available for use in Canada are corn, barley, oats and wheat. In Ontario and Quebec the practice has developed to feed a cereal grain and a 36% protein supplement separately to heavy calves after weaning. This system allows for more flexibility in choice of cereals and more flexibility to adjust cereal to supplement ratios to accommodate differing protein contents of the grains and differing animal needs during growth and fattening (Winters and Lachance 1983 and Drevjany 1986b).

Work by Latrille et al. (1983) showed that when fed whole, along with a protein supplement, corn gives acceptable calf performance to 200 kg live weight but performance on barley and oat diets is somewhat less. Daily gains were different on all three diets (1276.3, 1186.1 and 1019.6 g/d for corn, barley and oat diets, respectively). Total feed consumption was higher for barley (417.3 kg) and oats (426.2 kg) than for corn (362.9 kg) based diets, due to increased cereal consumption. As a result, feed to gain ratios were inferior for diets based on barley (3.50) and oats (3.70) than for those based on corn (2.86).

Figures reported by Kay et al. (1972), without statistics, further illustrate the relative values of these cereals for young calves. Daily gains for whole corn, barley, oats and wheat were 1.27, 1.22, 1.18 and 1.12 kg/d, respectively. Daily feed consumptions were 5.96, 6.32, 6.49 and 5.83 kg giving feed to gain ratios of 4.67, 5.18, 5.50 and 5.21.

Performance is somewhat improved when barley and oats are rolled. Work by Guertin et al. (1987a) showed that daily gains to 222 kg were not different on whole barley, whole corn or rolled barley (1.19 kg/d) but calves fed whole barley consumed more feed (4.11 kg/d) and required more feed to produce a kg of gain (3.49 kg) than did calves fed whole corn (3.37 kg feed/d; 2.83 kg feed/kg gain). Feed efficiency on rolled barley diets was 10% greater than on whole barley diets and similar to that on corn diets.

Beauchemin (1980) compared the performance of calves raised from 8 wk to market on a concentrate based on rolled barley with that of calves raised on ad libitum whole corn plus a protein supplement. Although calves fed whole corn tended to gain faster to a carcass weight of 88 kg (0.804 kg/d for barley concentrate vs. 0.817 kg/d for corn plus supplement) or 108 kg (0.818 kg/d for barley concentrate vs. 0.928 kg/d for corn plus supplement) the differences were not significant. At the lighter slaughter weight, feed efficiency ratios (kg feed/kg gain) were 2.76 for corn and 2.96 for barley based diets while at the heavier slaughter weights these values were 2.93 and 3.16. Although barley-concentrate fed calves tended to consume more feed, differences were not significant.

When rolled oats were fed to calves up to 12 wk, ADG were similar whether calves were given regular oats, high protein oats or ground corn (Shingoethe et al. 1982). The amount of feed required to produce a kg of gain was 8.6% higher for diets containing regular oats than for diets containing corn ($P<0.05$). Higher protein oats gave slightly, but not significantly higher feed to gain ratios than did corn.

Data on the use of wheat in calf starters are limited. The results of trials with calves up to 1970 were reviewed by Waldern (1970). They cited work by Asplund (1961) that showed better gains to 4 mo on a 20% CP calf starter

containing 64% wheat than on a commercial starter. Neither the CP content of the commercial starter, the ingredient composition of the commercial starter nor the form of the wheat was reported. Grieve and Winchell (1970) reported significantly reduced intakes and daily gains to 60 d on a barley based diet when compared to a wheat based diet. However, the CP content of the two diets differed by 6 percentage units (15.8% for the barley diet and 22.1% for the wheat diet) and the level of inclusion of the grains differed (68.5% wheat; 90.8% barley). Again the form of the grains was not reported.

Kay et al. (1972) reported data for calves from 100 to 400 kg that were raised on diets containing whole wheat, barley, oats or corn. No statistics were reported, but daily feed consumption appeared to be lower on the wheat based diet than on the barley or oat based diets (5.83, 6.32 and 6.49 kg, respectively). Consumption on corn based diets appeared to be intermediate at 5.96 kg/d. Daily gains on wheat, corn, barley and oat based diets were 1.12, 1.27, 1.22 and 1.18 kg. Thus it would appear that intakes and daily gains are somewhat impaired on wheat based diets.

Reduced feed intakes have been reported when wheat diets are fed to older animals. Oltjen et al. (1966) reported lower gains when yearling beef steers were fed diets containing 60 or 90% cracked wheat than when they were fed diets containing 60 or 90% cracked corn. Overall feed consumption and feed efficiency was not reduced, but during the last 28 days of the trial feed consumption on the high wheat diets was reduced. Over a 20 d period Fulton et al. (1979) reported an average intake of 6.60 k/d on wheat based diets, compared to 9.51 kg/d on corn based diets. Warner and Woods (1975) measured intake over 29 d and found that when wheat replaced 50 or 100% of corn in the diet feed intake was reduced by 13 and 24%. Koers et al. (1976) reported decreases in DM intake of 1-1.3% of body weight when the percent wheat based concentrate in the diet was increased from

0-92%, but when the concentrate was corn based, feed intake was not decreased when the percentage of concentrate in the diet was increased.

C. Effect of Added Fat

Adding fat to calf starters has been viewed as a way of increasing the energy density of the diet so as to either improve growth performance and/or carcass fat cover. In general, ADG are not improved with the addition of fat to the concentrate mix. Gardner and Wallentine (1972) found that calves gained at similar rates to 114 kg when raised on barley diets containing 0% (1.09 kg/d) or 5% (1.04 kg/d) added animal fat, when protein levels were adequate. In a second trial 5% added animal fat lowered daily gains to 125 kg by 0.12 kg but differences did not reach significance ($P>0.05$). Similar findings have been reported by Bouchard et al. (1980) using levels of 3 or 6% animal fat in barley diets, and Waldern and Fisher (1978) using 5% animal fat in barley diets, in that fat additions did not improve daily gains to 115 kg. Wrenn et al. (1979) reported a decrease in daily gains from 0.902 kg/d to 0.834 kg/d and 0.78 kg/d when 5% fat or 5% fat plus 1% cholesterol were added to corn based diets. Although added animal fats do not improve daily gains, 5% acidulated fatty acids (from canola oil refining) improved daily gains in barley diets by 5.5% ($P<0.05$) in the study by Waldern and Fisher (1978).

Work with older animals has shown similar trends. Stiles et al. (1973) reported daily gains to 200 kg of 1.02 kg and 0.92 kg for calves fed diets with 0 or 4% added fat ($P>0.05$). Chandler et al. (1968) in a study of fat and protein levels, found that corn oil additions of up to 4% did not affect growth of calves from 8 to 18 wk, but levels above 4% decreased growth rate. Miller (1959) also reported a depression in gains of 28% when 10% fat was added to calf starters.

Other authors (Hentges et al. 1954; Erwin et al. 1956) have reported no increase in daily gains when fat was added to fattening rations for older animals.

Results are variable with regards to the effects of added fat on feed consumption and feed efficiency. Miller (1959) reported a 38% decrease in feed consumption when 10% brown grease, 10% hydrogenated cottonseed oil, or 5% of both were added to calf starters. Similarly, Chandler et al. (1968) reported that for calves aged 8 to 18 wk there was a decrease in feed intake of 20 kg for each 2% increase in corn oil up to 8%. They noted that at low levels of soy protein additions (0 and 7%) decreased growth was associated with comparable decreases in feed intake, but at higher levels of soy protein (14, 21 and 28%), the decreased growth resulting from increasing dietary oil was greater than decreases in feed intake. These results suggest lower feed efficiency when oil is added to high protein diets.

Other authors have not reported large decreases in feed intake when fat was added to calf starters. Gardner and Wallentine (1972) found that 5% added fat in barley based diets decreased feed consumption non-significantly by 0-12%. However, feed conversion efficiency was improved by only 3.6-6.6% ($P>0.05$). Feed to gain ratios were 2.27 and 2.43 for diets containing 5 and 0% added fat when calves were raised to 114 kg, and 2.39 -2.47 (5%) and 2.48-2.58 (0%) when calves were raised to 125 kg. As daily gains were not improved, the extra digestible energy (DE) supplied by the added fat resulted in a (4-5%) increase in the amount of DE used to produce a kilogram of live weight gain.

Bouchard et al. (1980) did not find any difference in feed consumption when barley diets for calves slaughtered at 113 kg contained either 0, 3 or 6% added fat. Feed to gain ratios were similar on all diets, but 6% fat in the diet increased ($P<0.05$) by 8% the amount of total digestible nutrients (TDN) used to produce a kilogram of live weight gain. Similarly, Wrenn et al. (1979) found no

difference in feed consumption or feed efficiency to 115 kg when diets contained 0% fat, 5% animal fat or 5% animal fat plus 1% cholesterol. The amount of DE required per kilogram of gain was higher for diets containing added fat (9.8 kcal and 10.9 kcal) than for those containing no added fat (8.8 kcal).

Results with lighter weight calves appear to be better with acidulated fatty acids. Waldern and Fisher (1978) reported that while 5% tallow did not change feed intake or efficiency to 115 kg on barley diets, 5% acidulated fatty acids decreased feed consumption slightly (166.1 vs. 154.6 kg; $P>0.05$) and significantly decreased feed required per kg of gain (2.10 vs. 2.33, $P<0.05$) when compared to control diets.

Older animals appear to benefit from the addition of fat to grain diets. Stiles et al. (1974) found that 4% animal fat in corn rations for calves to 200 kg lowered feed consumption per day ($P>0.05$) from 3.88 to 3.42 kg. Feed efficiency ratios were improved significantly from 3.83 to 3.73. Work with fattening beef steers has also shown a decrease in the amount of feed required per unit of gain when fat is added to the diet (Hentges et al. 1954; Erwin et al. 1956).

Results investigating the effects of protected fats on calf performance are not consistent. Wrenn et al. (1973) found that 13% protected sunflower oil in calf starters decreased feed consumption compared with similar levels of unprotected oil. Decreased intakes resulted in sub-optimal protein intakes and daily gains. Fisher (1980) found that while 10% protected tallow reduced feed consumption 20% protected tallow did not affect consumption. Gains were slightly higher for diets containing 20% added fat ($P>0.05$) and feed conversion efficiency was better ($P<0.05$) for diets containing 10 or 20% protected fat. Fallon et al. (1986) reported that 5, 10 or 15% calcium soups of fat significantly lowered both feed consumption and daily gains after weaning.

The wide variety of results with regards to the effects of added fat on feed consumption could be related to the patterns of feeding in the experimental design. Heinrichs et al. (1982) showed that the length and size of initial meals were reduced when 10% fat was added to the ration but the number and size of spontaneous meals tended to increase, so that daily consumption of grain mixes was not different. de Visser et al. (1982) found that when cows were given concentrates containing 12% added fat the rate of intake declined and the concentrates were eaten in several small quantities.

When access to calf starters was limited, studies have shown decreased consumption with up to 5% added fat (Wrenn et al. 1979). Consumption of starter has also been decreased by added fat when it was offered once daily in amounts to ensure refusal (Caffrey et al. 1988). Other studies (Gardner and Wallentine 1972; Stiles et al. 1974; Waldern and Fisher 1978; Bouchard et al. 1980) have shown no effect of up to 5% added fat on feed consumption when calves were given free access to feed. Chandler et al. (1968) showed decreased consumption when calves were given free access to starters containing more than 4% fat, but this may also have been a palatability problem with higher fat levels. Miller (1959) showed that out of 10 calves in a cafeteria study 9 preferred a control starter to starters containing 10% fat.

D. Effects of Protein Level

The optimum protein level in calf starters would be of interest in veal production from a viewpoint of optimizing daily gains and carcass lean deposition at minimum cost. Gardner and Wallentine (1972) reported greater and more efficient gains to 110 kg when the CP content of the DM was 14.1% or 15.6% than when the CP was 12.6% of the DM. They reported that a ratio of 34 kcal of DE per gram of digestible protein (DP) optimised calf performance, and that at a wider

ratio (40.4:1) protein limited calf growth. These results are similar to those obtained for calves raised from 8 to 18 wk and similar live weights (Shurman and Kesler 1974). In this study 14.3% CP in the DM gave better gains and feed conversion (0.92 kg/d; 3.71 kg feed/kg gain) than did 11.5% CP (0.54 kg/d; 4.90 kg feed/kg gain) but 26.0% CP did not improve these parameters. The optimal DE:DP ratio in this study was 36.0:1.

Bouchard et al. (1980) weaned calves at 3 wk of age and found 5-6% better gains to 136 kg on diets containing 15 or 18% CP than on diets containing 13% CP, with no significant difference between the two higher levels. Calves consuming the 15% or 18% CP rations required less ($P<0.05$) DM (3.00-3.03 kg) and the same amount of protein (0.48-0.54 kg) per kg of gain as the calves consuming the 13% ration (3.25 kg DM; 0.45 kg protein). Similarly, Jones et al. (1974) increased daily gains to 136 kg by 0.22 kg ($P<0.05$) and decreased feed required per kg of gain by 1.8 kg by raising the protein in the starter from 10 to 15.3% of the DM. No improvement above the 15% level was reported for diets containing 18% CP.

Similar results with younger calves have been reported by Stobo et al. (1967) who found that 15.9% CP in the diet gave better calf performance to 12 wk than did 12.1%. A diet containing 20.9% CP did not improve calf performance. Winter (1976) found that Holstein bulls gained faster and more efficiently to 3 wk on diets containing 18% CP than on diets containing 13% CP when soybean meal was used as a protein supplement. Urea supplementation to 17.5% CP produced non-significantly better gains ($P>0.05$) and significantly better feed conversion ($P<0.05$) than 13% CP but supplementation with urea to 21.6% CP did not improve performance beyond levels attained with 17.5% CP.

Gardner (1968) did not find any difference in calf performance to 91 or 182 kg whether diets contained 12%, 14-15% or 16-17% CP (air dry basis). The lack of response to protein level in the younger calf is at variance with the other

reports reviewed here and no explanation can be readily seen. However, other authors (Stiles et al. 1974) have found that older calves (10 wk to slaughter wt at 200 kg) did not benefit from rations containing more than 13% CP on an as-fed basis, as increasing the protein content to 15 or 18% did not ($P>0.05$) improve daily gains, feed intakes or feed to gain ratios.

Pinkerton et al. (1971) raised calves to 92 kg on diets containing 18 or 15% DP (starter phase), from 92 to 177 kg on 15 or 12% DP (grower phase) and from 177 to 286 kg on 12 or 9% DP (finisher phase). The higher protein level did not improve ADG or feed to gain to 92 kg ($P>0.05$) but during the grower phase 15% produced better gains and feed conversion than did 12% ($P<0.05$) and during the finisher phase 12% CP improved weight gain and feed efficiency over 9% CP ($P<0.01$). Furthermore, the authors maintained that ADG dropped for about 2 wk after both lowerings of the protein level. As feed intake continued to rise during this period, feed efficiency was markedly impaired. They concluded that protein levels were prematurely lowered and no recommendations could be made with regard to lowering protein levels at these weights.

E. Effects of Protein Source

Protein sources that are available for use in calf starters include plant sources (cottonseed meal, rapeseed [canola] meal, soybean meal, sunflower meal, corn gluten meal, distillers dried grains), animal sources (meat meal, blood meal, fish meal) or non-protein nitrogen sources such as urea. Of these protein supplements, soybean meal would be considered the standard, against which the merit of other supplements is judged.

A review of the literature indicates that canola meal is an acceptable source of protein for calf starters if low glucosinolate, low erucic acid varieties (currently referred to as canola) are used. Stake et al. (1973) and

Stone and Wood (1973) both report inferior performance when rapeseed was included in the starter at 26-30% and this inferior performance was related to reduced feed intake. However, Ingalls and Seale (1971), Sharma and Ingalls (1973) and Stone and Wood (1973) reported that the feeding of 24%, or 20% and 6.8 or 13.7% rapeseed meal, respectively, did not adversely affect intake or performance in calves.

Differences in performance amongst studies of rapeseed meal appear to be related to variety. Shingoethe et al. (1974) reported a decrease in feed consumption of starters containing both commercial (high glucosinolate) and Bronowski (a low glucosinolate variety) rapeseed meals but found daily gains and feed efficiency on Bronowski comparable to soybean meal. Tower rapeseed meal, a low glucosinolate, low erucic acid variety, was shown to have no effect on daily gains or feed intake at levels up to 25% whereas Target (high glucosinolate) rapeseed meal at identical levels depressed daily gains ($P<0.05$) and tended to reduce feed consumption (Papas et al. 1979). The Tower variety of rapeseed meal has been used at 17% in calf starters without any adverse effects on calf performance to 12 wk (Wheeler et al. 1980) Candle rapeseed meal, another low glucosinolate, low erucic acid variety has been used at 20-25% in calf starters without any effect on daily gains, starter intake or feed efficiency (Fisher 1980) and this agrees with Bush et al. (1978) who concluded that this variety is equal to Tower for ruminant feeding.

Fiems et al. (1985) attribute the lower consumption of certain rapeseed meal containing starters to glucosinolate content of the meals. In a growth trial, they found that the inclusion of 10 or 20% rapeseed meal depressed consumption, though not significantly so. Daily gains and feed conversion efficiencies were also similar. However, feeding a high glucosinolate rapeseed meal as 20% of the diet significantly reduced starter intake to 259.3 kg compared

with 276.4 kg on the soybean meal diet. The reduction in intake due to the feeding of high glucosinolate rapeseed meal has been attributed to breakdown products of glucosinolates (Fenwick, 1982).

Only limited data is available concerning the use of other oilseed meals in calf starters. Sunflower meal at 22.6% of the starter was shown to produce daily gains, feed intakes and feed consumption comparable to soybean meal at 17.7% of the starter (Stake et al. 1973). Cottonseed meal, however, does not seem to be satisfactory as a source of protein in early growth. Gardner et al. (1971) found lower daily gains (0.70 vs. 0.92 kg) for calves on starters containing cottonseed meal as compared to meat and bone meal up to 91 kg. Overall daily gains to 136 kg did not differ significantly. This was also reported by Pinkerton et al. (1971) who found inferior daily gains and feed efficiencies for calves fed diets containing cottonseed meal as opposed to those containing a combination of soybean meal, meat meal and fish meal during the starter (birth to 92 kg) phase. Daily gains and feed efficiencies during the grower (92 to 177 kg) and finisher (177 to 286 kg) phases did not differ.

Urea can be successfully incorporated into calf starters at levels to supply 30-40% of the dietary nitrogen (Leibholz and Naylor 1971; Leibholz 1972, 1975; Drevjany et al. 1981). At higher levels of urea in the diet, feed consumption and feed conversion efficiency are impaired (Leibholz and Naylor 1971; Drevjany et al. 1981). The addition of molasses may improve feed consumption at lower levels of urea inclusion, (Leibholz 1975) but does not appear to have any effect at higher levels of inclusion. The impaired feed conversion efficiency would limit the rate of urea inclusion to the recommended levels of 2% of the diet or 33% of the dietary nitrogen, even if palatability is not a problem. Urea tended to give lower ADG than does SBM and less efficient gains than does SBM (Winter 1976).

Recently the concept of bypass protein has received much attention in ruminant nutrition. As summarized by Kaufmann and Lupping (1982), the use of protected proteins that bypass rumen fermentation can improve amino acid supply to the animal without increasing rumen ammonia, so nitrogen loss through ruminal escape of ammonia is minimized. Protein sources that have bypass potential include fish meal (FM), meat meal (MM), corn gluten meal (CGM), distillers dried grains (DDG), blood meal (BM), formaldehyde treated oilseeds and oilseed meals, and heat treated oilseeds and oilseed meals.

The use of bypass protein sources in calf starters has not given consistent positive results. Cummings et al. (1982) found no differences in daily gains or feed efficiencies when all concentrate rations were formulated to contain 30, 45 or 60% rumen degradable nitrogen (RDN) using combinations of soybean meal, cottonseed meal, corn gluten meal and dehydrated alfalfa. Trotta et al. (1984) reported no advantage in daily gains or feed efficiencies when oat based diets were supplemented with dried brewers grains to produce a range of soluble protein from 12.8 to 31.3% across three protein levels (13, 14-15 and 18% CP). Similarly, Veen and Vahl (1984) compared diets in which the difference between feeds with rapidly degradable and slowly degradable nitrogen was 28 and 36%, as measured in two trials by the nylon bag technique. They used a variety of protein sources but could demonstrate no consistent trends in calf performance. Gains were better on diets containing slowly degradable protein, but differences were only significant in one trial. Feed efficiencies were generally better in favour of diets containing slowly degradable protein.

Drevjany et al. (1986a) evaluated blood meal and distillers grains as sources of bypass protein in (15% CP) corn diets and compared calf performance to that on a corn plus urea control. Daily gains were improved with the addition of blood meal and distillers grains to the diet (0.81-0.95 kg/d) as compared

with those obtained on a diet containing corn and urea (0.69 kg/d). Feed conversion was improved non-significantly by 14%. However, it is difficult to evaluate their results in the absence of a corn soybean meal control. Several authors (Winters 1976; Miller et al. 1983) have shown inferior daily gains and feed efficiency with urea as compared to soybean meal. Furthermore, Miller et al. (1983) have shown that distillers dried grains did not improve daily gains (0.83 kg vs. 0.95 kg, $P<0.05$) or feed efficiency (3.01 vs. 3.19 kg feed/kg gain) over that of a soybean meal control. Zerbini and Polan (1984) found that corn gluten meal decreased feed consumption by 70% and daily gains by 6% as compared to a soybean meal control. Soybean meal resulted in more microbial nitrogen (N) reaching the abomasum.

Formaldehyde treatment of oilseed meals has not improved calf gains or feed conversion efficiency. Sharma et al. (1972) and Sharma and Ingalls (1973) found no significant improvement in calf gains or feed efficiency when formaldehyde treated rapeseed meal was included in calf starters. Similar findings have been reported for formaldehyde treated soybean meal (Miller 1983; Feims et al. 1987).

The inclusion of up to 15% meat meal in calf starters has been shown to give acceptable performance in studies comparing meat meal to soybean meal (Bouchard et al. 1980; Miller et al. 1983) or urea (Leibholz and Kang 1973). Inclusion of meat meal at levels above 13-15% results in palatability problems (Leibholz and Naylor 1971; Leibholz 1972; Leibholz and Kang 1973; Leibholz 1975). Intake has been improved by molasses additions (Leibholz 1975). Thus it seems that restricting meat meal to a maximum of 13-15% would circumvent palatability problems. Its inclusion has not improved calf performance in these trials, despite its value as a bypass protein.

Results in the inclusion of fish meal in calf starters have been more favorable. Fish meal was reported by Whitelaw et al. (1961b) to give better

gains than groundnut meal and a later report attributed the improvement to some bypass value of the fish meal as insoluble herring meal gave superior calf performance to either groundnut meal or a more soluble herring meal (Whitelaw et al. 1963a). In subsequent studies, which were conducted with ad libitum feeding over a longer time period, fish meal improved daily gains by 0.11 kg/d and feed efficiency ratios by 0.4 units over those obtained with groundnut meal (Whitelaw et al. 1963b). Zerbini and Polan (1984) reported slightly higher daily gains (0.856 kg vs. 0.805 kg) and a slightly lower feed requirement per kg of gain (3.08 kg vs. 3.35 kg) for diets containing fish meal as compared with soybean meal.

F. Effects of Whole Fat Oilseeds

Oilseeds with potential for use in calf starters to increase the energy density include soybeans, whole canola seed, sunflower seed and whole cottonseed. Daniels et al. (1973a) showed daily gains by 157 kg heifers of 1.06 kg whether calves were fed starters containing raw soybeans or soybean meal plus animal fat. However, feed intake was higher and feed efficiency lower, for a diet containing raw soybeans. Abdelgadir et al. (1984) found a non-significant increase in starter consumption to 8 wk when calves were fed raw soybeans rather than soybean meal or soybean meal plus added fat. As a result, daily gains were slightly increased. Differences between the 2 trials were possibly due to the young age of calves in the trial of Abdelgadir et al. (1984). These calves were tested during a time when more of their nutrients came from milk feeding so the extra consumption of starter would possibly boost daily gains.

Sharma et al. (1986) found lower gains from birth to 16 wk when canola meal was replaced with 12% whole canola seed but not with 18% whole canola seed. Dry matter intakes were slightly, but non-significantly reduced at the 12% inclusion

level and feed efficiencies did not differ between diets. In a second experiment they found that the inclusion of 10 or 20% whole sunflower seed in calf starters did not affect daily gains or feed intakes, but feed efficiency was lowered by the inclusion of 20% whole sunflower seed. Anderson et al. (1982) reported that whole cottonseed at 25% of the starter gave similar daily gains and feed intakes as control starters and that weights at 12 wk were higher for calves fed whole cottonseed.

Despite the proposed benefits of heat treating oilseed proteins there are few reports of improved calf performance when treated seeds are fed. Daniels et al. (1937b) could find no improvement in starter consumption, daily gains of feed conversion efficiency when extruded (118°C) soybeans replaced soybean meal plus added fat in calf starters to 95 d. When 157 kg heifers were used, neither roasting (108°C) nor extrusion (118°C) improved daily gains above those obtained with raw soybeans or soybean meal plus animal fat (Daniels et al. 1973a). Feed intake was lower for extruded soybeans than for raw soybeans, but the most efficient feed conversion was obtained with the soybean meal control. Extrusion of whole canola seed (105-110°C) did not improve calf gains, feed intake or feed efficiency above levels obtained with unprocessed seeds or canola meal (Sharma et al. 1986).

Using younger (birth to 8 wk of age) calves, Abdelgadir et al. (1984) reported better results when soybeans were processed in a Jet-Sploder^{R}. This process involves heating the seeds utilizing high temperatures for short time periods. As the seeds, containing superheated moisture at high pressure, leave the unit they are passed through a roller and "popped" or "exploded." The exit temperature of the seed is controlled by controlling the amount of time they remain in the heating unit. Soybeans were heated to exit temperatures of 138, 171 or 191°C, ground and added to starters, for comparison with ground raw

soybeans, soybean meal or soybean meal plus added fat. Calves given soybeans heated to 171°C had higher daily gains than did those fed raw soybeans, soybean meal or soybean meal plus added fat, with calves given soybeans heated to 138 or 191°C gaining at intermediate rates. Feed consumption was superior with the processed soybeans, and the highest consumption was with the soybeans processed at 171°C.

Conflicting results with regards to the effect of heat treated oilseeds on calf performance can be explained on the basis of processing temperatures. In studies showing no response to the inclusion of heat treated oilseeds in calf starters (Daniels et al. 1973a, b; Sharma et al. 1986) processing temperatures were in the range of 105-118°. Higher (140°C) temperatures would be expected to give better response in terms of increasing rumen undegradable protein (Yu 1978; Deacon et al. 1988). The only study showing a response to the inclusion of heat treated oilseeds was one in which soybeans were Jet-Sploded^{R} to temperatures of 138°C, 171°C or 191°C, with maximum response at 171°C (Abdelgadir et al. 1984). This is in conflict with reports indicating that temperatures in this range do not reduce protein degradability beyond that obtained at 140°C (Yu 1978; Deacon et al. 1988) and also tend to reduce in vivo protein digestibility (Yu 1978). Results were likely more favourable at 171°C because of higher feed intakes.

G. Effects of Hormonal Implants

Hormonal implants containing anabolic steroids can be used to improve calf gains, feed efficiency or carcass lean deposition. Experimental work with milk fed veal calves shows that several hormonal implants are useful for improving calf performance. Calf gains have been improved by 6 to 13% with implants of testosterone plus estradiol and by 3.5 to 13% with implants of progesterone plus estradiol (Vander Wal et al. 1975; Roy 1980). Improvements of up to 7% have been

reported for implants containing estradiol plus trenbalone acetate (Grandadam et al. 1975; Vander Wal et al. 1975; Roy 1980; Van Weerden, 1984). Zearanol, estradiol, zearanol plus trenbalone acetate or estradiol plus zearanol resulted in improvements of less than 7.7% (Vander Wal et al. 1975; Roy 1980; Van Weerden 1984). Improvements in feed conversion efficiency are lower in magnitude, with improvements of 8.81% reported for estradiol plus progesterone, 2-11.32% for estradiol plus trenbalone acetate, 5.28% for zearanol and 6.6% for zearanol plus trenbalone acetate (Roy 1980; Van Weerden 1984).

Work with grain fed veal calves indicates similar trends. An implant of estradiol plus testosterone improved calf gains by 21.5% and feed conversion by 16% (Drevjany et al. 1981), while improvements were less for implants of estradiol plus progesterone (13.11 and 7.4%) or zearanol (9.6 and 5.3%). They also showed that implantation of newborn calves with 1/4 of the adult dose of estrogen plus testosterone improved daily gains and feed efficiency by 9-10%. Implantation with zearanol at 7 d and with estradiol plus testosterone at 49 d improved gains and feed conversion by 11-13% compared with implants of zearanol at birth and at 49 d. No advantage was gained with combinations of implants when compared to single implant preparations.

It appears from the European work of Grandadam et al. (1975) and Vander Wal et al., (1975a) that maximum responses are obtained when calves are implanted at 9-14 wk of age, with response peaking 3-4 wk later. These results are for implantation in the dew lap. Implantation in the ear results in slower release (Dorg, Pers. Comm.), so it is likely that response would be maximized if implanted at the early end of this range.

II. DIGESTIBILITY

A. Effect of Type of Cereal

Differences in animal performance when the various cereal grains are fed to young calves can be related to the whole-tract digestibility of the grains and this in turn is related to characteristics of the grains and of the animals they are fed to. Latrille et al. (1983) reported that with calves 13 wk of age the apparent digestibility of DM and energy was about 75% for whole corn and this was not statistically different from the value for barley (70.5%). The digestibility of energy and DM in whole oat diets was lower, at 62% ($P<0.05$). This figure for DM digestibility with barley diets compares well with a value of 69.5% obtained using 17-20 wk old calves (Guertin et al. 1987b). These authors reported values for corn that were higher (81.7%) than those reported by Latrille et al. (1983) and that were significantly different from those of barley. In contrast to the results of Guertin et al. (1987b) and in agreement with those of Latrille et al. (1983). Kay et al. (1972) reported no significant differences between the digestibility of DM for whole corn (79.5%) and whole barley (77.3%) diets.

Digestibility values for corn diets in these studies are similar to those reported for older animals. Orskov et al. (1980) reported a DM digestibility value of 82.9% for whole corn using yearling steers and Galyean et al. (1979) reported a value of 77.1% for DM digestibility using 272 kg steers. White et al. (1972) reported a higher (≈ 90%) value for DM digestibility using yearling steers.

Whole oats appear to be less well digested than are other grains. Latrille et al. (1983) found that DM digestibility when whole oats were fed was only 62.2% and this agrees with a value of 60.5% reported by Orskov et al. (1980) using yearling steers. Higher values have been reported by Toland (1976; 1978) but these animals were also fed hay. It was shown by Nordin and Camplin (1976) that hay increases time spent ruminating on corn based diets. Provision of hay did not improve barley digestion despite increased rumination (Nicholson et al.

1971). However, a large percentage of oat grains is broken by rumination (Toland 1978) and thus the effect of hay on grain digestibility may not be enhanced with oat diets.

Whole wheat appears to be well digested by cattle when fed without hay. Kay et al. (1972) reported a DM digestibility of 81.3%, which was comparable to the DM digestibility of whole corn (79.5%). Orskov et al. (1980) have reported values of 78.8 and 79.0% for DM and organic matter (OM) digestibility in whole wheat. Corresponding values for corn were 82.9 and 83.5%. Six month old calves appear to be able to digest wheat as well as yearling steers when a ration of 2/3 whole wheat and 1/3 hay is fed (58.1% for calves; 58.5% for steers). There was no difference in the percent of whole grain voided in the feces (Kimberley 1976).

Studies which reported the digestibility of wheat when fed with hay indicate that the DM digestibility is lower, at 50-60% (Kimberley 1976; Toland 1976, 1978). This may be due to shifts in rumen microbial populations when hay is fed. Toland (1978) reported that 42% of wheat grain breakage is due to rumen fermentation, 17-22% to eating and 17-22% to rumination. Thus, a shift in microbial populations and fermentation patterns would be of importance in wheat digestion.

Younger cattle appear to be able to digest whole corn fairly well and this may be related to their capacity to chew the grain thoroughly, longer time spent ruminating and longer retention time in the reticulo-rumen (Nordin and Campling 1976). Whole tract digestibilities of DM and energy do not appear to be affected by grinding whole corn for yearling steers (White et al. 1972; Galyean et al. 1979). Viera and MacLeod (1980) did not find any benefit in grinding corn for calves fed for 105 d starting at 92 kg. Daily gains, feed efficiencies and DM digestibilities were not different between ground and rolled corn.

The digestibility of barley is improved by rolling the grain, although the improvement for calves is less than that seen for older animals. MacLeod et al. (1972) found that rolling barley for calves increased the digestibility of DM from 73.8 to 80.0%. Nicholson et al. (1974) fed milled barley to mature cattle and found that DM and energy digestibilities were improved by about 20 percentage units, but for younger heifers the improvement was only in the order of 6-7 percentage units. Later work by Guertin et al. (1987b) showed increases in digestible DM (74.3 vs. 69.5%) and digestible energy (73.1 vs. 68%) when rolled rather than whole barley was fed to calves aged 17-20 wk.

The digestbility of diets based on rolled barley is quite similar to that of corn based diets. Beauchemin (1980) reports DM and energy digestibilities of 82-84% irrespective of whether whole corn or rolled barley was the grain source for heavy calves. Guertin et al. (1987b) reported higher digestibilities of whole corn diets for calves aged 17-20 wk, but differences between whole corn and rolled barley were not significant. Dry matter and energy digestibilities for whole corn were 81.7 and 80.8%, while for rolled barley these figures were 74.3 and 73.1%. Oltjen et al. (1967) and Spicer et al. (1986) report DM digestibilities in the range of 80-84% for both cracked corn and rolled barley using older steers.

Processing oats may enhance digestibility to some degree. Kay et al. (1972) reported a digestible DM value of 70.4% for whole, pelleted oats and this is about 10 percentage units higher than values reported for whole oats (Orskov et al. 1980; Latrille et al. 1983). Dry matter and energy digestibilties for rolled oats, were not significantly different from those of corn (Shingoethe et al. (1982). However, Toland (1978) has shown that rolling the grain did not improve digestibility of oats (+7.4%) as much as that of barley (+62.3%), when mature steers were fed grain plus 2 kg of hay per day. Similar trends have been

reported by Morgan and Campling (1978), although rolling the oats greatly improved starch digestibility.

Rolling wheat improved organic matter digestibility of the grain by 39.4% when fed in diets containing 75% grain and 25% hay (Toland 1976). The digestibility of organic matter in the rolled wheat grain was 87.7%, compared with 85.2% for rolled barley grain and 81.0% for rolled oat grain. Oltjen et al. (1967) reported a DM digestibility of 87.5% when cracked wheat was fed to 188 kg Hereford steers.

Latrille et al. (1983) reported that starch was less completely digested when calves were fed whole barley based diets (86.4%) than either corn based (97.0%) or oat based diets (94.1%). Barley fed calves voided significantly more starch in the feces than did either corn or oat fed calves. Guertin et al. (1987b) have also reported higher starch digestibilities when whole corn (90.2%) rather than whole barley (69.3%) was fed. Similar values for starch digestion in whole corn have been reported by Galyean et al. (1979) and Beauchemin (1980) who reported digestibilities of 90.2 and 88.2%, respectively. Orskov et al. (1980) reported a starch digestibility of 82.8% when whole wheat was fed to yearling steers; which was considerably higher than a value of 63.9% reprted for barley treated with 15 g/kg NaOH. Values for untreated barley, oats or corn were not reported.

Processing corn does not appear to improve starch digestibility. Whole tract digestibility of starch in corn was not affected by grinding whole grain (White et al. 1972; Galyean et al. 1979). Viera and MacLeod (1980) did not find any difference in starch digestibility when either ground or rolled corn was fed. Rolling barley improved starch digestibility from 69.3% to 84.1% when fed to calves aged 17-20 wk (Guertin et al. 1987b). Morgan and Campling (1978) reported improved starch digestibility when oats (73.4 vs. 100%) or barley (50.9 vs.100%)

were rolled for 17 mo old steers and fed in a 1:1 ratio of hay:concentrate. Toland (1976) showed that rolling wheat improved starch digestibility by 59% when grains were fed with forage.

Guertin et al. (1987b) found higher values for starch digestibility when whole corn was compared to rolled barley (90.2 vs. 84.1%) but differences between diets were not significant. Spicer et al. (1986) reported starch digestibilities of 99% for both cracked corn and cracked barley.

Guertin et al. (1987b) reported lower apparent N digestibility values for whole barley (75.5%) than whole corn (80.1%). However, when grains are processed, there is little difference in apparent N digestibility. Beauchemin (1980) reported values of 77.3% and 72.5% for the apparent N digestibility on whole corn or rolled barley based diets, with differences due to higher N intakes on the barley diet. Oltjen et al. (1967) reported values of 73.6, 76.8 and 77.6% for diets containing cracked corn, wheat or barley, respectively. Using older steers Spicer et al. (1986) reported apparent N digestibilities of 66.17 and 68.2% when cracked corn or cracked barley were fed. Shingoethe et al. (1982) reported similar N digestibilities when rolled oats (74.8, 78.6%) or ground corn (81.5%) was fed to 13 wk old calves.

Processing grains for younger calves does not improve N digestibility. Nicholson et al. (1971) found an increase in CP digestibility of 11% when whole barley was milled for mature steers, but when the grain was milled for yearling heifers there was no improvement (60.6% for whole and 62.0% for milled barley). White et al. (1972) found CP digestibilities of 80-81% when ground or whole corn was fed. Viera and MacLeod (1980) found lower N digestibilities for ground and rolled corn (68-69%) but reported no significant differences between treatments.

Very few studies comparing whole grains for younger calves have reported fiber digestibiltes. Latrille et al. (1983) reported acid detergent fiber (ADF)

digestibilities of 38.8, 6.3 and 14.4% when whole corn, barley and oats were fed to 93 kg calves. Differences were significant for the corn diet. When fed with hay to 17 mo old steers, whole barley had slightly higher cellulose digestibility than did whole oats in 1 trial but in a second trial little difference was noted (Morgan and Campling 1978). Orskov et al. (1980) reported ADF digestibilities of 52.0, 41.9 and 17.0% when whole corn, wheat and oats were fed to yearling steers.

Grinding whole corn has been shown to decrease the digestibility of cellulose 8.5 percentage units below that of whole corn (White et al. 1972). Work with other grains has indicated that fiber digestion of rolled grains is comparable to that of corn. Shingoethe et al. (1982) reported similar ADF and cellulose digestibilities when rolled oat diets were compared to corn diets. Beauchemin (1980) reported ADF digestibilties of 61.0 and 54.4% for diets based on rolled barley and whole corn. Fallon et al. (1986) have reported ADF digestibilities of 50.0 and 52.0% when rolled barley diets were tested at 40 and 70 d. Fisher et al. (1986) reported digestibilities of 39.9 and 33.8% for ADF and lignin on oat based diets. Sharma et al. (1986) reported ADF digestibilties of 39.9% for rolled barley and 39.9-43.1% for crushed corn diets.

B. Effects of Added Fat

Literature on the effects of fat on diet digestibility in dairy cows was reviewed by Palmquist (1984). In general unprotected fats increased ether extract digestibility, but the effects on fiber digestibility were more variable and dependent on feed intake, rate of passage and level of concentrate feeding. They stressed that highly saturated fats are less well digested than are unsaturated ones, but the effects are not as great as with non-rumininants.

Data with regards to the effects of added fat on digestibility values determined with calves is limited. Chandler et al. (1968) found that dietary corn oil additions of up to 4% slightly increased DM, energy and N digestibility but additions of 4 to 8% corn oil decreased these values. Fatty acid digestibility was increased 15-20 percentage units when 4% oil was added to diets containing 14 and 21% soybean meal but higher levels of added oil decreased digestibility of fatty acids. Wrenn et al. (1979) found no increase in fat digestibility when 5% tallow was added to calf starters (45% vs. 48% for control diets). However, the addition of 1% cholesterol and 5% tallow to the starter increased fat digestibility to 58%.

Protected tallow at 10 or 20% of the ration increased apparent fat digestibility in 9 wk old calves from 79.8% on a control diet to 86.5 and 87.1% (Fisher 1980). Digestibilities of DM, OM, CP, lignin and ADF were not affected by diet. Fallon et al. (1986) found that at 70d 5 or 10% Ca soaps in calf starters did not affect DM or OM digestibilities but 20% Ca soaps depressed the digestibility of these components. Protein digestibility was higher on diets containing 20% added Ca soaps. Fat digestibility was increased from 36 to 59 and 56% ($P<0.05$) with 5 and 10% added Ca soaps and increases to 20% resulted in no increase (44%; $P>0.05$) in fat digestibility. Acid detergent fiber digestibility increased from 52% on unsupplemented diets to 61-66% on the fat supplemented diets.

Sharma et al. (1978) found that 5, 10 or 15% protected tallow in lactation rations did not affect digestibility coefficients for DM, energy, CP or ADF. Ether extract digestibilities were 46.2, 59.8, 66.5 and 74.3% for each level of added fat and corresponding values for acid solvent extract digestibiltes were 12.3, 39.9, 46.4 and 57.9%. They calculated the true digestibility of ether extract and acid-solvent extract to be 90%. They reported that this figure was

constant for both supplemented and control rations, suggesting no change in true digestibiity due to method of analysis. A similar value (94%) was reported by Sharma et al. (1986) for young calves fed canola or sunflower seeds.

C. Effects of Protein Level

The apparent digestibility of the various nutrients increases as percent CP in the diet is increased. Viera et al. (1980b) showed that the apparent digestibiltiy of DM and OM increased linearly from 71% to 75% as the CP content of the DM was increased from 9.9 to 12.0, 14.2, and 16.0%. Nitrogen digestibility increased from 61.6 to 72.2%, starch digestibility from 86.3 to 89.7% and ADF digestibility from 36.2 to 44.8%. No effect was observed on ether extract digestibility. Whitelaw et al. (1961a) reported a range of digestibilities of 74-78% for DM and 66-78% for CP when dietary CP ranged from 15 to 21.6%. In a second trial, with a range of 11.6% to 22.6% CP in the diet, digestibilities increased from 75-80% (DM) and 61-77% (CP).

Similar trends have been reported by Winter (1976) and Schurman and Kesler (1974). Gardner (1968) however, reported no change in apparent digestibility of DM, CP, ether extract, energy or ADF when protein levels were raised from 12 to 14 to 17%, with digestibilties in the 16% ration lower than those in the 12% ration.

D. Effects of Protein Source

Sharma and Ingalls (1973) have reported low values for digestibility of energy (68.3 and 69.4%), nitrogen (66.7 and 68.9%) and ADF (9.1 and 8.6%) for diets containing soybean meal and rapeseed meal but could find no significant difference between the two diets. Stake et al. (1973) reported digestibility coefficients of 75% for DM and energy and 80% for CP for diets containing 26%

rapeseed meal and 17.7% soybean meal. Wood and Stone (1970) reported a tendency for a rape-basal diet to be less well digested at maintenance compared to growth intake levels, but could find no differences in the digestibilities of diets containing 50% rapeseed meal or 50% soybean meal.

Others have reported lower digestibilities for rapeseed meal than for soybean meal. Fiems et al. (1985) reported depressed digestibility of all parameters except ether extract when a calf starter containing 20% rapeseed meal was compared with one containing 16.5% soybean meal. Inclusion of only 10% rapeseed meal depressed digestibility of only the crude fiber and nitrogen free extract fractions. At 20% inclusion of rapeseed meal DM and CP digestibilities were 80.9 an 78.0% while at the 10% level these values were 83.5 and 85.1%.

Some of the observed differences between the digestibility of rapeseed meal and soybean meal may be related to variety of rapeseed meal. Shingoethe et al. (1974) reported digestibilities of 84.1% and 80.6% for DM and nitrogen in soybean meal containing starters. These values were higher than those for starters containing commercial rapeseed meal (76.5 and 66.5%) but similar to those for starters containing Bronowski (a low glucosinolate variety) rapeseed meal (78.6 and 73.3%). Fisher (1980) found no difference in DM, protein or ADF digestibility for diets containing Candle (a low glucosinolate, low erucic acid variety) rapeseed meal or soybean meal. Sharma et al. (1980) found that a 50-50 mixture of basal diet and either Tower (a low glucosinolate, low erucic acid variety) or Candle rapeseed meal was lower in DM, CP and ADF digestibility than a 50-50 basal-soybean meal mixture. While it is possible that these results were confounded by the high level of rapeseed meal in the mixture and increased protein intakes on the basal-soybean meal diet, in situ data suggests that canola meal (low glucosinolate, low erucic acid rapeseed) protein is less digestible in the lower gastrointestinal tract than is soybean meal protein (Deacon et al.

1988; Kendall 1988). This depression in digestibility may be due to the low digestibility of the canola (rapeseed) hull fraction.

The apparent digestibility of the various fractions in the oilseed meals were determined by difference in the studies of Wood and Stone (1970) and Sharma et al. (1980). Wood and Stone (1970) reported DM, CP and energy digestibiltes of 89.1, 91.8 and 89.3% for rapeseed meal and 88.6, 92.6 and 87.7% for soybean meal, with no differences between the two diets. They estimated that rapeseed meal had about 287 kcal more digestible energy and 2% less digestible protein per kg of DM than did soybean meal. Sharma et al. (1980) reported that DM and energy digestibilties tended to be lower for rapeseed meal (76-78%) than for soybean meal (86-87.5%). Crude protein digestibility was higher for soybean meal (103.8%) than for canola meal (86.7-90.5%).

Limited information is available on the digestibility of rations containing other oilseed meals. Stake et al. (1973) showed the DM digestibility of a diet containing sunflower meal (67.5%) to be less than that of a diet containing soybean meal (75.5%) but similar to that of a diet containing rapeseed meal (74.0%). Energy digestibiity followed a similar pattern, and the digestibility of protein was similar for sunflower meal, soybean meal and rapeseed meal diets.

Urea in calf starters does not alter the digestibility of DM, energy, nitrogen free extract, CP or ether extract when compared to soybean meal or fish meal (Kay et al. 1967; White et al. 1972; Winter 1976). Urea additions to calf starters have slightly increased the digestibility of DM when compared to meat meal containing starters (Leibholz and Naylor 1971; Leibholz 1972, 1975). While CP digestibility remained unchanged (Leibholz 1972, 1975) cellulose digestibility was lower when whole corn was supplemented with urea but with gound corn this value was unaffected (White et al. 1972).

The inclusion of protein sources with by-pass potential has not generally affected ration digestibility. Fish meal and groundnut meal have resulted in similar DM and N digestibilites (Whitelaw et al. 1961b; Whitelaw et al. 1963a; Preston et al. 1964). Cummins et al. (1982) did not find any effect on DM digestibility when diets were formulated to contain 30, 45 or 60% rumen degradable N using combinations of urea, cottonseed meal, soybean meal, corn gluten meal and dehydrated alfalfa in corn rations. Similarly, Trotta et al. (1984) could find no differences in the digestibility of DM, organic matter, CP or ADF when percent soluble protein was varied from 13-31% of the ration.

The effects of adding formaldehyde treated oilseed meals to calf starters on diet digestibilty is dependent on the level of formaldehyde treatment. In vivo data from Sharma and Ingalls (1973) and Sharma et al. (1974) have shown no effects on digestibility coeffieients when rapeseed was treated at a level of 0.7 g formaldehyde/100 g rapeseed protein. Fiems et al. (1987) showed similar results when a level of 0.42 g formaldehyde/100 g rapeseed protein was used, although their work did show a decrease in ether extract digestibility. Sharma et al. (1972) showed that 5.6 g formaldehyde/100 g rapeseed protein decreased DM and CP digestibility. Thus, it appears that the higher levels of formaldehyde treatment overprotect the proteins, rendering them unavailable for complete digestion.

Using ruminal and intestinal disappearance data Deacon et al. (1988) showed that extrusion of canola or soybean meal did not affect the overall digestibility of crude protein.

E. Effects of Whole Fat Oilseeds

Sharma et al. (1986) showed that 12 or 18% whole canola seed in the diet of 7 wk old calves reduced by 6-13% the digestibilties of DM, CP, ether extract

and energy and tended to reduce the digestibility of ADF. At 15 wk of age the diets containing whole canola seed were well digested, with only CP digestibility depressed at the 12% inclusion level. At both ages, the addition of whole canola seed increased the digestibility of ether extract when compared to a control diet containing canola meal. At 10 wk of age 10 or 20% whole sunflower seeds tended to decrease the digestibility of DM, CP and energy, but increased the digestibility of ether extract above that of a canola meal control (Sharma et al. 1986). Diets containing raw soybeans, however, have been shown to depress the apparent digestibilities of DM, CP and energy when compared to diets containing soybean meal (Daniels et al. 1973a).

Extrusion of whole canola seed did not change CP digestibility when compared to untreated whole canola seed, untreated canola meal or extruded canola meal when samples were ground (1 mm) prior to rumen incubation (Deacon et al. 1988). This contrasts with results of Sharma et al. (1986) who showed that at 7 wk of age the apparent digestibility of DM, energy, CP and ADF was depressed by 6-10% with the addition of both whole and extruded canola seeds to calf starters. By 15 wk of age the digestibility of the diet containing whole canola seed was comparable to that of the canola meal control, but apparent digestibilities of DM, CP, ADF and energy were still lower on diets containing extruded canola seed than on diets containing canola meal. Pelleting the diet improved the digestibility of all components except ADF and the authors attributed this to reduced particle size of the seeds. Thus it appears that in the work of Sharma et al. (1986) the extrusion process did not disrupt the seed coat enough for complete digestion, but caused some heat damage as indicated by the depression in digestibility below that of the whole, untreated seed.

When roasted or extruded soybeans were included in calf starters apparent digestibility coefficients for DM, protein and energy were equivalent to those

obtained for a soybean meal diet and higher than those obtained for a diet containing ground raw soybeans (Daniels et al. 1973a). Daniels et al. (1973b) reported similar energy and protein digestibilities whether extruded soybeans or soybean meal was the protein source in calf starters. Prasad and Morrill (1976) reported a tendency to improved ether extract digestibility when soybeans were roasted, but found that crude fiber digestibility was depressed. Dry matter, nitrogen and nitrogen free extract digestibitilities were unchanged.

Jet-Sploding canola seeds to an unspecified temperature reduced the in sacco digestibility of DM and CP in one experiment below that of canola meal, whole canola seeds or extruded canola seeds when samples were ground (1 mm) (Deacon et al. 1988). In a second experiment they could not demonstrate any consistent trends in the data when the total tract disappearance from nylon bags of canola seeds Jet-Sploded over a temperature range of 116-177°C was evaluated, although there were marginal decreases in total tract disappearance of DM and CP. Yu (1978) showed that Jet-Sploded soybeans at temperatures of 100, 120 or 140°C resulted in only a 4% decrease in in vivo nitrogen digestibility, but at temperatures of 160, 180 or 200°C in vivo nitrogen digestibility was reduced by 40%.

III. RUMINAL METABOLISM, NUTRIENT FLOW TO THE INTESTINE AND NITROGEN AND ENERGY RETENTION

Digestion in ruminant animals can occur in the rumen and/or in the post-ruminal sections of the gastrointestinal tract. The extent of ruminal degradation of a feedstuff will affect the end products of digestion and will determine the proportion of digesta reaching the duodenum that is bacterial in origin and that which is feedstuff in origin. The sum of ruminal and post-

ruminal absorption will then determine energy and protein retention in the animal.

A. Effects of Type of Cereal

Kay et al. (1972) reported that about 600 g more starch per day passed through the abomasum on whole corn diets than on whole barley or whole wheat diets. Approximately 40.0% of the corn starch escaped ruminal digestion whereas the values for wheat, barley and oat diets were 17.5, 19.0 and 27.0%. However, processing both corn and barley has been shown to alter the site of digestion. Pavlicevic et al. (1972) reported that rolling barley reduced both the absolute amount of starch passing through the abomasum and the percent of feed starch that passed through the abomasum. Galyean et al. (1979) reported a decrease from 17% to 0.5-3.5% in the amount of feed starch digested in the intestine when whole corn was compared to ground corn. With ground corn diets 90-93% of the intake starch was digested in the rumen whereas with whole corn diets this value was 71%. Spicer et al. (1986) reported only small differences in the percentage of ingested starch digested in the rumen when rolled corn (83.7%) was compared with rolled barley (87.7%).

Kay et al. (1972) have reported a lower proportion of bacterial N in the abomasal N with corn diets (54%) than with wheat diets (74%), barley diets (72%) or oat diets (76%). Spicer et al. (1986) reported that with ad libitum feeding of corn diets 53.4% of the non-ammonia N in the abomasal contents was bacterial in origin. For barley fed animals this value was 71.8%.

The post ruminal digestibilities of barley and corn starch reported by Spicer et al. (1986) were quite high at 92.9 and 93.8%. The post ruminal digestibility of organic matter in these grains was 71.1 and 61.4%, while

nitrogen in corn and barley was 72.5 and 73.5% digested in the intestine. No values were found for the post ruminal digestion of wheat.

On high concentrate diets, wheat and barley results in higher total rumen volatile fatty acid (VFA) concentrations than does corn. Oltjen et al. (1967) found that cracked wheat and barley resulted in total ruminal VFA concentrations of 150.2 and 148.2 μmoles/l whereas for cracked corn the value was 99.3 μmoles/l. Similar results have been reported when cracked wheat was compared to cracked corn for cattle (Oltjen et al. 1966) or sheep (Kreikemeier et al. 1987). Fulton et al. (1979) reported higher total VFA levels on crushed corn diets than on crushed wheat diets, but intake was higher on the corn diets, so more carbohydrate was available for ruminal fermentation. The greater production of ruminal VFA's is related to the higher rate of DM and starch fermentation when barley or wheat rather than corn is the substrate (Varner and Woods 1975; Kreikemeier et al. 1987). Pelleting and grinding cereal diets has been shown to increase total VFA concentrations in the rumen (White et al. 1972; Orskov et al. 1974).

The molar proportions of acetate tended to be higher and those of propionate lower when sheep were fed ad libitum rations containing whole barley and whole wheat than when they were fed diets containing whole corn (Orskov et al. 1974). Butyrate levels were slightly elevated on barley diets and similar on corn and wheat diets. However, Oltjen et al. (1967) reported that when steers were fed restricted quantities of these diets in the cracked form there was a tendency to lower proportions of acetate and increased proportions of propionate on barley and wheat diets than on corn diets. Wheat diets produced higher proportions of butyrate and higher acids than did corn or barley diets. Oltjen et al. (1966) reported that on 90% concentrate diets there was a lower proportion of propionate and a higher proportion of butyrate, but not acetate, on crushed

wheat diets as compared to crushed corn diets. Similar findings were reported by Fulton et al. (1979).

Processing cereals alters the proportions of VFA's produced in the rumen. Grinding and pelleting wheat and corn for sheep increased the proportions of both propionate and butyrate, while acetate proportions were reduced (Orskov et al. 1974). White et al. (1972) reported lower acetate and higher propionate levels on ground rather than whole corn, but butyrate levels decreased when corn was ground. When barley was ground and pelleted for sheep, acetate proportions were reduced while proportions of propionate were increased. Isobutyrate, butyrate and isovalerate levels decreased when the barley was processed (Orskov et al. 1974).

The very rapid degradation of feedstuff protein in the rumen via the deamination of amino acids will yield ammonia and this is generally associated with inefficient protein usage. Rumen ammonia nitrogen (RAN) levels are slightly elevated on barley and wheat diets. Oltjen et al. (1966) reported higher RAN levels with wheat diets (18.7, 18.9 mg/100 ml) than with corn diets (15.0, 12.6 mg/100 ml) under ad libitum feeding conditions. When steers were fed restricted amounts, no differences were seen for RAN levels in corn (3.5 mg/100 ml), wheat (3.1 mg/100 ml) or barley (5.4 mg/100 ml) diets (Spicer et al. 1986). They suggested that the lack of response to diet may have been due to sampling time (4 h post feeding).

Blood urea nitrogen (BUN) levels were higher with whole barley diets (24.9 mg/100 ml) than with whole corn diets (14.7 mg/100 ml) (Guertin et al. 1987b). Oltjen et al. (1967) have also shown elevated BUN levels on cracked barley diets as compared to cracked corn diets (370.4 vs. 155.0 Mmoles/100 ml) whereas levels on wheat diets were intermediate.

Blood urea nitrogen may arise from either the absoption of nitrogen from the rumen in the form of RAN or from the deamination of excess amino acids after absorption from the intestine. Thus, the elevated BUN levels on barley and wheat diets could be either a reflection of higher RAN production on these diets and/or of the absorption of a better balance of amino acids on the corn diets.

Oltjen et al. (1967) showed that the cereal source affected the blood levels of several amino acids. Wheat resulted in higher levels of isoleucine and lysine than either corn or barley. Corn resulted in higher levels of histidine than barley, but not wheat. Tyrosine levels were higher on the corn diet than on either the wheat or barley diets. Spicer et al. (1986) showed that the abomasal flow of lysine was greater and that of leucine less on barley diets than on corn diets. Other amino acid levels did not differ. These results should be viewed with caution, however, as corn gluten meal provided the supplemental protein in the corn diets but not in the barley diets. While corn is high in leucine but low in lysine, with 50% of the lysine in the soluble fraction, corn gluten meal is higher in lysine, with little lysine in the soluble fraction (MacGreggor et al. 1978). Thus, the increased lysine in the abomasal contents of barley fed steers was likely due to the higher passage of bacterial N to the abomasum on barley based diets (112 vs. 80.8 g/d).

In addition to the shortage of information on the effects of cereal source on amino acid supply, little is known about the amino acid requirements for young bull calves. This is especially true for bull calves that are fed as ruminants for maximum growth. Until such time as this information becomes available it is of little use to speculate as to whether or not the different cereals make different contributions to the amino acid supply of the animal. This is even more evident when it is taken into account that certain diets (eg. barley, Spicer et al. 1986) result in higher flows of bacterial N to the abomasum.

Energy retention is altered by the inclusion of different cereals in the diet. Guertin et al. (1987b) have found greater energy retention of diets containing whole corn (77.3%) than on those containing whole barley (64.7%). Rolling the barley improved energy retention to levels intermediate between whole barley and whole corn (69.7%). Differences in energy retention between whole corn and whole barley (12.6 percentage units) and between whole barley and rolled barley (5 percentage units) were comparable to differences in DE (12.8 and 5.1 percentage units). Thus it seems that differences in energy retention are parallel to differences in digestibility, so it is likely that energy retained as a percent of absorbed energy are comparable between the two.

Nitrogen retention is not significantly affected by cereal source in the diet of heavy calves. Whole barley fed calves had greater intake and thus excretion of N than did whole corn fed calves, but overall N retention was not affected (Guertin et al. 1987b). Oltjen et al. (1967) also reported a tendency to higher urinary excretion of dietary N with barley diets. They reported slightly, non-significantly lower N retention as a percent of intake in barley diets (38.0%) than on corn (42.5%) or wheat (42.7%) diets, but this would be expected from the higher protein percentage of the barley diet. Grinding corn (White et al. 1972) or rolling barley (Guertin et al. 1987b) did not significantly affect nitrogen retention.

B. Effects of Added Fat

Fallon et al. (1986) showed that increasing the level of Ca soaps in calf diets decreased the molar proportions of acetate, butyrate and isobutyrate in the rumen fluid. Wrenn et al. (1979) showed a significant decrease in the total concentration of volatile fatty acids when calves were fed protected sunflower oil as compared to calves fed unprotected sunflower oil. Calves fed protected

sunflower oil had lower molar percentages of acetates, butyrate, isobutyrate, valerate and isovalerate but molar percentages of propionate did not differ on the two diets. Caffrey et al. (1988) found no effect on rumen pH when tallow as added to calf starters but Fallon et al. (1986) reported a tendency to lower pH when Ca soaps were added to calf diets. Rumen ammonia nitrogen levels were increased by the addition of 5, 10 or 20% Ca soaps to calf starters (Fallon et al. 1986).

Fisher (1980) found no change in blood urea nitrogen levels when protected tallow was included in oat based diets. Fallon et al. (1986) found that 10 or 20% Ca soaps in barley based diets decreased daily nitrogen retention and nitrogen retained as a percentage of nitrogen intake below that obtained with diets containing 0 or 5% Ca soaps. However, the percentage of absorbed N that was retained was slightly higher for diets containing 10 or 20% Ca soaps, so reductions in daily nitrogen retention and in the amount of intake nitrogen that was retained were likely due to decreased feed intakes at higher fat levels.

C. Effect of Protein Level

Viera et al. (1980a) varied the protein level in corn rations from 10 to 16% by replacing corn with soybean meal and found that protein level in the diet had no effect on the apparent rumen digestion of dry matter, organic matter or starch. When 146 kg steers were fed at a rate of 8 g $DM/W^{0.75}/d$, Owens et al. (1973) found similar results when urea was added to corn diets for restricted fed lambs but Orskov et al. (1972) found that organic matter disappearance from the rumen of lambs increased as increasing levels of urea were added to barley diets for lambs fed at near ad libitum levels. It is likely that under conditions of restricted feeding energy levels will limit the rate of rumen degradation.

When soybean meal replaced corn in calf diets to increase protein levels from 10-16% CP there was a linear increase in the flow of ammonia nitrogen, and residual feed nitrogen, but no effect on the flow of bacterial nitrogen, through the abomasum (Viera et al. 1980a). The net result was a linear increase in the total flow of non ammonia nitrogen through the abomasum.

Total volatile fatty acids in the rumen fluid are not increased when dietary protein levels are increased by the addition of soybean meal (Viera et al. 1980a) soybean meal and dried brewers grains (Curnick et al. 1983) or urea (Viera and MacLeod 1980) to corn based diets. Crude protein levels in these studies ranged from 9.4 to 17%. Molar proportions of volatile fatty acids did not change when soybean meal (Viera et al. 1980) or soybean meal and dried brewers grains (Curnick et al. 1983) were used to increase dietary protein levels but Viera and MacLeod (1980) reported a decrease in the molar proportion of butyrate and an increase in the molar proportion of propionate when 1.2% urea was added to ground corn diets. Adding 1.2% urea to rolled corn diets did not change the molar proportions of these fatty acids. Urea supplementation of both rolled and ground corn diets has been shown to decrease rumen pH (Viera and MacLeod 1980) but supplementation with soybean meal and distillers dried grains did not affect rumen pH (Curnick et al. 1983).

Rumen ammonia nitrogen levels increase when dietary CP levels increase. Over a range of 9-17% of the diet, this has been shown when urea (Viera and MacLeod 1980), soybean meal (Viera et al. 1980a) or a combination of soybean meal and dried brewers grains (Curnick et al. 1983) were the source of supplemental protein.

Studies evaluating levels of protein in calf starters consistently show increased blood urea nitrogen levels as percent CP in the diet increases. This response was shown when soybean meal (Viera et al. 1980a,b), meat meal (Leibholz

and Kang 1973), urea (Leibholz and Kang 1973; Viera and MacLeod 1980) or a combination of soybean meal and dried brewers grains (Curnick et al. 1983; Trotta et al. 1984) were used as sources of supplemental protein. As indicated by higher rumen ammonia nitrogen levels, the elevated blood urea nitrogen levels also indicate an inefficient use of dietary protein as CP levels in the diet increase.

As a result of increased protein intake and digestibility, absorbed nitrogen increases with higher dietary protein levels under conditions of ad libitum (Schurman and Kesler 1974; Curnick et al. 1983) and restricted (Viera et al. 1980b) feeding. This absorbed protein is utilized more efficiently at lower protein levels. Nitrogen retained, as a percent of absorbed nitrogen, is higher at low protein levels (Curnick et al. 1983) because of decreased urinary losses of nitrogen (Leibholz and Kang 1973; Schurman and Kesler 1974; Viera et al. 1980b; Curnick et al. 1983). The percentage of absorbed nitrogen that is retained does not appear to increase above dietary CP levels of 14% (Schurman and Kesler 1974; Viera et al. 1980b).

Nitrogen retained as a percent of nitrogen intake does not change with protein levels in the diet (Whitelaw et al. 1961a; Viera et al. 1980b; Curnick et al. 1983). Data by Schurman and Kesler (1974) showed that a higher percentage of nitrogen intake was retained on a low protein diet, but this may have been a result of low feed intake on this diet.

The net result of increased nitrogen intake and digestibility and increased urinary nitrogen excretion with increased dietary protein levels is that nitrogen retention per d is maximized at higher protein levels. Whitelaw et al. (1961a) found that nitrogen retention per d was higher on diets containing 19.4 or 21.6% CP (14.5 and 13.4 g/d) than on diets containing 14.9 or 16.9% CP (10.3 and 11.5 g/d). In a second experiment nitrogen retention rose from 8.6 to 14.3 g/d as CP

content increased from 11.6 to 20.4% but CP levels of 22.6% did not increase daily nitrogen retention beyond this. These results, obtained under conditions of restricted feeding, were confirmed by Viera et al. (1980b) who found that restricted feeding of diets ranging from 9.9 to 16.2% CP resulted in nitrogen retentions ranging from 17.0 to 25.8 g/d.

Results have been similar when nitrogen balance trials were conducted under conditions of ad libitum feeding. Schurman and Kesler (1974) reported nitrogen retentions of 19.1, 22.1 and 40.3 g/d when diets containing 11.5, 14.3 and 26.0% CP were fed to 19 wk old calves. Curnick et al. (1983) reported values of 4.2 g/d and 21.3 g/d when diets containing 12 and 17% CP were fed. Winter (1976) found that as CP levels rose from 12 to 16 to 20% there was a tendency for nitrogen retention to increase from 5.1 to 7.5 to 11.5 g/d. Leibholz and Kang (1973) found that nitrogen retention was not affected by CP in the diet until values were corrected for feed intake. When corrected for feed intake, nitrogen retention was greater on 18% than on 15% or 12% CP diets.

D. Effects of Protein Source

Protein sources of various origins are degraded to differing extents in the rumen, and this will affect the composition and digestibility of protein in the post-ruminal sections of the gastrointestinal tract. Orskov (1982) lists values of 64.3-72.6%, 51.2%, 80.8%, 80.6%, 87.4% and 85.9% for the ruminal degradability of fish meal, meat and bone meal, soybean meal, cottonseed, groundnut meal and sunflower meal at a rumen outflow rate of 0.02/h. At an outflow rate of 0.05/h these values were 49.6-58.5%, 45.4%, 62.5%, 69.6%, 74.1% and 76.9% and at 0.08/h the values were 41.5%-52.4%, 41.2%, 50.4%, 62.7%, 64.3% and 70.4%. NRC (1989) lists values of 49%, 55%, 43%, 60%, 49%, 28% and 35% for the amount of

undegradable protein in brewers dried grains, corn gluten meal, cottonseed meal, fish meal, meat and bone meal, rapeseed meal and soybean meal.

Several treatments have been used in attempts to alter the rumen degradability of plant proteins to make more of the dietary protein available for post-ruminal digestion by the host animal. Formaldehyde treatment has been shown to reduce the degradability of both soybean meal and canola meal by 22-23% (Mir et al. 1984; Fiems et al. 1987). Extrusion at an unspecified temperature was ineffective in reducing the degradability of either soybean meal or canola meal (Deacon et al. 1988). Dry heat (110 or 120°C) has also been shown to be ineffective in reducing the degradability of soybean meal, but was effective in reducing canola meal degradability by 6.7 percentage units (Mir et al. 1984). NRC (1989) lists values of 70%, 82%, 80% and 78% for the amount of undegradable protein in protected rapeseed meal, soybean meal dried at 40°C, formaldehyde treated soybean meal and a formaldehyde treated soybean-rapeseed meal mixture.

Sharma et al. (1972) and Sharma and Ingalls (1973) reported lower rumen ammonia nitrogen levels when calves were fed starters containing soybean meal rather than rapeseed meal. Stake et al. (1973) reported lower rumen ammonia nitrogen levels on rapeseed meal supplemented diets, but this may have been caused by reduced intake on this diet. Rumen ammonia nitrogen levels are lowered by treatment of soybean and canola meals with formaldehyde (Sharma et al. 1972; Sharma and Ingalls 1973; Kovalcyzk et al. 1982) and heat (Sharma et al. 1972). Work with fish meal also indicates that the inclusion of protein sources that are lower in rumen degradability will result in lowered rumen ammonia nitrogen levels (Preston et al. 1964; Kay et al. 1967).

Sharma and Ingalls (1973) found that the inclusion of rapeseed meal, soybean meal or formaldehyde treated rapeseed meal in calf starters had no effect on either the concentration of volatile fatty acids in the rumen fluid or on the

molar proportions of volatile fatty acids. Sharma et al. (1972) reported that formaldehyde treatment of rapeseed meal did not change the molar proportions of volatile fatty acids, but reported that the total concentrations of volatile fatty acids was higher for untreated than for formaldehyde treated rapeseed meal. Preston et al. (1964) reported lower ruminal pH at 1 h post feeding on a diet containing soluble groundnut meal than on diets containing insoluble herring meal or soluble herring meal. Higher concentrations of volatile fatty acids and lower rumen pH would result from faster degradation of the protein source.

The differing rates and extents of ruminal degradation of protein sources results in altered composition of the digesta entering the post-ruminal section of the gastrointestinal tract. Leibholz (1980) reported that replacing meat meal with urea in calf starters resulted in a greater proportion of DM being digested prior to reaching the duodenum. When urea was included in the diet the flow of nitrogen to the duodenum was reduced and the digesta reaching the duodenum contained more ammonia and microbial protein and less amino acid protein. Similarly, Zerbini and Polan (1984) reported a higher percentage of microbial nitrogen in the abomasal nitrogen with soybean meal and cottonseed meal supplemented diets than with fish meal or corn-gluten meal supplemented diets. However, Sharma et al. (1974) did not show any differences in the abomasal flow of nitrogen due to the feeding of formaldehyde treated rapeseed meal.

The ultimate value of a feedstuff that by-passes rumen fermentation will be determined by its potential for supplying an improved balance of amino acid to the animal. As calculated by Orskov (1982) the protein required by a bull of large breeds growing at a rate of 1.0 kg/d up to 200 kg exceeds the estimated amino acid contribution from microbial protein by approximately 88% in early growth (up to 100 kg) and by approximately 38% in later growth (200 kg). The balance of amino acids must be supplied by feed proteins so the relative

proportions of feedstuff amino acids that by-pass the rumen must be considered in evaluating the usefulness of a protein source.

In soybean meal 17-24% of all amino acids except arginine were in the soluble fraction whereas with brewers dried grains and corn gluten meal less than 13% of each amino acid was present in the soluble fraction (MacGreggor et al. 1978). Shingoethe and Ahrar (1979) reported similar values for the percentage of each amino acid in the soluble fraction of soybean meal (13-26%) but for sunflower meal the range was much broader (19-53%). They also found that heating tended to reduce the solubility of all amino acids in soybean meal to about the same extent, whereas the solubility of several amino acids in sunflower meal (methionine, threonine, aspartic acid, glycine and serine) was higher than in the heated sunflower meal.

Mir et al. (1984) analyzed the protein residue of untreated soybean meal after a 12 h rumen incubation and found that rumen fermentation had decreased the proportion of histidine, lysine, arginine and leucine. However, when the residue from soybean meal treated with 0.8% formaldehyde was analyzed after 24 hours rumen incubation, only the proportion of histidine was lower, indicating that formaldehyde treatment had protected the other amino acids from degradation in the rumen. Sharma et al. (1974) have showed formaldehyde treatment of rapeseed meal to be ineffective in changing the quantity of amino acids passing the abomasum, but this may have been due to the lack of effect of formaldehyde treatment on ruminal N metabolism.

Urea in calf starters resulted in the passage of 100-170% of the intake of all amino acids except histidine, glutamic acid and proline to the abomasal digesta (Leibholz 1980). On meat meal diets, amino acids were present in the abomasal digesta at 58-121% of intake. Total quantities of amino acids passing through the abomasum were greater on meat meal diets. The increase in the

percent of dietary amino acids passing through the gut on urea-supplemented diets was due to microbial synthesis of amino acids.

Calculations based on the data of Deacon et al. (1988) indicate that there are differences in the intestinal digestibility of different feed proteins after ruminal degradation. After 8 h rumen incubation the percent of undegraded feed protein that disappeared in the intestine was approximately 85% for canola meal and 96% for soybean meal due to higher (approximately 11%) amounts of residual CP for the canola meal samples. Kendall (1988) reported values of 81%, 80% and 68% for the intestinal digestibility of N in canola meal after 8, 12 and 16 h rumen incubation. Values for the intestinal digestibility of soybean meal after 8, 12 and 16 h rumen incubation were > 90%. Similar trends were reported in this study for DM digestibilities. Thus, DM and nitrogen digestibilities appeared to decrease with longer rumen fermentation periods for canola meal but not for soybean meal. The author attributed differences between canola meal and soybean meal to the lower digestibility of the canola meal hull fraction. Therefore, the slight depression in whole tract, apparent digestibility of canola meal when compared to soybean meal is likely due to the lower digestibility of canola meal hulls. Methionine digestibility in the lower gut was approximately the same for canola meal and soybean meal, but the digestibility of other essential amino acids tended to be lower for canola meal samples (Kendall 1988).

Extrusion of canola meal and soybean meal did not affect the digestibility of CP in the lower gut (Deacon et al. 1988). However, Sharma et al. (1974) showed that DM digestibility in the lower gut tended to be lowered by treatment of rapeseed meal with 0.7 g formaldehyde per 100 g protein. Kovalcyzk et al. (1982) reported that formaldehyde treatment at 22 g formaldehyde per 100 g rapeseed meal reduced DM disappearance in the intestine by 41 percentage units. Formaldehyde treatment of ground whole soybeans at levels of less than 3.5 g

formaldehyde per 100 g protein did not change nitrogen digestibility in an acid-pepsin solution, but levels of 3.5-8.0 g formaldehyde per 100 g protein reduced acid-pepsin digestibility by 21-26 percentage units (Yu 1978). Thus, the reduced apparent digestibilities of DM and N associated with higher levels of formaldehyde treatment are due to overprotection of the feedstuff and reduced intestinal disappearance.

Blood urea nitrogen levels do not show consistent responses to the inclusion of rapeseed meal or soybean meal in calf starters. Ingalls and Sharma (1973) reported higher BUN levels at 1 wk on test with rapeseed meal than with soybean meal but at 2, 4 and 8 wk BUN levels tended to be higher on soybean meal supplemented diets. Fisher (1980) found slightly elevated BUN levels on soybean meal diets, but differences were not significant. Stake et al. (1973) reported lower BUN levels on rapeseed meal diets, but consumption of starter was also much lower on this diet.

Formaldehyde treatment of rapeseed meal tended to lower BUN levels at 1 wk on test (Ingalls and Sharma 1973) but at 2, 4 and 8 wk BUN levels were not lowered by formaldehyde treatment of the rapeseed meal. Sharma et al. (1972) showed significantly lower plasma urea nitrogen levels in calves fed formaldehyde treated rapeseed meal than in those fed untreated rapeseed meal. Nishimuta et al. (1973) showed that formaldehyde treatment of soybean meal for lambs reduced plasma urea nitrogen levels whereas heat treatment did not significantly reduce plasma urea nitrogen levels.

Zerbini and Polan (1984) reported higher serum urea levels on SBM, corn gluten meal and cotton seed meal supplemented than on fish meal supplemented diet. Kay et al. (1967) reported non-significantly lower BUN levels in fish meal supplemented diets than on groundnut meal supplemented diets.

Blood urea nitrogen levels were not changed when rations containing canola meal were compared to rations containing 12 or 18% whole canola seed but extruding the canola seed tended to lower BUN levels while pelleting the diet containing 18% whole canola seed tended to increase BUN levels (Sharma et al. 1986). No change in BUN levels were reported when 10% whole sunflower seed was added to calf starters, but 20% whole sunflower seed tended to lower BUN levels.

Rapeseed (canola) meal and soybean meal results in equal N retentions when fed for growth (Wood and Stone 1970; Sharma et al. 1980). Several authors (Stake et al. 1973; Sharma et al. 1980) have reported lower N retention with rapeseed meal but these results may have been due to lower intakes of N on the rapeseed meal diets. Variety does not appear to alter N retention on rapeseed meal supplemented diets (Bush et al. 1978). Sharma et al. (1980) reported higher N retentions for Tower rapeseed meal but protein percentages were higher on this diet. Sunflower meal also results in comparable N retention to soybean meal (Stake et al. 1973).

Sharma et al. (1972) reported reduced urinary N excretion on diets containing formaldehyde treated rapeseed meal but due to increased fecal N excretion on this diet there was no difference in daily N retention. Thus, N retained as a percent of intake N was equal for the two diets, but N retained as a percentage of digested N was 5 percentage units higher for the diets containing formaldehyde treated rapeseed meal. Nishimuta et al. (1973) reported that formaldehyde treatment of soybean meal slightly decreased daily N retention and the percent of intake N that was retained, due to decreased digestibility of CP. The percentage of intake N that was retained was non-significantly higher for the formaldehyde treated diet. Heat treatment, while reducing digestibility, increased N retention slightly, whether expressed as g/d, as a percent of intake N or as a percent of digested N.

Replacement of meat meal with urea does not affect N retention at equal feed intakes unless urea is included at levels above 40% of dietary N (Leibholz and Naylor 1971; Leibholz 1972, 1975). At higher levels of urea inclusion nitrogen retention is reduced due to higher urinary losses of N (Leibholz and Naylor 1971). Similar results have been obtained when 1.6 or 3.0% urea partially or completely replaced fish meal in calf starters (Kay et al. 1967). Winter (1976) did not find significant differences in N balance on isonitrogenous diets containing urea or soybean meal but N retention was higher on the soybean meal diet (13.1 vs. 9.5 g/d).

Whitelaw et al. (1963a) showed increased N retention values when insoluble herring meal was compared to a more soluble herring meal, but not when insoluble groundnut meal was compared to a soluble groundnut meal. Whitelaw et al. (1961b) also showed higher N retention values on fish meal supplemented diets than on either soluble or insoluble groundnut meal supplemented diets.

Cummins et al. (1982) formulated diets to contain 30, 45 or 60% rumen degradable N using combinations of corn gluten meal, cottonseed meal, urea and dehydrated alfalfa. Results showed a trend towards increased N retention as a % of RDN in the diet increased but feed intake and thus nitrogen intake was increased slightly as well. As a percent of N intake or as a percent of absorbed N, N retention tended to decrease with increasing rumen degradable N. Thus, it appears that absorbed N was sightly less efficiently utilized when the protein source was more degradable in the rumen. Trotta et al. (1984) showed no response in N retention when diets were formulated to contain 12.8-31.3% soluble N using soybean meal and dried brewers grains.

E. Effects of Whole Fat Oilseeds

Heat treatments that have been used in attempts to improve the by-pass protein value of oilseeds include dry-roasting, extrusion at low temperatures using external moisture and Jet-Sploding at higher temperatures using the seeds internal moisture to create steam. As was the case with soybean meal, heating soybeans at 110°C for 2 h or at 120°C for 20 min was ineffective in reducing protein degradability in the rumen (Mir et al. 1984). Yu (1978) found that higher temperatures (140°C) and longer heating times (4 h) were necessary for reducing the degradability of protein in full fat soybeans. Lower temperatures (110 or 120°C) or shorter heating times (2 h) were ineffective in reducing protein degradability and little change in degradability was noted at higher temperatures (160, 180 or 200°C).

Deacon et al. (1988) showed Jet-Sploding to be an effective method of reducing the ruminal degradation of whole canola seed when samples were ground, but found little value in extrusion as a method of decreasing ruminal degradation. In a second trial they found that the reduction in degradability of CP in canola seed was maximized at 149°C. At this temperature, protein degradability was decreased to 37% from 75% for the control (ground whole canola seed). No further decreases in CP degradability were found when the temperature was increased to 160 or 177°C. The values for CP degradability reported by Deacon et al. (1988) when seeds were Jet-Sploded to exit temperatures of 116 or 127°C (61 and 57%) agree closely with values of 57 and 59% reported by Mir et al. (1984) for canola seed heated to 110°C for 2 h or 120°C for 20 min.

Wrenn et al. (1973) have reported higher levels of linoleic acid in the fat of duodenal and plasma samples when calves were fed formaldehyde protected sunflower oil rather than unprotected oil. Ackerson et al. (1976) found that while formaldehyde treatment of full fat soyflour provided good protection against the microbial hydrogenation of linoleic acid, treatment of ground whole

soybeans did not give as good results. Yu (1978) reported that neither formaldehyde nor heat (100-200°C for 4 or 8 h) adequately protected polyenoic acids in whole soybeans from rumen hydrogenation. Rule and Beitz (1986) reported that extruded soybeans did not change the proportion of polyunsaturated fatty acids in the lipids of the duodenal ingesta when compared to soybean meal, indicating that the polyunsaturated acids in both diets were hydrogenated in similar proportions. Due to higher levels of ether extract reaching the duodenum when extruded soybeans were fed (18.1 and 20.9 vs. 13.0%) more linoleic and linoleic acid was found in the plasma of these animals.

When compared to a canola meal control diet, 12% or 18% whole canola seed or 18% extruded canola seed did not change total VFA in the rumen fluid, but pelleting a diet containing 18% whole canola seed increased total VFA concentrations (Sharma et al. 1986). Dietary treatment did not change the molar percentage of acetic acid, propionic acid or valeric acid, but the molar percentage of butyric acid was higher on a pelleted diet containing 18% whole canola seed than on a diet containing 12% whole canola seed or 18% extruded canola seed and tended to be higher than on a canola meal diet or one containing 18% whole canola seed. In a second trial these authors reported that 10 or 20% whole sunflower seeds did not change rumen pH or total VFA concentrations. The acetate:propionate ratio tended to be higher on diets containing whole sunflower seed. Anderson et al. (1982) found that while 25% whole cottonseed did not change rumen pH, there was a higher molar percentage of propionate in the rumen fluid with rations containing whole cottonseed.

When 12 or 18% whole canola seed replaced canola meal in calf starters no differences were found in RAN levels (Sharma et al. 1986). Extrusion of the canola seed tended to reduce RAN levels whereas pelleting the diet containing whole canola seed tended to increase RAN levels. In a second study no

differences were found in RAN levels when 10 or 20% whole sunflower seeds were added to the diet. Grumpelt (1987) found that whole or extruded canola seeds in lactation rations did not affect RAN levels but Kennelly (1983) reported a reduction in RAN levels when 18%, but not 6% or 12% whole canola seeds replaced canola meal in lactation rations.

Calculations based on data reported by Deacon et al. (1988) show that the by-pass protein from whole canola seed was less digestible in the intestine (approximately 40%) than was the protein from canola meal (approximately 85%). Extrusion and Jet-Sploding the whole canola seed increased intestinal protein digestibility to approximately 62.5% and 74.0% respectively, resulting in reduced residual losses of CP. Jet-Sploding whole canola seed over a temperature range of 116-177°C resulted in a range of intestinal digestibility of rumen undegraded feed material of 77-98% as compared to a value of 95.7% for ground whole canola seed but there was no consistent effect of Jet-Sploding temperature on intestinal disappearance of rumen undegradable protein.

Little information is available on the effects of whole fat oilseeds on N retention in calves. Prasad and Morrill (1976) reported higher N retention (15.8 vs. 6.6 g/d) when diets containing roasted soybeans were compared to diets containing raw soybeans for young (11 wk old) calves. The nitrogen retained as a percent of nitrogen intake (31.8 vs. 15.6%) was also higher in calves fed roasted soybeans. Abdelgadir et al. (1984) reported small, significant differences in nitrogen retention when calves were fed raw soybeans (0.31 g/kg body weight) as compared to soybeans Jet-Sploded to exit temperatures of 138°C, 171°C or to 191°C and held for 10 min (0.32 g/kg body weight for all three temperature regimes).

F. Effects of Implants

Work of Vander Wal et al. (1975b) revealed that the major part of the extra weight gained by hormonally implanted calves was due to increased N retention. In two experiments, implantation of estradiol plus testosterone increased N retention by 136 and 240 g after 24 and 38 d. Estradiol plus trenbalone resulted in a 551 g increase after 38 d, while estradiol alone increased N retention by 88 and 53 g after 24 and 38 d. Zearanol, testosterone, progesterone or trenbalone by themselves did not improve N retention. Maximum response occurred 4 to 5 wk after treatment at 11 or 12 wk.

IV. CARCASS COMPOSITION

Carcass muscling, conformation, external fat cover, kidney fat and carcass colour are the major parameters considered in veal carcass grading (Government of Canada 1984). Of these, muscling, conformation and fat characteristics determine the major grade classifications (A, B, C) whereas carcass colour is of importance only in determining secondary classification (1, 2, 3, 4). From a consumer viewpoint, however, meat colour is still deemed to be of major importance, the preferred meat being the pale white meat as would be obtained from calves raised on low fat milk or milk replacers. Kidney fat cover is of importance in assessing the degree of finish in calves slaughtered hide-on (ie. without skinning). This practise is employed to minimize water loss from the carcass.

A. Effects of Age and Weight

Brekke and Wellington (1969) report values for percent water and ether extract in the carcass tissue of 76.5 and 3.0% at birth, 68.9 and 11.8% at 90 kg and 64.8 and 6.5% at 131 kg. These numbers differed significantly between weight groups. Percent protein did not show consistent trends, being higher at birth than at 90 kg (19.1 vs. 16.8%, $P<0.01$) and intermediate at 131 kg (17.4%).

Waldman et al. (1969) report figures of 17.23, 18.04 and 17.84% protein and 4.84, 6.82 and 15.32% fat at birth, 91 and 227 kg, respectively.

Waldman et al. (1971) studied carcass composition in Holstein steers at birth, 91 kg, 227 kg, 341 kg, 455 kg and 590 kg. Their results showed that percent protein in the carcass tissue increased slightly from birth (17.9%) to 227 kg (18.46%) but accounted for a lesser portion of the tissue weight thereafter (14.48 to 16.52%). Moisture levels decreased at all weights ($P<0.01$) from 75.55% at birth to 49.15% at 590 kg, while carcass ether extract increased ($P<0.01$) from 4.33 to 35.12%. Plotting percent ether extract in the carcass against live weight yielded a sigmoidal curve, with the point of inflection between 227 and 341 kg live weight. At 227 kg the carcass contained 65.4% water, 18.46% protein and 14.14% ether extract.

At birth, the carcass of Holstein calves contain about 6-7% fat, 27% bone and 63.64% muscle (Waldman et al. 1969; Waldman et al. 1971). By 91 kg these percentages are 9% fat, 24% bone and 65% muscle and at 227 kg fat had increased to 15-16%, with a slight decrease in muscle and bone to 63 and 20% (Waldman et al. 1969, 1971). During this period the bone to muscle ratio decreased non-significantly from 0.42 to 0.33 and the fat to muscle ratio increased ($P<0.01$) from 0.09 to 0.24 (Waldman et al. 1971).

Waldman et al. (1971) showed that during early growth (i.e. up to 227 kg) muscle weight increased rapidly from 8.77 to 38.48 kg. Increases in fat weight (0.80 to 9.17 kg) and bone weight (3.70 to 12.77 kg) were slower. After 227 kg however, fat deposition accelerated and paralleled increases in muscle mass. In reviewing the literature Berg and Butterfield (1968) reached similar conclusions, in that muscle growth proceeds at a faster rate than fat growth in the early stages. After the onset of fat deposition at about 150 kg carcass weight, fat growth is parallel to muscle growth.

Waldman et al. (1971) showed that increased lipid deposition in the longissimus dorsi (l. dorsi) and the semitendenosis muscles was coincident with the point of inflection of the ether extract deposition curve. From birth to 227 kg, total lipids of these muscles was less than 1.60% and the values did not differ ($P>0.01$) at birth, 91 or 227 kg. After 227 kg total lipid of the l. dorsi muscle increased to 6.82% and that of the semitendenosis muscle increased to 5.41%.

Brekke and Wellington (1969) reported dressing percentages of 58.3, 60.9 and 63.2% for milk-fed calves slaughtered at birth, 90 kg and 131 kg. Differences were significant ($P<0.01$) between weight groups. In contrast, Butterfield et al. (1971) did not show increases in dressing percentages over a weight range of 44 to 82 kg for milk fed calves. Beauchemin (1980) reported a slight decrease in dressing percentage of milk-fed calves when carcass weight was increased from 88 to 108 kg, but daily gains were lower at the heavier weight.

Butterfield et al. (1966) reported a decrease in dressing percentage from 55.24 to 46.07% when calves were slaughtered from 4 through to 22 wk (41 to 90 kg). For this experiment this is likely due to increasing visceral growth (Gardner and Wallentine 1972) and poor daily gains. For calves slaughtered from 180 kg to 540 kg, Andersen (1975) reports an increase in dressing percentage with increasing live weight; and also with increasing feeding levels. Beauchemin (1980) reported a slight decrease in dressing percentage for barley concentrate fed calves when carcass weight was increased from 88 to 108 kg, but increasing the carcass weight increased the dressing percentage of corn-supplement calves from 52.7 to 54.9% ($P<0.05$). They attributed this increase to slightly better daily gains (0.82 vs 0.93 kg) when calves fed corn were slaughtered at 108 kg carcass weight rather than 88 kg carcass weight. Anderson (1975) reported slight increases in dressing percentages when daily gains were increased.

Beef fat is generally characterized by high levels of saturated fatty acids, owing to the reduction of fatty acid double bonds by hydrogen produced in rumen fermentation. Moran (1986) lists the major fatty acids in beef fat as oleic acid (C18:1), palmitic acid (C16:0) and steric acid (C18:0), these comprising 47, 26 and 14% of the total fatty acids. Myristic (C14:0), palmitoleic (C16:1), linoleic (C18:2) and linolenic (C18:3) acids each made up less than 3% of total fatty acids in beef.

Fats of the various depots vary in fatty acid composition, with the degree of saturation higher in internal (kidney fat) depots than in muscle depots, which in turn are more saturated than subcutaneous depots (Callow 1962; Waldman et al. 1968). This increase in the percent saturated fatty acids is due primarily to an increase in the content of C18:0 and a decrease in the content of C18:1 (and to a lesser extent, C16:1) in the internal fat depots (Ostrander and Dugan 1962; Waldman et al. 1968). There is also considerable variation in fatty acid composition due to different muscles or sample location (Callow 1962; Ostrander and Dugan 1962; Marchello et al. 1968; Waldman et al. 1968). In addition, the phospholipid fraction of muscle fat differs from the neutral fraction in that phospholipids contain more arachidonic (C20:4), linoleic and linolenic acids, but less palmitic, palmitoleic and oleic acids; the net result being a decreased saturated fatty acid content of the phospholipid fraction (Hornstein et al. 1961; Ostrander and Dugan 1962).

The C18:1 content of beef fat is positively correlated with age, carcass weight and carcass fat percent, but negatively correlated with daily gain (Link et al. 1967; Waldman et al. 1968). Carcass weight did not affect the concentration of C16:0 or C18:0 but the concentrations of C14:0, C16:1, C18:2 and C18:3 were lower at heavier carcass weights (Waldman et al. 1968). The content of C18:0 was negatively associated with carcass fat and the content of C16:0 was

negatively associated with age. The C18:2 content of beef fat was negatively associated with daily gain. Thus, as summarized by Waldman et al. (1968), it appears that as the animal approaches physiological maturity (i.e. increased age, carcass weight and carcass fat) the concentration of C18:1 in the fat increases.

B. General Nutritional Effects

Butterfield et al. (1971) reported that milk fed calves up to a weight of 82 kg did not differ in the amount of fat or bone in the carcass irrespective of whether milk was fed ad libitum, at 10-15% of body weight or at levels aimed at keeping the calves at starting body weight for 72 d. Although muscle weight was different between the three planes of nutrition (after adjustment for live weight), the muscle to bone ratio did not differ, whether adjusted for differences in live weight or not. Fat percentage in the carcass did not differ between the three planes of nutrition when adjustments were made for variations in live weight. Similarly, Butterfield et al. (1966) reported that up to 22 wk calves that suffered an early weaning check were lighter, had lighter carcasses, muscle weights and bone weights at any given time, but after these parameters were adjusted to equal weights of muscle plus bone no differences were apparent between feeding levels.

Working with older (birth to 590 kg) animals Waldman et al. (1971) found that feeding calves at a high or a medium level did not influence weight of carcass fat, muscle, or bone at equal live weights. Although the bone:muscle ratio was slightly altered in favour of animals fed at a high level, the ratio of fat to muscle was not altered by treatment. Andersen et al. (1975) found that when bulls were slaughtered at lower weights (180 kg live weight) differences in percent muscle, fat and bone in the carcass were small despite large differences

in feeding levels. Again, the muscle to bone ratio was slightly higher in favour of bulls fed on an ad libitum feeding regime.

From the above studies it appears that the percentage of a carcass that is muscle, fat and bone is more a function of animal weight than of feeding level. Differences in feeding level appear only to alter the rate at which an animal reaches a certain body composition. However, Waldman et al. (1971) reported an increase in % ether extract and a decrease in % moisture at 91 and 227 kg when calves were fed on a high rather than a medium plane of nutrition. Percent protein in the carcass decreased with increased feeding at 91 kg but not at 227 kg. These results are at variance with results for the physical dissection of carcasses in the same trial. Kerz et al. (1982) reported that the % fat increases and the % water decreases in subcutaneous adipose tissue when animals are fed ad libitum rather than restricted levels. It is probable then, that on a high plane of nutrition more fat is being deposited in the adipose tissue that is present, even if the amount of carcass fat remains unchanged.

Butterfield et al. (1966) showed a decrease in dressing percentage when calves suffered an early weaning check to live weight gains. Dressing percentage of milk fed animals (up to 82 kg) has been shown to decrease in response to decreased levels of feeding (Butterfield et al. 1971). This finding did not change when dressing percentage was adjusted for live weight or for carcass weight. Andersen (1975) reports decreased dressing percentages for calves fed restricted amounts of feed when slaughtered at 180-540 kg. This effect of lower plane of nutrition on dressing percentage has been attributed to the laying down of relatively more fat in the carcass, rather than the non carcass, parts in animals fed at higher levels (Berg and Butterfield 1976).

C. Carcass Quality of Calves Fed Grain Based or Milk Based Diets

Bray et al. (1959) and Jones et al. (1974) report inferior grades for carcasses of grain fed animals compared to grades for milk fed animals when grading systems emphasizing kidney fat, fat cover and color were used. However, Gardner and Wallentine (1972) found that the carcasses of grain fed animals graded similarly to those of milk fed animals. When fat was added to grain diets, they maintained that more fat was deposited externally and over the kidney, and that this fat was similar in quality (i.e. firm and white) to that of milk fed veal. A study by Beauchemin (1980) showed that increasing slaughter weights improved the grading of carcasses, especially those on a corn-supplement feeding system. Furthermore, they showed that a grading system which emphasized general carcass conformation as well as external fat cover resulted in improved grades for grain fed veal calves. Under such a system, milk fed and grain fed carcasses graded similarly.

The carcass yield (dressing percentage), as a percent of live weight, is lower for grain fed calves than for milk fed calves. Studies have reported dressing percentages of 53.3 and 60.8 (Kunz et al. 1969), 53.8 and 60.8 (Gardner and Wallentine 1972), 59.0 and 67.5 (Jones et al. 1974) and 50.5 and 56.5 (Bouchard et al. 1980) for grain fed and milk fed calves, respectively, when slaughter weight was less than 136 kg. At heavier weights the trend towards higher dressing percentages for milk fed animals is also evident. Beauchemin (1980) reports values of 53.4 and 57.1% for grain fed and milk fed calves slaughtered to yield 88 kg carcasses. When calves were slaughtered to yield 108 kg carcasses, values were 54.3 and 56.0%. Brisson et al. (1979) reported dressing percentages of 55.3 and 59.5% when grain fed and milk fed calves were slaughtered at approximately 150 kg live weight. When the slaughter weight was 170 kg these values were 52.8 and 55.5%. The lower dressing percentage of the

grain fed animal is due to greater rumen development and gut fill with grain feeding (Gardner and Wallentine 1972).

Only small differences are apparent in the carcass composition when grain fed animals are compared to milk fed animals, even when slaughter weights differ. Bray et al. (1959) slaughtered calves at 6 wk of age and found significantly less fat in the l. dorsi muscle of calves fed limited milk or milk replacer plus starter and hay (0.44%) than of those fed ad libitum milk diets (0.61 and 0.79%). Kidney fat was higher for the milk fed groups (1.04 and 1.07% of body weight) than for grain fed groups (0.55 and 0.25% of body weight). Kunz et al. (1969) reported ether extract and CP percentages of the 11-12th rib section to be 5.8 and 20.6% for grain fed calves and 8.3 and 22.8% for milk fed calves. Kidney fat weights were 1214 g and 769 g. These calves were slaughtered at 136 kg live weight.

Seewald et al. (1987) slaughtered calves at 4 mo of age, resulting in live slaughter weights of 158 kg for milk fed calves and 123 kg for grain fed calves. They found that milk fed calves had more total lipid in the l. dorsi muscle, the supraspinitus muscle and the subcutaneous fat (1.31, 1.58 and 74.35%) than did grain fed calves (0.89, 1.17 and 69.90%). The percent total lipid in the perinephric fat did not differ between the two groups (88.01 and 86.0%).

When both milk fed and grain fed calves were slaughtered at 113 kg live weight Bouchard et al. (1980) could find no difference in the percent dissectible fat at the 12th rib, which was approximately 16% for both groups. However, they found that grain fed calves had less muscle at the 12th rib (57.6 vs. 60.3%) and a smaller rib-eye (27.7 vs. 32.2 cm^2) than did milk fed calves. In contrast, Beauchemin (1980) found no difference in these measurements when grain fed and milk fed calves were compared at 167 and 204 kg live weight and Waldman et al. (1971) have reported that at 91 and 227 kg feeding level does not greatly

influence the percentage of physically separated bone, muscle or fat in the carcass. However, Pinkerton et al. (1971) showed smaller rib-eye area with low protein diets and Donnelly and Hutton (1976) report lower protein gains and percent protein in the carcass with lower dietary protein. Thus, the lower percent muscle at the 12th rib as reported by Bouchard et al. (1980) may have stemmed from inadequate dietary protein quantity or quality.

Gardner and Wallentine (1972) could demonstrate no differences in the chemical composition of either the 11th-12th rib section or the semitendenosis muscle when grain fed or milk fed animals were slaughtered at 110-114 kg or 125 kg live weight. Milk fed animals had slightly higher levels of ether extract and slightly lower levels of CP in these muscles than did grain fed calves but differences were not significant. Kidney fat weights were higher for milk fed calves in trial II (1214 g vs. 490-699 g) but not in trial I (335 g vs. 257-625 g).

Beauchemin (1980) reports a higher percentage protein (84.5, 84.1%) and a lower percentage fat (5.31, 6.08%) in the l. dorsi muscle of grain fed animals as compared to the same muscle in milk fed animals (81.6% protein and 6.96% fat). These values are averages for carcasses weighing 88 and 108 kg. At these carcass weights, grain fed animals weighed 167 and 204 kg and milk fed animals weighed 150.5 and 182.6 kg. Batra et al. (1973) reported an increase in the percent fat in the minor and major cuts of 3.70 and 2.67 percentage units when milk fed calves were compared to grain fed calves at 128 kg. Similarly, Brisson et al. (1979) report that milk fed carcasses had 2.2% more fat and 0.5% less protein than did grain fed carcasses when calves were taken to 150 and 170 kg live weight.

In summary, increases in fat percentage in the carcass DM of milk fed animals are in the order of 2-3 percentage units. Increases in the percentage

visual fat at the 12th rib have not been reported. Kidney fat is usually heavier with milk fed calves, but the percentage fat in the kidney fat is comparable for both milk fed and grain fed calves.

The 18 carbon fatty acids appear to be the most abundant fatty acids in milk fed veal. Ostrander and Dugan (1962) compared the polyunsaturated fatty acids of beef and veal and found that the oleic acid content of veal intramuscular, intermuscular and covering fat was 34.1, 43.3 and 48.0% of total fat. Corresponding values for beef fats were 42.6, 41.9 and 44.9%. Veal fats had a higher percentage of linoleic acid in the intramuscular depots (4.2%) than did beef (1.1%). Veal had higher levels of linolenic acid in the intramuscular depots (2.0%) than in the intermuscular or covering depots (0.6%). In beef fats these levels were similar in all depots at 0.2-0.3%.

Ono et al. (1986) reported values for the fatty acid content of raw lean from arm steaks, blade steak, rib roasts, loin chops, sirloin chops and cutlets of milk fed veal. They also found the C18 fatty acids to be the most abundant. Stearic acid ranged from 0.14 g/100 g raw lean in the cutlet to 0.42 g/100 g raw lean in the rib roast. The ranges for oleic and linoleic acid were 0.47 to 1.57 and 0.18 to 0.33 g/100 g raw lean. They found that palmitic acid was present in quantities ranging from 0.23 to 0.69 g/100 g raw lean, while myristic and palmetoleic acids were present at less than 0.14 g/100 g raw lean. Values for bob veal (less than 4 wk of age) followed similar patterns but were much lower, and bob veal had proportionately less myristic and linoleic acids than did milk fed veal.

Ostrander and Dugan (1962) reported the arachadonic acid content of veal intramuscular fat to be 2.1%. Values for the intermuscular fat and covering fat of veal and for beef were less than 0.2%. When they separated the muscle fat into phosphatides and neutral fat they found that the arachadonic acid content

was higher in the phosphatide fraction for both veal (1.4 vs. 0.7%) and beef (3.7 vs. 0.00%). Hornstein et al. (1961) also found higher levels of arachadonic acid in the phospholipid fraction than in the neutral fat fraction of beef fat. Ono et al. (1986) reported that veal contains 0.05-0.06 g arachadonic acid/100 g raw lean. The phosphatide fraction of veal contains less linoleic acid than does the neutral fat (0.1 vs. 3.9%) whereas quantities of linolenic and pentaenoic acids are similar. The phosphatide fraction of beef fat contains more linoleic, linolenic and pentaenoic acids than does the neutral fat.

Seewald et al. (1987) compared the fatty acid content of milk fed veal with that of grain fed veal. They found that oleic and linoleic acids each made up 20-30% of the fatty acids in the l. dorsi and supraspinatus muscles. Palmitic acid ranked third in abundance, making up 19-25% of the fatty acids. Unlike the fat of muscle tissue, the perinephric and subcutaneous fat contained < 5% linoleic acid. Oleic acid on the other hand made up 34-40% of the fatty acids in perinephric and subcutaneous tissue.

Stearic acid made up 11.4% of the fatty acids in the l. dorsi muscle of milk fed calves and 14.2% of the fatty acids of this muscle in grain fed calves ($P<0.01$). In the supraspinatus muscle these values were 14.7 and 16.2% ($P>0.05$). Likewise, stearic acid was more abundant in the perinephric and subcutaneous fat of grain fed animals. Lauric (C12:0) and myristic acids (C14:0) were more abundant in the fat of milk fed calves, and differences were statistically significant for all cases except lauric acid in the subcutaneous and perinephic fat depots. Arachidonic acid made up to 9.1% of the fatty acids of both muscles with lower value ($P<0.05$) for the milk fed calves. Only trace amounts of this acid was present in the subcutaneous and perinephric fats.

The polyunsaturated fat to saturated fat ratio was reported by Ono et al. (1986) to vary from 0.31 to 0.59 for milk fed veal. Bob veal had lower ratios

(0.19 to 0.40) due to the lower levels of linolenic acid in this meat. Ostrander and Dugan (1962) reported that veal intramuscular, intermuscular and covering fat had 51, 49.7 and 41.4% saturated fatty acids, while for beef these values were 59.3, 52.1 and 48.8%.

D. Effects of Cereal Source

Work by Latrille et al. (1983) indicates that barley and corn both give acceptable carcass quality when animals are slaughtered at 185 kg live weight. Carcass quality was somewhat deficient in oat fed calves. Whereas 74% of barley fed and 83% of corn fed calves graded A, only 55% of oat fed calves graded A. Oat-fed calves had lower dressing percentages (50.0%) and carcass weights (97.9 kg) than did corn (53.2%, 114.8 kg) or barley (54.3%, 110.0 kg) fed calves. These results are likely due to a combination of lower daily gains and lower carcass weights with oats, as discussed in sections IV. A and B.

Other authors have reported little difference in carcass measurements on corn and barley diets. Guertin et al. (1987a) found no differences in the muscle composition of the 12th rib or in the composition of the 9th-10th-11th rib section when calves were fattened on whole corn, rolled barley or whole barley. Carcass weights and dressing percentages were lower on whole barley (111.5 kg, 52.0%) than on rolled barley (118.8 kg, 53.6%).

Beauchemin (1980) reported no differences in rib-eye area, composition of the 12th rib or chemical composition of the l. dorsi section at the 12th rib when animals were raised on either whole corn plus supplement or barley based concentrates. However, at heavier slaughter weights corn fed calves had higher dressing percentages than at lighter weights (54.9 vs. 52.7%) whereas barley fed calves did not (53.6 vs. 54.0%). Thus it appears that the slight improvement in daily gain with corn feeding may improve dressing percentage. Andersen et al.

(1975) noted improved dressing percentage with increasing slaughter weight and with higher energy levels.

No work could be found relating to wheat diets for calves in this weight range but work with older animals (Oltjen et al. 1966) indicates no effect on carcass parameters when wheat was compared with corn. This was true despite reduced live performance with wheat diets.

E. Effects of Added Fat

Dressing percentage does not appear to be affected by fat additions to the diet. Gardner and Wallentine (1972) and Bouchard et al. (1980) showed no change in dressing percentage with fat additions to barley diets of up to 6%. Fisher (1980) added 10 or 20% protected tallow to barley diets and found no increase in the carcass yield. Work with corn diets has also shown no effect of added fat on the dressing percentage (Wrenn et al. 1979). No information was found for calves slaughtered at 200 kg.

Reports are contradictory as to whether added dietary fat increases carcass fat deposition. Gardner and Wallentine (1972) found no difference in the chemical composition of the 10th-11th-12th rib section or of the semitendenosis muscle when barley based diets containing no added fat were compared to diets with 5% added fat. They stated that external fat cover was improved when fat was added to the diet but this observation was not quantified. Furthermore, grades were not improved with added fat in the diet. Kidney fat deposition however, was increased 100% with 5% added fat at a slaughter weight of 114 kg and by 30% at a slaughter weight of 125 kg. Fisher (1980) also found that kidney fat as a percent of body weight increased from 0.57 to 0.61 to 0.69% when percent protected tallow in the ration was increased from 0 to 10 to 20%.

Bouchard et al. (1980) reported that the percent physically dissected fat in the 12th rib increased by 2.0 and 2.9 units when 3 and 6% fat was added to barley diets. Percent muscle in the rib was decreased by 2.5% and rib eye area decreased non significantly with 6% fat in the diet. This is in contrast to the results of Gardner and Wallentine (1972) who reported no change in the chemical composition of the rib section with added fat, and Wrenn et al. (1979) who found that the meat from half carcasses did not vary in lipid or protein percent when 5% fat or 5% fat plus 1% cholesterol was added to corn diets.

Stiles et al. (1974) slaughtered corn fed calves at 200 kg and found a slight, non-significant decrease in percent ether extract with 4% added fat in the diet (22.0% vs. 31.5% for controls). Protein percent was increased non-significantly from 64.5% at 0% dietary fat to 68.1% at 4% dietary fat. Furthermore, there was a significant interaction between percent dietary protein and percent dietary fat for ether extract content of the meat samples. As dietary protein decreased from 18 to 15 to 12% at 0% dietary fat, percent ether extract in the meat samples increased from 20.1 to 30.0 to 37.2%. These values for diets containing 4% added fat were 19.3, 22.6 and 23.2%.

Work with beef cattle indicates that high concentrate diets support rumen microbial populations that are less active in biohydrogenation of polyunsaturated fatty acids than do high forage diets (Cabezas et al. 1965). The feeding of 6% safflower oil was found to be effective in increasing the unsaturated fatty acid content of beef fat, whereas animal fat either caused no change or an increase in the saturated fatty acid content (Dryden and Marchello 1973). Dinius et al. (1974) showed an increase in the (C18:1 content of beef fat when unprotected safflower oil was fed to beef steers. Thus there is potential for changing the fatty acid content of meat by feeding supplemental oil in high concentrate diets.

The feeding of up to 4% corn oil in calf starters increased total blood lipids whereas levels greater than 4% decreased blood lipids (Chandler et al. 1968) but no information on the fatty acid composition of the blood lipids or of the carcass lipids was given. Wrenn et al. (1979) reported that 5% tallow or 5% tallow plus 1% cholesterol increased plasma lipids, but their results showed no change in the fatty acid composition of the carcass fat.

The feeding of Ca soaps at 5, 10 or 20% of calf starters was effective in increasing plasma lipids (Fallon et al. 1986). Wrenn et al. (1973) reported an increase in the concentration of linoleic acid and a decrease in the concentration of myristic and palmitic acids in biopsy samples and in the fat of the chuck and round cuts when calves were fed milk that was high in linoleic acid and starters containing protected safflower oil. The feeding of protected safflower oil (Dinius et al. 1974) or a supplement of protected whole sunflower seed and soybeans (Garrett et al. 1976) to beef steers has also been effective in increasing the content of linoleic acid in the fat. This increase was concurrent with a decrease in the amount of C14, C14:1, C16 and C16:1. Adding extruded soybeans to beef steer rations to raise the fat content of the diet to 6% has also been shown to be effective in increasing the polyunsaturated fat content of the carcass fat (Rule and Beitz 1986). In this case, there was an increase in the proportions of C18:2 and C18:3.

F. Effects of Protein Source

Information on the effects of various protein sources on carcass quality of calves in this weight range is limited. Pinkerton et al. (1971) compared carcasses of calves raised to 286 kg on diets containing soybean meal, fish meal and meat meal with those of calves raised on diets containing cottonseed meal. They found that rib-eye area and rib-fat thickness was slightly lower on diets

containing cottonseed meal. Carcass grades were similar on both diets. Bouchard et al. (1980) found that meat and bone meal gave larger rib-eyes and a greater % fat and a lower % bone at the 12th rib than did soybean meal. In a comparison of soybean meal and rapeseed meal, soybean meal resulted in significantly more kidney fat (Fisher 1980). Dressing percentage was not affected in any of these studies.

G. Effects of Protein Level

Work with pre-ruminant calves has shown that increasing protein levels in the diet increases protein deposition in the carcass (Berg and Butterfield 1976; Donnelly and Hutton 1976). Similar results have been obtained for ruminant calves slaughtered at less than 300 kg.

Stiles et al. (1974) found that increasing the CP content of the concentrate mix from 12 to 15 to 18% produced a significant linear increase in protein content of the carcass DM from 63.3 to 65.8 to 72.0%. There was a tendency for ether extract content to decrease, dropping from 31.2 to 26.3 to 19.7%. Water content of the meat samples was 68.8, 70.1 and 71.8%. Gardner and Wallentine (1972) reported a similar increase in protein content of the 10th-11th-12th rib section but their results did not reach significance. Lower protein in the diet (12.6% CP vs. 14.1% CP) resulted in 17% more kidney fat.

Bouchard et al. (1980) reported that the percent physically dissected muscle at the 12th rib was similar for calves fed diets containing 13 or 15% CP (56.1, 57.4%) but 17.5% CP in the diet significantly increased the percent muscle (59.4%). Fat content was decreased with higher protein levels (18.6, 16.8 and 14.2%). Rib-eye area tended to be higher on higher protein levels (28.4 vs. 27.1 cm^2). Pinkerton et al. (1971) have also reported larger rib-eyes in calves raised on higher protein diets.

Dietary CP levels in the range of 12-18% CP did not affect carcass yields when calves were slaughtered at lighter (< 125 kg liveweight; Gardner and Wallentine 1972; Bouchard et al. 1980) or heavier (285 kg liveweight; Pinkerton et al. 1971) slaughter weights.

Neither grades nor carcass color are affected by dietary protein levels (Pinkerton et al. 1971; Gardner and Wallentine 1972; Bouchard et al. 1980). The lack of response in carcass grades to dietary protein levels was likely due to the emphasis that these grading systems place on fat cover and carcass color.

H. Effects of Hormonal Implants

Grandadam et al. (1975) found that implantation with estradiol and testosterone significantly improved carcass grades, due to improved meatiness of the carcasses. They also found that the graders tended to place more of these carcasses in the white, rather than the pink or red categories, and that the carcasses tended to be less fat. Van Weerden (1984) also showed meatiness was judged to be slightly better in estradiol-testosterone or estradiol-trenbalone implanted calves, but they could demonstrate no effect on meat color. Dressing percentage is not affected by implantation (Grandadam et al. 1975; Van Weerden 1984) but carcasses of implanted calves are usually heavier, due to heavier live weights at slaughter (Grandadam et al. 1975).

Data presented by Van Weerden (1984) indicates that there is no real effect of implantation with estradiol plus testosterone or trenbalone on the chemical analysis of muscle tissue. The l. dorsi muscle had slightly less water (0.4-0.6%) and slightly more protein (0.3-0.9%) when implanted with estradiol plus trenbalone acetate, but analysis of the l. dorsi, pectoralis profundus and rectus femoris muscles of calves implanted with zearanol plus trenbalone acetate or estradiol plus trenbalone acetate in a second trial revealed no differences from

control, unimplanted groups. Thus it would seem that the implants exert their effect through increased muscling and not through increased protein concentration in the muscles.

V. MEAT COLOR

A. Effect of Age and Weight

The color characteristics of veal meat change with increasing age of the animal at slaughter. Beauchemin (1980) reported a decrease in color reading (and hence a darker colored meat) as slaughter weight increased to give a carcass weight of 88 or 108 kg (58.8 vs. 50.1% reflectance). This decrease in meat color readings occurred when calves were fed milk (72.7 vs. 60.6%), concentrate (50.7 vs. 46.1%) or corn plus a protein supplement (52.8 vs. 43.3%). Sheper (1978) also reported that raising the slaughter weight over a range of 80-175 kg resulted in a darker colored meat. Using biopsy samples of the vastus lateralis muscle St. Laurent and Brisson (1967) found a constant increase in the redness of the muscle over the age range of 15 to 60 d. They reported that the brightness and yellowness readings appeared to decrease from 15 to 45 d and then increase from 45 to 60 d, but these differences were not significant.

B. Effect of Supplementary Iron

In calves fed solely on milk replacer the level of supplementary Fe in the milk replacer will affect meat colour. Supplementation of milk replacers with less than 40 ppm Fe in the DM has no effect on meat colour (MacDougall et al. 1973; Bremmer et al. 1976) but supplementation at levels above 40 ppm Fe in the DM have been shown to result in darker-coloured meat (MacDougall et al. 1973; Bremmer et al. 1976; McFarlane et al. 1988). When calves were slaughtered at 60 d, St. Laurent and Brisson (1968) reported less pronounced effects on meat colour

when dietary Fe was supplemented at a rate of 50 mg/calf/d but DM intake was not reported. However, feeding supplemental Fe at a level of 240 mg/calf/d was shown by Bray et al. (1959) to have a pronounced effect on meat colour when calves were slaughtered at 6 wk. Injesting Fe at a rate of 800-900 mg/d over 12 weeks has also been shown to result in darker coloured meat (Mollerberg et al. 1975).

When Fe levels in the basal diet were 8-10 ppm the feeding of only 5 ppm supplemental Fe has been shown to darken meat colour at 21-23 wk (Wensing et al. 1986). However, these authors reported no effect on meat colour at 21-23 wk if supplemental Fe feeding was discontinued at 16 wk. McFarlane et al. (1986) also reported that supplemental Fe (140 ppm) in the early (<3-4 wk of age) growth stage does not affect meat colour if Fe levels thereafter are low (5 ppm).

Feeding milk replacers that are low in iron results in a microcytic, normochromic anemia, the symptoms of which include reduced blood hemoglobin level, reduced red blood cell counts, reduced packed cell volumes and reduced plasma iron concentrations (Bremner and Dalgarno 1973; Blaxter et al. 1975). Supplementation of diets with 40-45 ppm of iron or 50 mg Fe/d appears to be adequate to improve the hematological status of the blood (St. Laurent and Brisson 1968; Bremner and Dalgarno 1973; MacDougall et al. 1973; Bremner et al. 1976) but is insufficient to effect large increases in myoglobin synthesis (St. Laurent and Brisson 1968; MacDougall et al. 1973). Higher levels of Fe supplementation (100 mg Fe/kg DM or 240 mg Fe/d) increase myoglobin content of the muscle (Bray et al. 1959; MacDougall et al. 1973). Thus it seems that increasing dietary iron will first allow the calf to increase its requirement for hemoglobin synthesis, and further increases will allow for increased myoglobin synthesis. Hence, marked changes in meat color in response to dietary iron will likely only occur when changes in myoglobin content are possible.

C. Effect of Dietary Regime (Milk vs. Grain Feeding)

Feeding grain to calves results in meat that is darker in color than does the feeding of milk. Bray et al. (1959) reported that feeding calves to 6 wk on milk or milk replacer plus starter and hay resulted in meat color readings of 28.3% as compared to values of 29.5% for calves fed only whole milk. The lower numbers indicate lower percentage reflection and hence a darker meat. Bouchard et al. (1980) reported color readings of 48.4 and 58.4% for grain fed and milk fed animals respectively. Beauchemin (1980) reported that when veal calves were fed milk replacer, barley based concentrate or whole corn plus a protein supplement the color readings averaged over 2 carcass weights (88 and 108 kg) were 66.7, 48.0 and 48.4%, with significant differences between milk fed and grain fed animals. Wood and Froehlich (1981) reported that milk fed veal was less pink in color, but not lighter, than grain fed veal as measured with a Hunter Color Meter. A trained panel also judged the milk fed veal to be less pink than the grain fed veal. Differences between grain fed and milk fed veal however, generally disappeared with cooking and with freezing the meat. An exception to this was the instrumental measurement of degree of redness of the rounds, which was significantly different between treatments after 4 mo in the freezer. Gardner and Wallentine (1972) also reported that the meat of milk fed calves was judged to be lighter than that of starter fed calves and that the difference disappeared when the meat was roasted. Smulders and Visser (1988) reported that Hunter color readings were higher (and thus the meat lighter) for calves fed milk replacer than for calves fed milk replacer and wheat straw or milk replacer plus calf starters.

D. Effects of Cereal Source

Guertin et al. (1987a) found no difference in the meat color of heavy calves regardless of whether they had been fed whole corn, whole barley or rolled barley. Beauchemin (1980) found similar meat color readings for calves fed diets based on whole corn (48.4) or rolled barley (48.0). Latrille et al. (1983) reported that 75-80% of calves fed whole corn or whole barley graded A whereas only 55% of oat fed calves graded A. They did not report color readings but reported that the inferior grades of oat fed calves was due to inferior finish on the carcass.

E. Effects of Added Fat

Supplementation of fat to skim milk diets did not significantly affect meat color but there was a tendency towards lighter colored meat at higher levels of fat supplementation (Johnson et al. 1988). This was probably related to increased marbling at these higher levels of fat supplementation. Bouchard et al. (1980) however, have reported that added fat in grain rations resulted in a darker colored meat. Gardner and Wallentine (1972) reported that 5.0% fat in grain rations did not change visual color ratings of the carcass.

F. Effects of Protein Source and Protein Level

High levels (29%) of fish protein concentrate in a milk replacer resulted in a more reddish colored meat as assessed by a colorimeter when raw or visually by a taste panel when cooked (Jenkins et al. 1982). This most likely occurred because of an elevation in Fe content of the milk replacer when fish protein replaced milk protein, as has been reported by Huber and Campos (1982). Bouchard et al. (1980) found that the inclusion of meat meal in calf starters resulted in a lighter colored meat than did soybean meal and they attributed this to the

lower levels of dicalcium phosphate (a rich source of iron) needed when meat meal was the protein supplement. Protein levels (13.2, 15.4 or 17.7%) did not significantly affect the meat color in the study by Bouchard et al. (1980).

VI. SENSORY EVALUATION

A. Effects of Age and Weight

Age and/or weight of the calf at slaughter appear to exert some effect on the organoleptic properties of the meat. When calves were slaughtered over a weight range of 80-175 kg water binding capacity deteriorated with increasing slaughter weight (Sheper 1978). However, over a range of 100-500 kg Zupka et al. (1970) reported an improvement in water binding capacity as slaughter weight increased. Brekke and Wellington (1972) slaughtered calves at 44 kg (3-4 d), 91 kg (8-11) wk) or 124 kg (13-14 wk) and found that Warner-Bratzler shear values were lower for calves slaughtered at 44 kg (2.23 kg) than for calves slaughtered at 90.0 kg (3.29 kg) or 124.2 kg (3.23 kg), thus indicating decreasing tenderness as the animals increased in size and/or age. Warner et al. (1988) have also reported that meat from the l. dorsi and semimembranous muscles decreased in tenderness as animal age increased from 10 to 18 wk. As determined by a triangle palatability test there were significant differences in the palatability of leg roasts from three weight groups with the greatest difference between those calves slaughtered at 44.1 kg and those slaughtered at 124.2 kg (Brekke and Wellington 1972).

B. Effect of Dietary Regime (Milk vs. Grain Feeding)

Despite concern over the eating quality of grain fed veal there is little evidence from the literature to indicate that feeding regime per se affects the eating quality of veal. Hanning et al. (1957) published results from an

evaluation of veal roasts and chops from calves raised under four feeding regimes: 1) liberal whole milk, 2) liberal whole milk supplemented with iron and copper, 3) limited whole milk plus hay and concentrate ad libitum, and 4) liberal milk replacer plus ad libitum hay and concentrate. Despite the more favorable carcass grades of calves in groups 1 and 2 and the lighter meat colour and lower hemoglobin and myoglobin values for calves in group 1 (Bray et al. 1959; Neidermeier et al. 1959) only calves fed liberal whole milk plus iron and copper produced more tender meat, as measured by either the Warner-Bratzler Shear values or the evaluation of a sensory panel. Variation among samples within treatment (i.e. among animals) and variation among judges was quite high but variation between duplicates was quite low. Total % cooking loss, % drip loss, % evaporation loss, or panelists evaluation of juiciness did not differ among diets but the % pressed juice was lower for calves reared on only milk than for those fed milk or milk replacer plus hay and concentrate.

Wood and Froehlich (1981) evaluated loin and round roasts (fresh and frozen) from grain fed (200 kg live weight) and milk fed (100 kg live weight) calves. Panelists judged fresh grain fed veal to be more pink than fresh milk fed veal but this difference disappeared with cooking and with freezing. Likewise, the colour differences measured by the Hunter Color Meter disappeared with cooking and with freezing of the loins. Panelists did not judge the roasts from the 2 feeding regimes to be different for flavour, juiciness or general acceptability. Fresh round roasts from milk fed calves were judged to be more tender than were fresh round roasts from grain fed calves. The Warner Bratzler Shear values for fresh round and loin roasts from milk fed calves (1129 and 990) were lower than those for fresh round and loin roasts from grain fed calves (2131 and 1614). Also, the frozen roast from milk fed calves had lower Warner Bratzler Shear values than did the corresponding roast from grain fed calves (1318 vs.

1872). However, the 100 kg difference in the live weight of calves at slaughter may have contributed to some of the observed differences in tenderness (Brekke and Wellington 1972; Warner et al. 1988). Cooking loss was lower for the fresh loins from milk fed calves than for fresh loins from grain fed calves (15.56 vs. 18.18%) but no other differences were significant.

Brisson et al. (1979) reported no differences between grain fed and milk fed calves for the Instron measurement of tenderness on thawed meats after freezing for 2, 4, 6 or 8 wk. Water loss on thawing was different for the 2 groups ($P<0.05$) but the magnitude of this difference was only 0.3% and probably of little practical significance. Cooking loss during roasting of the loin samples did not differ between milk fed and grain fed calves. Warner Bratzler Shear values for cooked loin samples were higher for grain fed (7.17) than for milk fed (5.95) calves and panelists judged the milk fed veal to be more tender than the grain fed veal ($P<0.05$). Judges were unable to detect differences between diets for sensory parameters other than tenderness.

Brisson et al. (1979) reported that the variation in tenderness ratings were more related to differences inherent to the evaluators rather than to differences between samples. The F-value for the between sample variance was significant for the grain fed, but not the milk fed calves, whereas the F-value for the variation due to evaluator was significant in both cases. Evaluations of flavour, texture and order of preference also revealed that there was more of a relationship between these parameters and the evaluator rather than the samples. This may have been due to the absence of training for the evaluators. However, their results were consistent with those of Hanning et al. (1957) and Wood and Froehlich (1981) in that diet exerted some effect on tenderness ratings.

Smulders and Visser (1987) found no difference in sarcomere lengths or shear force values for calves fed to 24-35 wk on milk replacer, milk replacer

plus wheat straw, milk replacer plus wheat straw plus high energy calf starter, or milk replacer plus wheat straw plus high energy calf starter with added fat even though Hunter Color Meter readings showed that calves fed milk replacer only had lighter meat. The percent drip loss on cooking was higher for calves fed milk replacer plus wheat straw plus calf starter than for those fed milk replacer plus wheat straw or milk replacer only.

These studies indicate that despite measured differences in meat colour between grain fed and milk fed calves panelists were unable to differentiate between treatments for any sensory parameter except tenderness (Hanning et al. 1957; Wood and Froehlich 1981). In the study of Brisson et al. (1979) there was an observed, but not quantified, difference between grain fed and milk fed calves for meat colour but again only the evaluation of tenderness differed between diets. Instrumental measurements made in these studies generally supported panelists conclusions regarding tenderness and juiciness. However, the relationship between meat colour and tenderness is not clear. In several studies the lighter coloured milk fed veal was judged and measured to be more tender (Brisson et al. 1979; Wood and Froehlich 1981) but in the work of Hanning et al. (1957) the darker coloured meat from iron supplemented milk fed calves was more tender than meat from either grain fed calves or milk fed calves receiving no supplementary iron. Warner et al. (1988) reported that while calves weaned onto pasture and concentrate pellets at 8 wk produced a darker meat with higher pigment concentration than did calves raised inside on milk and concentrate pellets, Warner Bratzler Shear values did not differ between the two groups of calves. Similar conclusions were reached by Smulders and Visser (1987) for calves raised on milk replacers or milk replacers plus wheat straw and calf starters.

C. Effects of Added Fat

Work by Johnson et al. (1988) showed that supplementation of skim milk with animal tallow to provide increasing energy densities (54, 100, 123 and 147 KJ kg^{-1}) increased kidney (0.11, 1.13, 1.36 and 1.08 kg), external (0.53, 2.92, 2.05 and 2.60 mm) and intramuscular (0.18, 0.96, 1.31 and 1.44%) fat deposition, while muscle color remained unchanged. Calves fed unsupplemented skim milk had higher Warner Bratzler Shear values, % drip loss and lower sensory panel scores for tenderness in both the l. dorsi and the semitendinosis muscles and lower juiciness ratings in the semitendenosis, but not the l. dorsi muscle. Total cooking loss, flavour ratings and cooked colour measurements did not differ between diets for either muscle.

Beyond the lowest level of added fat there was no advantage in increasing the level of fat in the diet (in terms of sensory qualities). Calves fed the lowest level of added fat had the highest % drip loss of the supplemented groups and those fed the highest level of fat had intermediate juiciness ratings. Warner Bratzler values did not differ between the three highest fat levels.

Stiles et al. (1974) added 4% animal tallow to grain rations for veal calves and observed a decrease in taste panel ratings for flavour, tenderness and overall satisfaction of rib roasts. They found no difference in juiciness ratings. They also reported a non-significant decrease in percent carcass fat when fat was added to the diet. External fat measurements were not reported.

A review by Moran (1986) indicates that while the eating quality of meats is influenced by the presence of fat, there is poor correlation between eating quality and the amount of fat in the meat. Others have reported that external fat cover may be of importance in preventing water loss during chilling and cooking (Lawrie 1985) and in preventing muscle shortening during chilling (Smith et al. 1976). With beef, some authors report a relationship between marbling and

palatability traits (Jennings et al. 1978; Smith et al. 1984) while others report that marbling accounts for very little of the variation in tenderness ratings (2-3%) or acceptability ratings (6-8%) (Crouse and Smith 1978).

Calves fed fat supplemented diets in the study of Johnson et al. (1988) had more tender meat but went to market at heavier weights (40-50 kg), which, according to Brekke and Wellington (1972) decreases tenderness of the meat. No further improvements in sensory properties were noted when additional fat was given to the calves. Thus it seems that while a certain base level of fat is necessary for adequate eating quality of the meat, its effects on organoleptic aspects beyond this point are unclear. Given the complex nature of the factors involved in the acceptability attributed of meat (Lawrie 1985) it would likely be the case that beyond the minimum required for acceptable eating quality fat level alone would be of relatively minor importance in determining meat quality.

Low-erucic acid rapeseed oil has been successfully incorporated into milk replacers without adverse effects on cooking losses, drip losses, or meat flavour (Seoane et al. 1978). The tenderness rating was decreased at an inclusion rate of 18% rapeseed oil but the Warner-Bratzler Shear values did not substantiate the panelists' evaluation.

D. Effects of Protein Source and Protein Level

St. Laurent and Brisson (1972) added up to 19.2% fish protein concentrate to calf milk replacers and found no undesirable odour or flavour. Gorrill et al. (1975) found that fish protein concentrate at 15% of the milk replacer did not affect taste panel ratings for odour, flavour or tenderness but 19% herring meal resulted in undesirable odour and less tender meat. Flavour of the meat was rated lower with herring meal, but not significantly so. Jenkins et al. (1982) reported that while 15 or 29% partially hydrolyzed fish protein in a milk

replacer did not affect total loss, % drip loss, Warner-Bratzler Shear values, tenderness ratings or juiciness ratings, the flavour and overall acceptability ratings were inferior and the number of off-flavour scores were increased when fish protein was added to the diet. They thus recommended limiting the inclusion of fish protein concentrate to 50% of the total protein and using a withdrawal period to avoid off-flavour problems.

Stiles et al. (1974) evaluated the effects of increased protein in the concentrate (12 vs. 15 or 18% CP) on the taste panel ratings of the l. dorsi muscle. Percent protein in the diet had no affect in the evaluation of flavour, juiciness, tenderness or overall satisfaction.

E. Effects of Anabolic Agents

It appears from the report of Van Weerden (1984) that implants of estradiol and trenbalone acetate do not affect water binding capacity, weight loss at boiling or the shear force values. Collagen content of the meat was not affected by implants of zeranol plus trenbalone acetate or estradiol plus trenbalone acetate, nor did these implants affect shear force values or tenderness ratings of the pectoralis produncis or the rectus femoris. Shear force values did not differ between control and implanted calves when the l. dorsi muscle was examined but the evaluation of tenderness for this muscle was lower in the calves implanted with estradiol plus trenbalone. Other authors cited in this report also indicate that while pH, water holding capacity and cooking losses do not differ between control and treated groups, there is indication that implanted calves have less tender l. dorsi muscles (as measured instrumentally) than do control animals.

MATERIALS AND METHODS

I. GROWTH TRIAL

Forty-five male Holstein calves were allotted at random to one of five dietary treatments. Diets were formulated to contain one of the following as the dietary energy source: corn, barley, barley + canola oil, barley + added oil in the from of Jet-Sploded^{R} canola seed (JSCS) or barley + wheat in a 50:50 ratio (Table 1). All diets except the barley diet were formulated to be isocaloric at a calculated DE content of 3696 kcal/kg. Diets were isonitrogenous at 16% crude protein (CP) (Table 2) with canola meal supplying the supplemental protein in the corn, barley and barley + oil diets and JSCS supplying the supplemental protein in the barley + JSCS diet. No supplemental protein was necessary to formulate a 16% CP diet using barley + wheat.

Over the period from December 1986 to November 1987 calves were obtained from three sources: the University dairy herd, a local dairy farm and a local auction barn. Prior to starting on test they were fed milk at a rate of 1.8 - 2.0 kg/head/d in 2 equal feedings. When calves were at least 7 d but not more than 13 d they were started on test. All calves were fed milk replacer as per Table 3. Milk replacer was bucket fed warm two times per day. During the 5th wk of the schedule the milk replacer allotment was cut by half and during the 6th wk milk replacer feeding was discontinued. Water was available ad libitum at all times during the test period.

Test diets were offered ad libitum to the calves as soon as they started on test. Fresh feed was given daily and weekly feed weighbacks were recorded on the morning following weighing of the calves. After weaning the test diet was the only feed offered until market. Calves

Table 1. Ingredient composition of calf starter diets fed from start of test to final market weight

Ingredient (%)	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat
Corn	78.2	-	-	-	-
Barley	-	87.8	82.7	81.5	45.6
Wheat	-	-	-	-	45.6
Canola meal	13.5	3.4	5.0	-	-
JSCS^{R}	-	-	-	9.70	-
Canola oil	-	-	3.5	-	-
Corn gluten meal	2.8	3.0	3.0	3.0	3.0
Molasses	2.8	3.0	3.0	3.0	3.0
Limestone	1.0	1.1	1.1	1.2	1.2
Biophos	0.24	0.32	0.34	0.30	0.24
Potassium chloride	0.28	0.34	0.36	0.34	0.38
Co-I salt	0.40	0.40	0.42	0.40	0.40
Trace mineral premix†	0.48	0.50	0.50	0.50	0.50
Vitamin premix‡	0.20	0.20	0.20	0.20	0.20
Total	100	100	100	100	100

†Formulated to provide 22 mg copper sulphate, 0.11 mg selenium, 28 mg zinc oxide, 28.5 mg manganese oxide, 750 mg magnesium oxide, 2,000 mg potassium chloride and 1,600 mg cobalt-iodized salt per kg of mixed diet.

‡Formulated to provide 7,000 IU vitamin A, 3,000 IU vitamin D_3 and 6 IU vitamin E per kg of mixed diet.

Table 2. Proximate analysis (DM basis) of experimental diets fed from start of test to final market weight and of commercial milk replacer fed from birth/arrival of calves to 6 weeks on test

	Diet						
						Milk replacer†	
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat	Lot 1	Lot 2
Dry matter (%)	90.25	90.15	90.78	90.48	90.37	97.90	97.88
Gross energy (kcal/kg)	4398	4302	4472	4522	4320	ND‡	ND
Digestible energy (kcal/kg)§	3003	2572	2972	3132	3064	ND	ND
Crude protein (%)	16.63	15.61	16.07	15.51	16.11	23.14	26.45
Total lipid (%)	5.09	3.63	7.92	9.15	3.65	24.39	15.63
Acid detergent fiber (%)	5.68	7.02	6.89	7.65	5.02	Trace¶	Trace

†Laboratory analysis of the milk replacers (2 Lots of 1000 kg) fed from start of test to weaning at 0-6 weeks.

‡ND = not determined.

§ Determined in digestibility trial.

¶ Present in amounts <0.01% of sample.

Table 3. Schedule for feeding milk, milk replacer and experimental diets from birth/arrival of calves to 6 weeks after the start of test at 7-13 days of age

	Milk (kg/d)	Milk replacer (kg/d)	Water (l/d)†	Calf starter‡
Birth/arrival - start	2.0	-	-	-
Days on test:				
1-7	-	0.340	2.00	as libitum
8-14	-	0.454	2.75	ad libitum
15-21	-	0.560	3.75	ad libitum
22-28	-	0.784	4.50	ad libitum
29-35	-	0.500	2.50	ad libitum
35-42	-	-	-	ad libitum

†Water was also available free choice throughout the experiment.

‡Each calf was offered ad libitum the diet to which it was randomly assigned.

were weighed bi-weekly, and feed intake was tabulated in the periods corresponding to the weigh periods. Overall weight gaisn and total feed intakes were tabulated for the preweaning (0-6 wk on test) and postweaning (6 wk on test to slaughter) periods. The number of days to slaughter was calculated as the number of days from 6 weeks on test to the first weigh day on which the calves weighed > 210 kg liveweight. Average daily gains, daily feed intakes and feed to gain ratios were calculated using overall weight gains, total feed intakes and the number of days to slaughter.

Two calves in each treatment (diet) were implanted with 4 pellets of Synovex C^R at 100 kg. The remaining 7 calves per treatment were implanted at 80 kg live weight as it became clear that the original slaughter weight decided on was not high enough to obtain reasonable fat cover and muscle development.

Calves were housed in individual 1.2 x 1.8 m pens bedded with wood shavings until ≈ 180 kg. At that time calves were moved to individual 1.4 x 3.7 m pens where they were kept until market weight. Lighting was controlled at 16L:8D.

Feed samples were taken from each batch of feed as it came into the barn by sampling the bags with a sampling probe. These were dried at 60°C for 2 d, ground through a 1 mm screen and stored for later analysis. Because of a problem with the vitamin-mineral premix in the first batch of feed, this batch was analyzed separately and will henceforth be referred to as composite 1. All other batches were composited over time into three composites and analyzed as such. All chemical analysis except the mineral analyses is presented as the average value for the four composites (Table 2).

The grouping of calves by dietary treatment, implant weight, slaughter weight, season of marketing and source of calves is given in Appendix Table A.

II. DIGESTIBILITY TRIAL

A digestibility trial was conducted when calves reached 11-12 wk of age. Calves were given their respective test diets containing 0.3% chromic oxide for 10 d prior to fecal collection. Fecal samples were collected every morning and evening by grab sampling from harness bags for 5 d and frozen for later analysis. On the 5th d of the collection period blood and rumen samples were taken at 1 and 3 h following feeding in the morning. Blood was collected in a Vacutainer^{R} containing heparin and spun. The plasma was decanted and frozen for later analysis. Rumen fluid was collected using a syringe and rubber tubing with a screened ball on the end for screening out feed particles. A pH reading was taken immediately using a Digi-sense^{R} digital pH meter, model #5994-10 (Cole-Parmer Instrument Co., Chicago, IL). The samples were then spun at 4354 G and the supernatant was then frozen (-20°C) for later analysis.

After collection had been made from 6 calves per treatment fecal samples were thawed and composited over 5 d (10 collections) for each calf. These were dried at 60°C for 3 d and ground through a 1 mm screen.

Grab samples of chromic oxide containing diets were taken on the Friday prior to fecal collection from each calf. These were dried at 60°C for 2 d, ground through a 1 mm screen and then composited according to treatment to obtain a single sample. Those samples from calves given

the first batch of feed were analyzed as a separate composite because of the problem with the vitamin-mineral premix.

III. RUMEN DEGRADABILITY TRIAL

A. Protein Sources

Protein sources tested were canola meal, the Jet-Sploded canola seed used in the growth trial (JSCS) and the Jet-Sploded canola seed sampled at the end of the Jet-Sploding run when the exit temperature was properly regulated (End Sample). The canola meal was incubated as received and the Jet-Sploded canola seed samples were incubated as intact seeds.

Animals and Diets

Two ruminally fistulated mature steers (1 Angus and 1 Jersey) were fed a total mixed diet of alfalfa hay, alfalfa silage and dairy concentrate mix at a rate of 14.3 kg/head/day. The concentrate portion of the diet contained rolled corn (28.8%), rolled barley (28.4%), beet pulp (8.2%), canola meal (24.6%), molasses (2.3%), urea (0.5%), tallow (3.0%), and vitamin-mineral premix (4.2%) and the ratio of forage:concentrate was 68:32.

In Situ Incubation

Five gram samples of each protein source were weighed into double sewn 7.0 x 11.0 cm nylon bags and the bags were tied at the top. Thirty-six bags (18 bags per steer) were prepared for each protein source. Two bags per steer per treatment were suspended by clips on a weight in the rumen for 4 and 8 h and 2 bags per steer per treatment

were washed (time=0 h) to obtain estimates of soluble DM and CP. Bags were introduced into the rumen in reverse sequence and all bags were removed at the same time. After ruminal incubation bags were rinsed with cold tap water to remove surface debris and then washed, once for 5 min and again for 2 min in an old wringer washing machine.

Washed nylon bags were dried at 60°C for 3 d in a forced air oven to determine DM loss. Single, empty bags were incubated in each steer for each time of incubation and the change in weight was used to adjust DM loss for DM picked up in the bags themselves. Bag contents were analyzed for CP (n x 6.25) using the micro Kjeldahl procedure as per AOAC method #7.015 (Association of Official Analytical Chemists, (AOAC) 1984).

Dry matter and CP disappearance after 0, 4 and 8 h rumen incubation were expressed as a percent of the initial amounts of DM and CP present in the bags.

B. Experimental Diets

Ground (1 mm screen) composite samples from composites 1, 2, 3 and 4 of the experimental diets from the growth trial (corn, barley, barley plus canola oil, barley plus JSCS and barley plus wheat) were composited to obtain one sample per diet.

Animals and Diets

Two ruminally fistulated mature steers (1 Angus and 1 Jersey) were fed alfalfa hay at a rate of 9 kg per head per day.

In Situ Incubation of Experimental Diets

The in situ incubation procedure was as described for the in situ incubation of protein sources with the exception that CP and DM disappearance at one additional time of incubation (36 h) was evaluated also, duplicate empty bags per steer per time period were incubated to adjust DM loss for DM picked up by empty bags. The effective degradability of DM (EDDM) and CP (EDCP) was calculated using the equation of Orskov (1982):

$$\text{EDDM or EDCP} = a + \frac{bc}{c + k}.$$

where a = disappearance at 0 h.

b = disappearance at 36 h - disappearance at 0 h.

c = rate of degradation per hour from 0-8 h.

k = outflow rate = 0.08.

IV. CARCASS DATA

Two calves per treatment were slaughtered at 180 kg live weight. The remaining seven calves were slaughtered at 210 kg live weight in an attempt to obtain improved muscle development and fat cover. Calves were weighed unfasted 1 d and 4 d prior to slaughter. Four days prior to slaughter blood samples were taken for hematocrit and hemoglobin determination. The liveweight at slaughter was taken as the average of the unfasted weights taken at 1 and 4 d prior to slaughter. Calves were slaughtered with the hide off according to routine procedure at a local plant.

Warm carcass weights were recorded immediately after slaughter. The dressing percentage was calculated using the warm carcass weight and the unfasted average liveweight at 1 and 4 d prior to slaughter. Twenty-four h after slaughter color readings were taken on the brisket

according to Agriculture Canada Specifications and on the 1. dorsi muscle between the 12th and 13th ribs using a Minolta^{R} reflectance meter. A pH reading was taken at the same point on the muscle using the Fisher^{R} pH-temperature meter #119 (Fisher Scientific, Winnipeg, Manitoba).

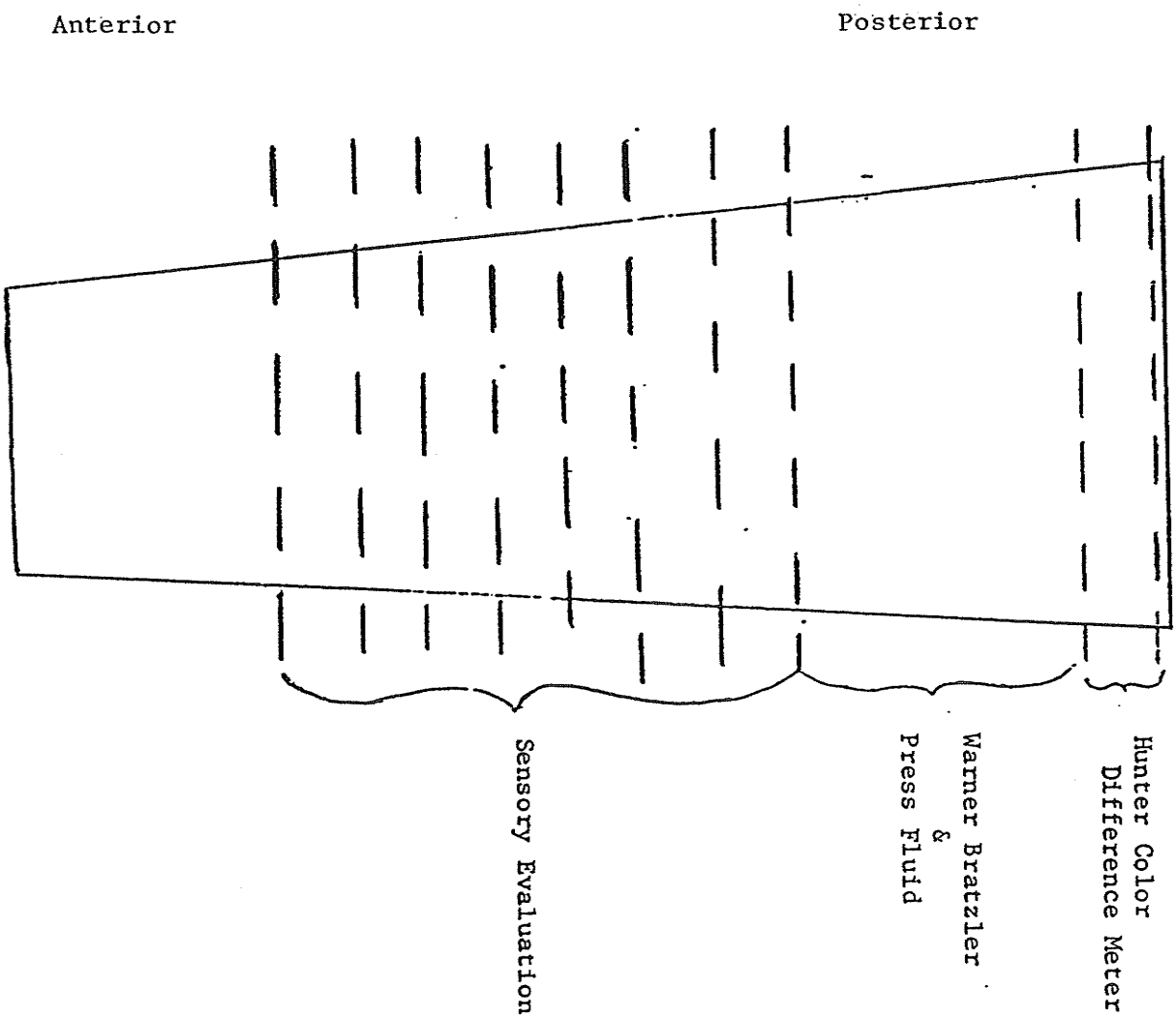
At this time the kidney plus renal fat and the 13th rib section were removed by the packing house staff. A tracing was made of the 1. dorsi muscle on the anterior side of the rib for determination of rib-eye area. The kidney fat was removed from the kidney and weighed.

Half of each carcass was picked up by a local butcher shop where, after aging for 5 d at 2°C the 12th rib and a 5 rib roast from the 7th to 11th rib inclusive were removed and frozen in plastic wrap at -23°C. After all animals had been slaughtered the 12th rib sections were thawed and the 1. dorsi muscle was removed. All intermuscular fat and connective tissue was removed from around the muscle. The muscle was then freeze dried for 2 d for DM determination and ground using a coffee grinder. Samples were then refrozen until analysis. Rib roasts remained frozen (-23°C) until used for sensory evaluation (Section V).

V. SENSORY EVALUATION

Veal rib roasts cut from the 7th to 11th rib inclusive were obtained from calves in the growth trial. Animals had been slaughtered at various times depending on the date they reached slaughter weight, therefore roasts went into frozen storage and were held for differing time intervals (1-9 months). The animals had been slaughtered and cut at East-West Packers in Winnipeg, Manitoba. Weights of the rib roasts ranged from 1.9 to 3.0 kg, and the grades ranged from A1 to C4.

Figure 1. Sampling from *L. dorsi* muscle for sensory and instrumental measurements



Six roasts per treatment were selected at random. Roasts were thawed for 72 h at refrigerator temperature and weighed. Thermocouples were inserted into the center of the l. dorsi muscle. The roasts were placed on a rack in an open pan and roasted at 160°C until the internal temperature reached 65°C (medium doneness). After the pans were removed from the oven, the roasts were allowed to sit on the racks for 30 min. The cooked roasts and the drippings were then weighed separately.

Cooked roasts were placed on cutting boards and the l. dorsi muscle was removed from the roast. Working from the posterior to the anterior end, the slices were taken from the muscle for Hunter Color Meter readings, Warner-Bratzler Shear and press fluid determinations and for sensory evaluation.

Cooking Losses

Total cooking loss was calculated using the weight of the cooked roast, drip loss was calculated using the weight of the drippins and evaporative losses were calculated as the difference between total and drip losses. Each of these losses were calculated as a percentage of the raw weight (American Meat Science Association, 1978).

Press Fluid

Press fluid was determined in triplicate, as an adaptation of the method of Stanley and Swatland (1976). Two 5 cm square pieces of aluminum foil were preweighed. A sample of cooked veal (0.5 g) at 21°C taken from the centre of the slice, was placed between the foil squares. Three Whatman #1-12.5 cm filter papers were placed on each side of the foil. The sample packages were placed between plexiglass plates and

compressed for 1 min at 12,500 lbs pressure. The filter paper was removed and the pressed meat and foil weighed. Press fluid was calculated as the percentage of fluid lost over the original weight.

Hunter Color Difference Meter

A Hunter-Lab D25-9 Color Difference Meter (Hunter Associates Laboratory Inc., Reston, Virginia) was used to obtain CIELAB values for the cooked meat. The machine was calibrated using a white plate with a petri dish over the small porthole. Samples were cut, wrapped in plastic wrap and then taken to the instrument to be read (21°C). Samples were placed in the petri dish, read once and then turned, 90° and color values read again.

Instron Force

An Instron Universal Texture Testing Machine (Instron Canada ltd., Burlington, Ont.) was used to evaluate tenderness of the cooked veal. The 3-blade Warner Bratzler attachment was used with the 91 kg load cell. A 4 cm slice (Figure 1) was turned on its side and three cores (1.3 cm diameter, 4 cm length) were taken parallel to the muscle fibers.

Evaluation was carried out with the Apple II (Apple Computer Inc., 1985) computer assisted Engineering and Statistical Research Institute (Agriculture Canada) Texture Data Acquisition and Analysis System (Timbers et al. 1985). Peak force was measured with a crosshead speed of 10 cm/min and a maximum force of 80 kg.

Sensory Evaluation

(a) Training:

Five training sessions were carried out prior to the actual panels. The purpose of the training sessions was to familiarize panelists with the veal, since it was not frequently consumed by the panelists. As well, familiarity with the sensory characteristics juiciness and tenderness was developed and the techniques for evaluation defined. Training sessions also gave panelists experience using the scales on the ballot.

(b) Panels:

An eight-member panel consisting of graduate students and staff in the Department of Foods and Nutrition at the University of Manitoba evaluated the veal. The panel evaluated 6 dietary treatments of veal: corn, barley, barley + canola oil, barley + canola meal, barley + wheat, and milk-fed animals. To ensure consistency of samples among grades of veal, only the B grade roasts were used for sensory evaluation. Roasts for each session were selected at random from the B grade roasts. Milk-fed veal (grade A) roasts were purchased locally and were handled like the other roasts.

Slices for sensory evaluation (Figure 1) were sampled so that each panelist received three cubes of meat. Panelists received samples from the same position in the roast at each session to avoid any differences that might have occurred due to position in the roast. Samples were placed in 30 mL ceramic egg cups and covered with plastic lids. Cups were coded with 3 digit random numbers. Sample cups were presented to the panelists in water baths (50°C, 15 min prior to evaluation). Veal was evaluated for juiciness, flavour intensity, tenderness and flavour pleasantness. One cube of veal was picked up with a toothpick, placed

with the grain running crosswise between the molar teeth and evaluated firstly for juiciness and then flavour intensity. A second cube was then evaluated for tenderness and flavour pleasantness. The third cube was used by panelists only if they wanted to verify their first two judgments.

The technique for evaluating juiciness and tenderness was defined during training, and descriptions were presented on the ballot (Appendix Table C). An eight-point intensity scale with verbal descriptors was used to score the veal. Samples were presented randomly and distilled water and unsalted crackers were used to rinse and clear the mouth between samples.

VI. CHEMICAL ANALYSIS

Growth Trial

Dry matter of the feed samples was determined after drying at 60°C for 2 d. Acid detergent fibre was determined as per AOAC method 7.076 (AOAC 1984) using a Fibertec System 1020 Hot Extractor (Tectator AB, Hoganas, Sweeden). CP (n x 6.25) in the feed samples was determined using the macro-Keldjahl method as per AOAC method 7.015 (AOAC 1984). Amino acids were analyzed according to a revision of the procedure of Sauer (1976) as follows:

a) for amino acids other than methionine and cystine:

   1) weigh 100 mg of sample into 19 mm hydrolysis tubes

   2) add 4 ml 6NHCl to the sample

   3) evacuate the sample and hydrolyze at 110°C for 24 h

   4) after hydrolysis, neutralize with 4.1 ml NaOH (25%)

   5) bring volume to 50 ml using a sodium citrate buffer (pH=2.2)

6) shake mixture and filter using a Whatman No. 40 filter paper

7) apply 50 µl of filtered sample to a 4151 Alpha Plus amino acid analyzer (LKB Biochrom, Cambridge, England) and determine amino acid content using a Hewlett Packard 3393A integrator (HP (Canada) Ltd., Mississauga, Ont.).

b) methionine and cystine were determined according to the procedure of Hirs (1967) with the following modifications:

1) after oxidation add 0.5 ml conc. HCl mix and let stand for 3 h

2) add 2 ml 6NHCl

3) evacuate and hydrolyze at 110°C for 6 h

4) after hydrolysis, neutralize solution with 2.3 ml NaOH (25%)

5) proceed with steps 5-7 in a).

Fats were extracted using a 60:40:1 ratio of chloroform:methanol:HCl according to the procedure of Marchello et al. (1971). Following determination of percentage fat in the feed sample a 10 ml aliquot of the fat dissolved in chloroform was stored in the freezer under nitrogen for subsequent fatty acid analysis. Prior to fatty acid analysis the aliquots from the 4 composites of each treatment were pooled, the solvent was evaporated under a stream of nitrogen and fatty acids were methylated according to the procedure of Shehaeta et al. (1970) as described by Seewald et al. (1987). Following transesterfication 1 µl aliquots were injected into a Vista 6000 gas chromatograph (Varian Canada Inc., Georgetown, Ont.). The program was started at 140°C and increased by 5.0°C per minute to a final temperature of 210°C. Peaks were identified by comparison with the retention times of the standard fatty acid methylesters (Supelco Inc., Oakville, Ont.) area under the peaks were calculated using a Vista 402

Data System (Varian Canada Inc., Georgetown, Ont.) and the individual fatty acid methyl esters were reported as a percentage of the total amount. A flame ionization detector was used in the procedure.

Preparation of the feed samples for mineral analysis was done according to the following procedure:

1) weigh 1.0 g sample into digestion tube

2) add 6 ml concentrated HNO_3 and let stand overnight.

3) on the following morning add 3 ml conc. HCL

4) mix and digest over low heat until the solution becomes clear and colorless, then digest over high heat until near dryness

5) add 2.5 ml conc. HCL to residue and let sit overnight.

6) on the following morning add 10 ml of distilled water to each sample, shake and let sit until the next day

7) filter each sample using Whatman # 42 Ashless filter paper into a 50 ml volumetric flask using 3 washes of 10 ml of distilled deionized water

8) bring to volume (50 ml) and invert several times

The 50 ml of solution was then analyzed for Ca, P, Mg, S, K, Mn, Zn, Cu and Fe using an ICP 3510 (Applied Research Co., Scarborough, Ont.) at the Feed Testing Laboratory, Manitoba Agriculture.

Digestibility Trial

Dried, ground feed and fecal samples were analyzed for CP (Nx6.25) ADF, DM and fat content as described for the growth trial. CR_2O_3 in the feed and feces was determined according to the procedure of Williams et al. (1962). The gross energy content of the feed and feces was determined by complete combustion in an Adiabatic Bomb Calorimeter (Parr

Instruments Company Inc., Moline IL). The digestibility coefficients form DM, energy, CP, fat and ADF were calculated according to the equations of Maynard et al. (1979).

Volatile fatty acids 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). Blood urea nitrogen was determined using an autoanalyzer (Marsh et al., 1965).

Carcass Trial

The DM content of the meat samples was determined after samples were lyophilized for 2 d. Crude protein (Nx6.25) was determined by the micro Kjeldhal method as per AOAC #38.014 (AOAC 1965) using a Kjeltec Auto 1030 Analyzer (Tectator AB, Hoganas, Sweeden). The fat content of the meat sample was determined according to the procedure of Seewald et al. (1987) and fatty acids were determined as described for feed samples. Ash content was determined by a modification of AOAC method #7.009 (AOAC 1984) after subjecting 1 g samples to 550°C for 24 h.

Blood samples taken prior to slaughter were analyzed for hematocrit and hemoglobin content using the microhematocrit method and the Spencer Hb-Meter (American Optical Co., Buffalo, NY) as described in Benjamin (1978).

VII. STATISTICAL ANALYSIS

Growth Trial

Growth and feed consumption data for the period from start of test to 6 wk on test were analyzed using diet as the main effect and weight at start of test as the covariate. Data for the period from 6 wk on

test to slaughter were analyzed using diet as the main effect, weight at 6 wk on test as the covariate and one of the following as the blocking effect:slaughter group, implant group, source of calves or marketing season. All data were analyzed using the General Linear Model (GLM) procedure (Statistical Analysis Service (SAS) Institute Inc., 1986) and multiple comparison analysis of least square means was completed using the Bonferroni option under GLM.

Digestibility Trial

As was the case in the growth trial, composite 1 of the CR_2O_3 containing diets contained an excess of micromineral premix. Therefore, the effect of composite was first tested in the GLM Procedure. Since composite affected ($P<0.05$) the digestibility of gross energy, ADF and CP and tended ($P<0.10$) to affect the digestibility of DM (Appendix F) and since composite 1 was not represented in treatment 4 it was decided to omit those calves receiving composite 1 of the Cr_2O_3 diets from the statistical analysis. Data were analyzed using diet as the main effect under the GLM Procedure (SAS Institute Inc., 1986) and multiple comparison analysis of the least squares means was completed using the Bonferroni's option under GLM.

Rumen fluid volatile fatty acids, rumen fluid pH, rumen fluid ammonia nitrogen and blood urea nitrogen were analyzed using a split plot design (Steele and Torrie, 1960) with diet as the main plot and sampling time as the sub-plot. Data were analyzed using the GLM Procedure (SAS Institute Inc., 1986) and multiple comparison analysis of the least squares means was completed using the Bonferroni's option under GLM. Only data for calves fed composite 2 of the Cr_2O_3 diets were

used in the analysis.

Rumen Degradability Trial

Dry matter and CP disappearance from the protein sources at 0, 4 and 8 h were analyzed using protein source as the main effect and steer (protein source) as the error term under the Anova option (SAS Institute Inc., 1986) and the means were compared using Duncans Multiple Range Test (SAS Institute Inc., 1986). Because of missing values, the DM and CP disappearance from the experimental diets at 0, 4, 8 and 36 h was analyzed using the GLM Procedure (SAS Institute Inc., 1986) and least squares means were compared using the Bonferroni's option under GLM Procedure (SAS Institute Inc., 1984). Diet was used as the main effect and steer (diet) was used as the error term. The effective degradability of DM and CP was analyzed using diet as the main effect and steer as a blocking effect using the GLM Procedure (SAS Institute Inc., 1986) and least squares means were compared using Bonferroni's option under GLM.

Carcass Trial

All slaughter data (carcass weight, dressing percent, kidney fat weight, 12th rib composition, rib-eye area at the 13th rib and hematocrit and hemoglobin at the time of slaughter) were analyzed using diet as the main effect and slaughter group as the blocking effect. Data were analyzed using the GLM Procedure (SAS Institute Inc., 1986) and multiple comparison analysis of the least square means was completed using the Bonferroni's option under GLM.

Sensory Evaluation

Data for the paramters measured for meat quality (Warner-Bratzler Shear press fluid, cooking losses, and Hunter-Lab colour readings) were analyzed using the GLM Procedure (SAS Institute Inc., 1986) and multiple comparison analysis of the Least Squares Means was completed using the Bonferroni's option under GLM. All data were analyzed using diet as the main effect and panel as the blocking effect.

The following model was used in the statistical analysis of the panelists' evaluation of cooked meat samples:

TR, JR, FIR, FPR = EVAL DIET EVAL * DIET PAN DIET * PAN

where TR = Tenderness Rating (Scale of 1-8)

JR = Juiciness Rating (Scale of 1-8)

FIR = Flavour Intensity Rating (Scale of 1-8)

FPR = Flavour Pleasantness Rating (Scale of 1-8)

EVAL = Evaluator (n=8)

DIET = Diet (n=6)

PAN = Panel (n=6)

The data were analyzed using the procedure described by Christian and Harvey (1985) and linear contrasts were used to compare the least squares means.

RESULTS AND DISCUSSION

I. GROWTH TRIAL

Diets

Corn, barley and barley-wheat diets had similar gross energy (GE) values. The slightly higher value for the corn diet was due to a higher lipid content (Table 2). The analyzed lipid content of the barley diet was increased by 4.29 and 5.52 percentage units with the addition of 3.5% canola oil and 9.7% Jet-Sploded Canola Seed (JSCS). Corresponding increases in GE content were 170 and 220 kcal/kg. These figures were 44 and 39% less than the expected increases of 326 and 361 kcal/kg with the addition of 3.5% canola oil or 9.7 % JSCS. The GE content of the diet containing barley + JSCS was higher than that of the barley + canola oil diet as would be expected with (+1.23%) lipid content of samples from this diet.

Measured digestible energy (DE) levels for all diets were below the formulated levels of 3596 kcal/kg for the energy supplemented diets, and reasons for this will be discussed in Section II A. As was intended by experimental design, the DE content of the barley diet was below that of the other diets.

Diets were formulated to contain 16% crude protein and all diets fell within the range of 15.5 to 16.6%. Using barley rather than corn as an energy source reduced by 10 percentage units the amount of canola meal needed to formulate a diet containing 16% CP (Table 1). When a 50:50 mixture of barley and wheat was used as the energy source no supplementary protein was necessary, as wheat in this year contained high levels of crude protein. Acid detergent fiber (ADF) levels in the barley and barley + oil diets were similar, but the addition of JSCS slightly increased the ADF levels, while adding wheat or replacing barley with corn decreased ADF levels.

Mineral levels in all diets were formulated according to the NRC (1979) specifications for calf starter mixes. However, composite 1 of all diets contained high levels of a micromineral premix and as a result several minerals were present in this composite at levels well above the formulated levels (Table 4). Zinc (980-1300 ppm) and Cu (300-430 ppm) levels were in excess of the maximum tolerable levels of 300-1000 ppm (Zn) and 200 ppm (Cu) as set by NRC (1980). Manganese levels (720-820 ppm) were below the NRC (1980) maximum tolerable level of 1000 ppm. Actual levels of Ca, P, Mg, S and K were within range of the formulated levels (Table 4).

Additional iron was deliberately withheld from diets in an attempt to minimize its effects on meat colour. However, iron levels in the diets (100-270 ppm) were still in excess of the NRC (1979) recommendations of 50 ppm. Additional iron would have come from the grains and protein supplements and possibly from the other mineral supplements.

Puls (1981) lists normal serum Zn levels as 0.7-1.4 ppm and toxic serum Zn levels as 5.2-7.5 ppm. Normal copper levels are listed as 0.8-1.50 ppm and high-toxic Cu levels are listed as 2.5-11.0 ppm. Blood samples taken from twelve calves when the mistake in premixes was discovered (at this time tested calves had been fed the diets for periods ranging from 4 to 19 weeks) showed copper levels to be within the normal range (0.76-1.68 ppm). However, six out of twelve calves sampled (on test from 9-19 weeks) had toxic serum Zn levels (5.86-12.57 ppm), four out of twelve calves (on test from 9-16 weeks) had borderline toxic serum Zn levels (4.58-4.78 ppm), one (on test 5 weeks) had elevated serum Zn levels (2.24 ppm) and one (on test 4 weeks) had normal serum Zn levels (1.70 ppm) as determined by the Manitoba Veterinary Services Laboratory.

It is difficult to assess the impact of the Zn toxicity on animal

Table 4. Mineral analysis of diets fed from start of test to slaughter

Mineral	Batch‡	Diet				
		Corn	Barley	Barley oil	Barley + JSCS	Barley + wheat
Ca (%)†	1	0.76	0.91	0.98	0.81	0.95
	2	0.68	0.71	0.66	0.73	0.70
P (%)†	1	0.58	0.63	0.60	0.58	0.58
	2	0.55	0.55	0.58	0.55	0.54
Mg (%)†	1	0.21	0.16	0.15	0.16	0.14
	2	0.23	0.20	0.20	0.21	0.19
S (%)†	1	0.28	0.25	0.25	0.23	0.23
	2	0.25	0.20	0.21	0.21	0.18
K (%)†	1	0.55	0.91	0.99	0.91	0.88
	2	0.83	0.89	0.89	0.90	0.92
Mn (ppm)†	1	719.1	820.5	774.6	717.3	732.8
	2	32.6	40.9	163.5	32.7	38.1
Zn (ppm)†	1	1156.2	1027.7	977.2	1112.6	1294.6
	2	48.0	51.6	102.30	58.1	50.5
Cu (ppm)†	1	300.1	359.5	433.9	301.5	326.5
	2	13.4	17.0	37.9	19.4	15.3
Fe (ppm)†	1	195.9	235.6	271.2	270.4	238.2
	2	106.4	127.7	148.3	144.6	126.7

†DM basis.

‡Batch 1 is the values for mineral analysis of batch 1, which contained excessive amounts of micro-mineral premix. Batch 2 is an average of the values for mineral analysis of composites 2, 3 and 4 (normal micromineral premix).

performance due to the low number of animals on test at this time. Also, many of the calves that received these diets were also slaughtered at the lighter (180 kg) slaughter weight, so this may have confounded the effects of the Zn toxicity. Comparative performance parameters are listed, without statistics, for calves fed Zn-toxic diets for at least 5 weeks versus those who did not receive any Zn-toxic diet (Table 5). Daily gains and daily feed consumptions appeared to be reduced and the feed required per kilogram of gain appeared to be increased for the calves fed Zn toxic diets. The impaired calf performance agrees with reports by OTT et al. (1966a; 1966b) who also found that high dietary Zn levels for steers (900 ppm) and lambs (1500 ppm) reduced feed intake, daily gains and feed conversion efficiency. Their reports indicate that the reduction in feed intake when diets contain high levels of Zn was in part due to a palatability problem.

Despite high dietary copper levels in these diets serum copper levels were not elevated. This is likely explained by the interactions between Cu and other metals in the gastrointestinal tract. Therefore, it seems likely that the reason for the absence of elevated serum Cu levels was the high levels of Zn in the diets. Ivan and Grieve (1976) reported reduced copper absorption in young calves when the basal dietary Zn levels were raised from 50 mg/kg to 100 mg/kg. The inhibitory action of Zn on Cu absorption was shown to occur in the rumen and the small intestine. It is known that high levels of dietary Zn causes increased metallothionein synthesis in the intestine of rats and chicks (Richards and Cousins 1975a,b; Starcher et al. 1980; Menard et al. 1981). High levels of Zn cause accumulation of copper in the murosal cell (Evans and Hahn 1974; Fischer et al. 1983; Oistreicher and Cousins 1985) due to the binding of Cu to metallothionein (Fischer et al. 1983). As a consequence, the rate of transfer of copper to the plasma is impaired.

Table 5. Effect of premix on calf performance from 6 weeks to slaughter

	Composite†	
	1	2
No. of calves	16	29
Days to slaughter (kg)	125.56	119.00
Average daily gain (kg)	1.07	1.31
Average daily feed (kg)	3.21	3.61
Kg feed DM/kg gain	3.06	2.77

†Average growth performance and feed consumption data for those calves fed diets containing high levels of micromineral premix for at least 5 test weeks (Composite 1) and those receiving only normal diets (Composite 2).

Calf Performance

Although initial weights for calves on the five dietary treatments varied from 43 to 48 kg no differences among treatments were found ($P>0.05$), as was the case for age at start of test (Table 6). Average age and weight at the start of test were 10 days and 47 kg. There were no differences ($P>0.05$) among dietary treatments for consumption of milk replacer, calf starter or total dry matter from 0-6 weeks. Slight differences in milk replacer consumption were due to feed refusals as animals adjusted to the milk replacer. Daily gains and feed conversion efficiency did not differ among diets ($P>0.05$) but the slight differences in daily gains resulted in lower 6 week weights ($P>0.05$) for calves on the barley-wheat diet. For this reason, all subsequent (6 weeks to market) data has been adjusted by covariate analysis for weight at 6 weeks on test.

Daily gains from 6 wk to market on the barley + wheat diet were lower ($P<0.05$) than on the barley + oil diet and tended to be lower than on the barley + JSCS diet (Table 7). Average daily gains on barley and corn based diets were intermediate to, but not different ($P>0.05$) Than, those on the barley + wheat and barley + oil or barley + JSCS diets. Although the GLM procedure showed significant ($P<0.05$) differences among treatments for average daily feed (Appendix Table E); the means separation test was unable to distinguish where the differences were (Table 7). Calves fed diets based on corn or barley + wheat had the lowest apparent daily feed consumptions, averaging 7-9% less feed per day than those fed barley, barley + oil or barley + JSCS. Similarly, although the differences among the least square means for feed efficiency ratios approached significance ($P<0.10$), the trends were not detected with the means separation test. Feed efficiency ratios were lowest on diets containing corn, barley + oil and barley + JSCS, with those calves

Table 6. Effect of diet on the least square means for calf growth and feed consumption data from start of test at 7-13 d to 6 weeks on test

	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat
No. of calves†	9	9	8	9	9
Age at start (d)	9.33 (0.821)‡	11.33 (0.821)	9.75 (0.870)	10.89 (0.821)	8.33 (0.821)
Wt at start (kg) §	47.67 (1.36)	46.44 (1.36)	47.13 (1.44)	45.78 (1.36)	43.44 (1.36)
Wt at 6 wk (kg) §	60.66 (1.85)	62.70 (1.82)	59.40 (1.94)	60.18 (1.82)	60.22 (1.91)
ADG to 6 wk (kg) §	0.347 (0.044)	0.396 (0.043)	0.317 (0.046)	0.336 (0.043)	0.337 (0.045)
Feed consumption:					
MR ¶ DM/d (kg)	0.461 (0.020)	0.480 (0.020)	0.455 (0.021)	0.447 (0.020)	0.462 (0.021)
Starter DM/d (kg) §	0.304 (0.035)	0.345 (0.035)	0.258 (0.037)	0.353 (0.035)	0.294 (0.037)
Total DM/d (kg) §//	0.765 (0.036)	0.825 (0.036)	0.714 (0.038)	0.799 (0.036)	0.756 (0.037)
Kg DM/kg gain §	2.57 (0.464)	2.15 (0.456)	2.56 (0.487)	2.80 (0.456)	2.96 (0.477)

†One calf from the treatment barley + canola oil was omitted from the analysis because of ill-health during this period.

‡Numbers in parentheses are the standard errors of the least square means.

§Adjusted by analysis of covariance for differences in weight at start of test.

¶MR = milk replacer.

//Includes milk replacer and starter DM.

Table 7. Effect of diet on the least square means for calf growth and feed consumption data from 6 weeks on test to slaughter

	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat
No. of calves	9	9	9	9	9
Initial 6 wk weight (kg)	64.89 (3.37)†	61.18 (3.37)	59.29 (3.37)	58.61 (3.37)	56.71 (3.37)
Slaughter weight (kg)‡	203.09 (2.07)	201.21 (2.02)	200.77 (2.02)	200.40 (2.02)	200.47 (2.05)
Weight gain on test (kg)‡	140.22 (3.58)	139.13 (3.49)	138.79 (3.50)	136.18 (3.50)	134.31 (3.55)
Days to slaughter‡	119.51ab (4.94)	128.38ab (4.81)	112.28b (4.81)	111.44b (4.83)	135.08a (4.88)
Average daily gain (kg)‡	1.19ab (0.057)	1.11ab (0.056)	1.25a (0.056)	1.23ab (0.056)	1.01b (0.057)
Total feed consumed (kg)‡	376.75 (16.21)	428.71 (15.81)	383.18 (15.81)	385.39 (15.84)	417.28 (16.04)
Average daily feed (kg)‡	3.17 (0.093)	3.38 (0.090)	3.44 (0.090)	3.45 (0.091)	3.14 (0.092)
Kg feed DM/kg gain‡	2.67 (0.135)	3.11 (0.132)	2.78 (0.132)	2.82 (0.132)	3.15 (0.134)

a,b Means in the same row with different letters are significantly different ($P<0.05$).

†Numbers in brackets are the standard errors of the least square means.

‡Least square means adjusted by covariate analysis for weight at start of period (6 weeks on test).

fed barley or barley + wheat diets apparently requiring 10-18% more feed per kg of liveweight gain (Table 7).

Daily gains and feed efficiency ratios obtained in this study for diets containing corn and barley are in good agreement with those reported elsewhere in the literature (Latrille et al. 1983; Guertin et al. 1987a). Stiles et al. (1973) and Beauchemin (1980) have reported slightly lower values but this was possibly due to a lower starting weight and the addition of 10% hay to the diet. Reports comparing whole corn and rolled barley have indicated that daily gains are comparable on the two, but as was the case in the present work, more feed appeared to be required to produce a kg of gain with barley diets (Beauchemin 1980; Guertin et al. 1987a).

The 9% reduction in daily gains observed when 50% of the barley was replaced with wheat appeared to be due to a similar reduction in average daily feed intake, as feed efficiency was similar for both diets (Table 7). Work with calves weighing 100-400 kg has also shown that replacing barley with wheat reduces daily gains and feed intakes by about 8% but does not affect feed efficiency (Kay et al. 1972). However, the apparent 15% decrease in daily gains when diets containing barley + wheat were compared to those containing corn were not accompanied by a similar apparent reduction in feed intake (Table 7). Feed efficiency appeared to be greater ($P>0.05$) on the corn diet than on the barley wheat diet by about 18%. Similar findings have been reported by Kay et al. (1972) in that when wheat was compared to corn as an energy source for calves weighing 100-400 kg, daily gain and feed efficiency was impaired but feed intake remained unchanged. Thus, the intake problems associated with feeding wheat in comparison to corn to feedlot cattle (Oltjen et al. 1966; Varner and Woods 1975; Fulton et al. 1979) are not apparent when wheat is fed to younger (< 400 kg) calves at a level of 45% of the DM.

The addition of oil to a barley based diet, either in the form of canola oil or JSCS, did not reduce average daily feed intake. Others have also found that dietary fat additions of up to 6% have not depressed feed intake when diets were offered ad libitum (Gardner and Wallentine 1972; Stiles et al. 1974; Waldern and Fisher 1978; Bouchard et al. 1980). The slight ($P>0.05$) increase in daily gains obtained when canola oil was added to the diet contrasts with the findings of Gardner and Wallentine (1972), Stiles et al. (1974) and Bouchard et al. (1980) who found no increase in daily gains when animal fat was added to calf starters. However Waldern and Fisher (1978) have reported that while 5% animal fat did not change daily gains, 5% acidulated fatty acids from canola oil processing increased daily gains.

As feed intake was not changed when canola oil was added to the barley diet the apparent increase in daily gains was due to a slightly ($P>0.05$) more efficient use of feed (Table 7). Work with older animals that are possibly laying down more body fat has shown a decrease in the amount of feed required per kg of gain when fat is added to the diet (Hentges et al. 1954; Erwin et al. 1956; Stiles et al. 1974). With younger (<136 kg) animals, feed conversion efficiency was not changed when animal fat was added to the starter (Gardner and Wallentine 1972; Waldern and Fisher 1978; Bouchard et al. 1980) but the addition of acidulated fatty acids from canola oil processing significantly improved feed efficiency by 10% (Waldern and Fisher, 1978).

These results indicate that the inclusion of JSCS did not benefit calf performance beyond the improvements obtained by adding canola meal and canola oil separately. Other authors have shown that 18% extruded canola seeds (Sharma et al., 1986) or 16-17% roasted or extruded soybeans (Daniels et al., 1973a; 1973b) did not improve calf performance, even though in one study (Sharma et al., 1986) ether extract contents were higher for diets containing

the extruded canola seeds. Work with calves less than 8 weeks of age has shown better calf gains with soybeans processed at 171°C than with raw soybeans, soybean meal or soybean meal plus added fat, but no evidence was provided of whether feed efficiency or the extent of rumen bypass was changed (Abdelgadir et al., 1984).

Average liveweight at slaughter was 200-203 kg after adjustment for weight at 6 weeks on test and for weight group at slaughter. As was intended by experimental design, this did not differ among treatments ($P<0.05$), with calves in all treatments gaining approximately 134-140 kg from 6 weeks to slaughter (Table 7). As a result of lower daily gains on the barley + wheat diet days to slaughter was higher ($P<0.05$) on this diet than on the barley + oil or barley + JSCS diets.

Total DM consumption from 6 weeks to slaughter tended to differ among treatments ($P>0.10$; Appendix Table E) but trends were not detected using the means separation test (Table 7). Diets containing corn, barley + oil and barley + JSCS resulted in the lowest apparent total feed consumptions. Although daily feed intake was apparently lowest on the barley + wheat diet, the longer time to market for these calves appeared to result in higher total feed consumption. Total feed consumed on the barley diet appeared to be similar to that on the barley + wheat diet. Higher total feed consumption of barley diets as compared to corn diets for comparable weight gains have been reported elsewhere (Beauchemin 1980; Latrille et al. 1983).

Although calves slaughtered at 180 kg liveweight gained less weight than those slaughtered at 210 kg liveweight, days to slaughter did not differ ($P>0.05$) between the two groups (Table 8). This discrepancy was due to the lower ($P<0.01$) daily gains of calves in weight group 1. Feed conversion efficiency was similar ($P>0.05$) for the two groups.

Table 8. Effect of slaughter weight on the least square means for calf growth and feed consumption data from 6 weeks on test to slaughter

	Slaughter weight	
	180 kg	210 kg
No. of calves	10	35
Initial 6 wk weight (kg)	59.90 (2.66)†	60.37 (1.42)
Live weight at slaughter (kg)‡ §	185.58A (1.59)	216.79B (0.85)
Weight gain on test (kg)‡ §	122.47A (2.75)	152.98B (1.47)
Days to slaughter‡	121.34 (3.79)	121.33 (2.03)
Average daily gain (kg)‡	1.04A (0.044)	1.27B (0.024)
Total feed consumed (kg)‡	363.12A (12.46)	483.40B (6.66)
Average daily feed (kg)‡	3.04A (0.071)	3.58B (0.038)
Kg feed DM/kg gain‡	2.96 (0.104)	2.85 (0.056)

A,B Means in the same row with different letters are significantly different ($P<0.01$).

†Numbers in brackets are the standard errors of the least square means.

‡Least square means adjusted by covariate analysis for weight at start of period (6 weeks on test).

§ Liveweight at slaughter and likely weight gain on test were different due to experimental design.

The results of other studies that deal with calves of various weights from 110 to 222 kg would indicate that animals slaughtered at lighter weights have similar daily gains but more efficient feed conversion than do those slaughtered at heavier weights (Gardner and Wallentine 1972; Stiles et al. 1974; Bouchard et al. 1980; Latrille et al. 1983; Guertin et al. 1987a). Results in this experiment were likely confounded by the high levels of micro-minerals in the premix of composite 1. The effect of premix on daily gains and feed conversion efficiency was similar to the effect of slaughter group (Table 5). All calves slaughtered at 180 kg (Table 8) received composite 1 of their respective diets for part of the growth trial.

Although it appears that calves gained faster ($P<0.01$) and more efficiently ($P>0.05$) when implanted at 80 rather than 100 kg (Table 9) this effect was likely the effect of calf weight at slaughter and/or premix. Appendix Table A shows that all but 1 calf that was implanted at 100 kg were slaughtered at 180 kg. Furthermore, the effect of slaughter group was almost identical to the effect of implant group (Tables 8, 9).

A significant ($P<0.05$) interaction occurred between source of calves and treatment for the feed efficiency ratio. It appeared that calves from outside sources fed supplemental energy in the form of canola oil, JSCS or wheat were less efficient at utilizing feed than were calves from the University herd fed the same diets (Table 10). No explanation can be suggested for these results and since several cells contained only a few animals no valid conclusions can be drawn from these data. No other parameters were affected by source of calves (Table 11).

When season (i.e. the last two months prior to slaughter) was used as a block effect in the statistical model the GLM procedure indicated a significant effect of season on growth and feed consumption parameters. Due

Table 9. Effect of weight at implanting on the least square means for calf growth and feed consumption data from 6 weeks on test to slaughter

	Weight at implanting	
	80 kg	100 kg
No. of calves	35	10
Weight at implant (kg)†	83.31A (0.70)§	104.01B (1.31)
Age at implant (d)† ‡	80.91A (1.49)	108.11B (2.79)
Initial 6 wk weight (kg)	60.49 (1.41)	59.50 (2.64)
Live weight at slaughter (kg)†	215.71A (1.40)	189.35B (2.61)
Weight gain on test (kg)†	151.93A (1.85)	126.15B (3.46)
Days to slaughter†	120.46 (2.18)	124.38 (4.08)
Average daily gain (kg)†	1.27A (0.02)	1.04B (0.04)
Total feed consumed (kg)†	428.68a (7.61)	379.66b (14.24)
Average daily feed (kg)†	3.57A (0.04)	3.10B (0.07)
Kg feed DM/kg gain†	2.84 (0.06)	3.00 (0.10)

A,B,a,b Means in the same row with different letters are significantly different; A,B - $P<0.01$; a,b - $P<0.05$.

†Least square means adjusted by covariate analysis for weight at start of period (6 weeks on test).

‡Weight at implanting and age at implanting were different due to experimental design.

§ Numbers in brackets are the standard errors of the least square means.

Table 10. Effect of interaction of source of calves and diet on the least square means for feed efficiency ratio†

	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat
University Herd	2.73 (5)‡	3.03 (3)	2.60 (4)	2.75 (4)	2.89 (7)
Outside Sources	2.74 (4)	2.99 (6)	2.78 (5)	2.92 (5)	3.79 (2)

†Least square means adjusted by covariate analysis for weight at start of period (6 weeks on test).

‡Numbers in brackets are the number of calves in each cell.

Table 11. Effect of source of calves on the least square means for calf growth and feed consumption data from 6 weeks on test to slaughter

	Source	
	University	Outside sources
No. of calves	23	22
Initial 6 week weight (kg)	58.10 (1.65)†	62.34 (1.74)
Live weight at slaughter (kg)‡	208.32 (3.43)	212.23 (3.62)
Weight gain on test (kg)‡	145.85 (3.72)	144.88 (3.92)
Days to slaughter (kg)‡	119.80 (2.89)	123.64 (3.05)
Average daily gain (kg)‡	1.24 (0.04)	1.18 (0.04)
Total feed consumed (kg)‡	404.96 (11.11)	436.90 (11.71)
Average daily feed (kg)‡	3.42 (0.08)	3.54 (0.08)
Kg feed DM/kg gain‡	2.80 (0.06)	3.04 (0.07)

†Numbers in brackets are the standard errors of the least square means.

‡Least square means adjusted by covariate analysis for weight at start of period (6 weeks on test).

to the high number (10/12) of calves slaughtered in the summer that were slaughtered at 180 rather than 210 kg (Appendix Table A), the summer slaughtered calves gained less weight ($P<0.01$) and had lower daily feed intakes ($P<0.01$) than did those slaughtered in fall or winter (Table 12).

Less clear are the effects of fall and winter periods on growth and feed consumption data. Although these calves were of similar slaughter weight ($P>0.05$) and had equivalent weight gains on test ($P>0.05$) (Table 5), winter slaughtered calves gained faster ($P<0.05$) and took less time to reach market ($P<0.05$) than did fall slaughtered calves. The calves slaughtered in the winter utilized feed more efficiently for gain ($P<0.01$) than did fall slaughtered calves. As all calves were on similar light regimes no explanation can be offered for these results other than a temperature effect.

II.

Digestibility Trial

The digestibility of DM, energy and CP was not affected ($P>0.05$) by dietary treatment (Table 13). The addition of wheat to the barley diet increased ADF digestibility above that obtained on the corn and barley diets ($P<0.05$). Acid detergent fiber digestibility was higher ($P<0.05$) on the barley + JSCS diet than on the barley diet and tended ($P<0.10$) to be higher than on the corn diet. There was a tendency ($P<0.10$) for the digestibility of TL on the barley diet to be lower than that on the corn diet.

Values for DE and DM digestibility as determined in the present experiment (Table 13) were lower than the literature values of 75-90% for corn (Kay et al. 1972; White et al. 1972; Orskov et al. 1980; Beauchemin 1980; Latrille et al. 1983; Guertin et al. 1987b) 75-85% for rolled barley (Oltjen et al. 1967; Nicholson et al. 1971; MacLeod et al. 1972; Beauchemin 1980 and

Table 12. Effect of marketing season on the least square means for calf growth and feed consumption data from 6 weeks on test to slaughter

	Marketing season†		
	Summer	Fall	Winter
No. of calves	12	15	18
Initial 6 week weight (kg)	60.13 (2.52)‡	59.03 (2.27)	60.85 (2.04)
Live weight at slaughter (kg) §	189.57A (2.37)	217.36B (2.14)	216.14B (1.91)
Weight gain on test (kg) §	126.80A (3.17)	152.00B (2.87)	153.48B (2.57)
Days to slaughter §	122.80a (3.22)	127.01a (2.91)	115.07b (2.61)
Average daily gain (kg) §	1.06a (0.037)	1.21b (0.033)	1.34c (0.030)
Average daily feed (kg) §	3.09A (0.066)	3.63B (0.060)	3.56B (0.054)
Kg feed DM/kg gain §	2.96A (0.081)	3.05A (0.073)	2.67B (0.065)

A,B,a,b Means within row with different letters are significantly different. A,B - $P<0.01$; a,b - $P<0.05$.

†Refers to the season during which the last two months of growth occurred.

‡Numbers in brackets are the standard errors of the least square means.

§ Least square means adjusted by covariate analysis for weight at start of period (6 weeks on test).

Table 13. Effect of diet on the least square means for the apparent digestibility coefficients of dry matter (DM), energy (GE), crude protein (CP), acid detergent fiber (ADF) and total lipids (TL)

	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat
No. of calves	5	4	5	6	4
DM intake (kg/d)	2.92 (0.231)†	2.67 (0.259)	3.07 (0.231)	2.80 (0.211)	2.85 (0.259)
CP intake (kg/d)	0.432 (0.034)	0.399 (0.038)	0.435 (0.034)	0.424 (0.031)	0.440 (0.038)
Digestibility of:					
DM (%)	68.82 (2.83)	64.38 (3.16)	71.66 (2.83)	71.66 (2.58)	75.57 (3.16)
GE (%)	67.53 (2.96)	62.58 (3.31)	69.39 (2.96)	69.24 (2.70)	74.17 (3.31)
CP (%)	61.37 (3.16)	59.12 (3.53)	65.04 (3.16)	65.23 (2.88)	69.72 (3.53)
ADF (%)	7.98ab (4.35)	5.27a (4.86)	20.04abc (4.35)	24.61bc (3.97)	30.85c (4.86)
TL (%)	62.05 (5.89)	35.71 (6.58)	53.16 (5.89)	48.27 (5.37)	52.14 (6.58)

a,b,c Means in the same row with different letters are significantly different ($P<0.05$).

†Numbers in parentheses are the standard error of the least square means.

Guertin et al. 1987b) and 78-82% for wheat (Oltjen et al. 1967; Kay et al. 1972; Orskov et al. 1980). MacGuire et al. (1966) reported that digestion coefficients determined with the Cr_2O_3 method were lower than those determined with the total collection method due to low (94.2%) recovery of Cr_2O_3. Substituting this value into the calculation for apparent digestibility as suggested by Lucas (1952) did not increase digestibility coefficients to values obtained in other studies (Table 14). While it is possible that extremely low Cr_2O_3 recovery may have resulted in lower digestibility coefficients (Schneider and Flatt 1975) in the absence of Cr_2O_3 recovery data this speculation cannot be verified.

Other authors have not found significant differences in DM and energy digestibilities when corn diets were compared to rolled barley diets for cattle (Oltjen et al. 1967; Beauchemin 1980; Spicer et al. 1986; Guertin et al. 1987b). The absence of significant differences between the digestibility coefficients for barley-wheat diets and barley or corn diets is also in agreement with the work of others who found no difference in DM and energy digestibilities when wheat was compared with barley or corn (Oltjen et al. 1966; Kay et al. 1972; Orskov et al. 1980).

Crude protein digestibility coefficients for diets containing corn, barley or barley + wheat (Table 13) were lower than values of 70-80% reported elsewhere by Oltjen et al. (1967), MacLeod et al. (1972), Beauchemin (1980) and Guertin et al. (1987b). This was likely related to the lower digestibility coefficients obtained for dry matter and energy in the present work. That there were no differences in the CP digestibility coefficients for corn, barley and barley + wheat diets is in agreement with the work of Oltjen et al. (1967), Beauchemin (1980) and Spicer et al. (1986) who found no large differences in N digestibilities on cereal diets when rolled wheat or rolled

Table 14. Effect of diet on the least square means for the apparent digestibility coefficients of DM, GE, CP, ADF and TL†

	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat
No. of calves	5	4	5	6	4
Digestibility of					
DM (%)	70.63 (2.67)‡	66.45 (2.98)	73.31 (2.67)	73.31 (2.43)	76.99 (2.98)
GE (%)	69.42 (2.79)	64.75 (3.12)	71.16 (2.79)	71.03 (2.54)	75.67 (3.12)
CP (%)	63.61 (2.98)	61.49 (3.33)	67.07 (2.98)	67.24 (2.72)	71.48 (3.33)
ADF (%)	13.31ab (4.10)	10.77a (4.58)	24.68abc (4.10)	28.98bc (3.74)	34.86c (4.58)
TL (%)	64.25 (5.54)	39.44 (6.20)	55.87 (5.54)	51.27 (5.06)	54.92 (6.20)

a,b,c Means in the same row with different letters are significantly different ($P<0.05$).

†Coefficients of apparent digestibility calculated using 94.2% recovery of Cr_2O_3 (MacGuire et al., 1966).

‡Numbers in parentheses are the standard error of the least square means.

barley diets were compared to corn diets.

The digestibility of total lipids on corn and barley reported in this study were lower than the literature values of 64-80% digestibility of ether extract (Parrott et al. 1969; White et al. 1972; Shingoethe et al. 1982; Sharma et al. 1986). Fallon et al. (1986) reported a value of 36% for the digestibility of acid solvent extract in barley based calf starters. Therefore, the lower numbers obtained in this study were probably a function of the acid solvent-method of extraction, which has been shown by Sharma et al. (1978) to yield lower coefficients than does ether extraction. No studies were found reporting fat digestibilities on wheat diets.

The apparent digestibility of acid detergent fiber in the corn-based diet reported in the present work was lower than values reported elsewhere for diets containing whole or processed corn (38-67%; Beauchemin 1980, Orskov et al. 1980; Shingoethe et al. 1982; Latrille et al. 1983; Sharma et al. 1986). Also, the apparent digestibility of ADF in the barley diet was lower than values of 60-61% reported by Beauchemin (1980) and Fallon et al. (1986) for rolled barley diets, but similar to the value of 6.3% reported by Latrille et al. (1983) for a whole barley diet. Diets that are high in easily digested carbohydrates have lower fiber digestibilities (Schneider and Flatt, 1975) but as there was little difference between dietary ADF levels in the present work (Table 2) and those reported by Beauchemin (1980) (4.4-7.6% ADF) or Latrille et al. (1983) (6.0-8.2% ADF). The low acid detergent fiber digestibilities reported in this study are probably related to the low digestibility coefficients for dry matter and energy. As was reported by Beauchemin (1980), the ADF digestibilities for rolled corn and rolled barley diets were not different ($P>0.05$).

Adding wheat to the barley-based diet increased ($P<0.05$) the

digestibility of ADF over that of corn or barley-based diets (Table 13). As the barley diet contained slightly higher ADF levels than did the barley-wheat diet, it would be expected that the ADF digestibility would be similar on the two diets, or slightly higher for the barley diet (Schneider and Flatt, 1975). Replacing high moisture corn with dry rolled grain sorghum in the diets of finishing cattle resulted in a linear increase in ADF digestibility (Stock et al., 1987).

Other authors have found that adding up to 5% fats or oil to calf starters has little effect on diet digestibility. Dry matter and organic matter digestibilities were not affected by the addition of 10 or 20% protected tallow (Fisher, 1980) or 5 or 10% Ca soaps (Fallon et al., 1986). Chandler et al. (1968) found only slight increases in dry matter and energy digestibilities when 4% corn oil was added to corn-based diets. Higher levels of fat addition has been shown to depress dry matter and energy digestibilities (Chandler et al., 1968; Fallon et al., 1986). The absence of any effect on CP digestibility when 3.5% canola oil was added to the barley diet is in agreement with results of Chandler et al. (1968), Fisher (1980) and Fallon et al. (1986) who found no effect on crude protein digestibility when 4% corn oil, 10 or 20% protected fat or 5 or 10% Ca soaps were added to calf starters.

The increase in fat digestibility when canola oil was added to the barley diet did not reach significance ($P>0.05$) due to high variability of the data. Other authors (Chandler et al., 1968; Fisher, 1980; Fallon et al., 1986; Sharma et al., 1978) have reported increased apparent digestibility coefficients of fat when fat is added to diets. As dietary fat increases, the depressing effect of metabolic fecal fat on fat digestibility coefficients is diluted.

Dry matter, energy and CP were as well digested in diets containing whole Jet-Sploded canola seed as in those containing canola meal or canola meal plus canola oil (Table 13). As was the case when canola oil was added to the barley diet the digestibility of fat was not affected by the addition of JSCS. The slight, non-significant increase in the value for apparent fat digestibility was probably due to a diluting of the effect of metabolic fecal fat on the percent digestibility. Others (Prasad and Morrill 1976; Sharma et al. 1986) have reported improved fat digestibility when oilseeds are added to calf starters.

The addition of JSCS to barley diets increased ($P<0.05$) the digestibility of ADF above that of the barley diet. Canola oil at 3.5% also resulted in a higher digestibility of ADF but because of high variability results did not reach significance. In contrast, Sharma et al., (1986) reported that 18% extruded canola seed reduced ADF digestibility as compared to a diet containing canola meal whereas whole canola seed did not affect ADF digestibility. Prasad and Morrill (1976) have also reported a decrease in the apparent digestibility of crude fiber when roasted soybeans were added to calf starters. However, the addition of protected tallow to calf diets (Fisher, 1980) had no effect on ADF digestibility and Ca soaps in calf starters have been shown to improve ADF digestibility (Fallon et al., 1986).

Sampling time did not affect ($P>0.05$) the rumen concentration of total volatile fatty acids, rumen ammonia nitrogen, molar proportions of volatile fatty acids, rumen pH or blood urea nitrogen. Values for two sampling times, therefore, are combined for further discussion (Tables 15 and 16).

Cereal source had no affect ($P>0.05$) on the total concentration of volatile fatty acids, molar proportions of volatile fatty acids (Table 15) or on rumen pH (Table 16). Others however, have reported higher total volatile

Table 15. Effect of diet on the least square means for rumen volatile fatty acids on the 5th day of the digestibility trial

	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat
No. of calves	5	4	5	6	4
Total VFA (mol/100 ml)	8.581 (0.772)†	8.891 (0.863)	7.842 (0.772)	7.951 (0.705)	7.257 (0.863)
mol/100 mol of:					
acetate	42.8 (0.841)	45.6 (0.941	45.5 (0.841)	45.7 (0.768)	42.0 (0.941)
propionate	43.6 (1.28)	41.7 (1.43)	41.7 (1.28)	39.9 (1.17)	47.3 (1.43)
butyrate	7.7 (0.589)	6.4 (0.659)	6.6 (0.589)	7.3 (0.538)	6.2 (0.659)
isobutyrate	0.6 (0.148)	1.2 (0.165)	0.9 (0.148)	1.0 (0.135)	0.6 (0.165)
valerate	4.5 (0.394)	3.6 (0.440)	4.3 (0.394)	4.7 (0.360)	3.1 (0.440)
isovalerate	0.8 (0.173)	1.4 (0.194)	1.1 (0.173)	1.3 (0.158)	0.9 (0.194)
acetate/propionate	0.99 (0.070)	1.15 (0.078)	1.10 (0.070)	1.18 (0.064)	0.89 (0.078)

†Numbers in parentheses are the standard error of the least square means.

Table 16. Effect of diet on the least square means for rumen ammonia nitrogen (RAN), blood urea nitrogen (BUN) and rumen pH on the 5th day of the digestibility trial

Treatment	No. of calves	RAN (mg/100 ml)	BUN (mg/100 ml)	rumen pH
Corn	5	5.098 (1.558)†	5.425 (0.567)	6.19 (0.172)
Barley	4	7.666 (1.742)	6.131 (0.634)	6.39 (0.192)
Barley + oil	5	12.427 (1.558)	7.469 (0.567)	6.02 (0.172)
Barley + JSCS	6	8.540 (1.422)	8.810 (0.518)	6.23 (0.172)
Barley + wheat	4	6.897 (1.742)	5.825 (0.634)	6.16 (0.222)

†Numbers in parenthesis are the standard error of the least square means.

fatty acid production on wheat and barley diets than on corn diets (Oltjen et al. 1967; Kreikemeier et al. 1987) and rumen pH has been reported to be lower on wheat diets than on corn diets (Oltjen et al. 1967; Varner and Woods 1975; Fulton et al. 1979; Kreikemeier et al. 1987). Other authors have also reported changes in the molar proportions of volatile fatty acids (less propionate and more acetate and butyrate) when wheat and barley diets are compared to corn diets (Oltjen et al. 1967; Orskov et al. 1974; Fulton et al. 1979).

Oltjen et al. (1967) reported significantly lower rumen ammonia nitrogen levels on corn diets than on wheat diets but differences among cereals in the present study did not reach significance ($P>0.05$; Table 16). Likewise, blood urea nitrogen levels in this study were not different among diets ($P>0.05$) although Oltjen et al. (1967) reported that corn diets results in lower blood urea nitrogen levels than did barley diets, while levels on wheat diets were intermediate.

The addition of canola oil or JSCS to the barley diet had no effect ($P>0.05$) on any of the rumen or blood parameters measured (Tables 15 and 16). Sharma et al. (1986) also reported that 12 or 18% whole canola seed or 18% extruded canola seed in calf starters had no effect on total volatile fatty acids in the rumen fluid, molar proportions of volatile fatty acids or rumen ammonia nitrogen levels. Little information was found on the effect of unprotected oils in calf starters on rumen measurements. Caffrey et al. (1988) found no effect on rumen pH when tallow was added to calf starters.

III.

Rumen Degradability Trial

The dry matter and crude protein disappearance (Table 17) from JSCS

Table 17. Effect of protein source on disappearance of dry matter (DMDIS) and crude protein (CPDIS) from nylon bags at 0, 4 and 8 hours rumen incubation

	Incubation Time (hours)					
	0		4		8	
	DMDIS (%)	CPDIS (%)	DMDIS (%)	CPDIS (%)	DMDIS (%)	CPDIS (%)
Canola meal	31.05A	25.58a	47.72A	53.68A	61.48a	68.34A
JSCS†	6.40B	3.19b	17.72B	14.83B	26.67b	25.42B
End of Run‡	11.40B	9.83c	22.68C	27.90C	32.84b	38.67C
± SEM §	1.71	2.20	1.60	1.65	3.66	3.81

A,B,C,a,b,c Means in the same column with different letters are significantly different A,B,C, $P<0.01$; a,b,c, $P<0.05$).

†Sample of canola seeds used in growth trial.

‡Sample of canola seeds from end of the Jet-Sploding run. At the beginning of the run seed temperature did not reach the desired level.

§ ± standard error of the mean.

samples was consistently lower than the DM and CP disappearance from samples obtained at the end of the Jet-Sploding run and this was significant for CP disappearance at 0 ($P<0.05$), 4 ($P<0.01$) and 8 ($P<0.01$) hours and for dry matter disappearance at 4 hours ($P<0.01$). These lower values were likely due to the fact that JSCS samples had less broken seed coats than did samples from the end of the run. Crude protein disappearance from the canola meal sample was within the range reported by Kendall (1988).

Values obtained for CP disappearance from samples taken at the end of the Jet-Sploding run after 0 and 4 h rumen incubation were comparable to values of 11.6 and 27.3% reported for JSCS by Kennelly and de Boer (1986). In their work, incubation for 8 hours did not result in higher CP disappearance (28.1%) whereas in the present study 38.7% of the CP disappeared during an 8 hour incubation. This is comparable to a value of 39.9% at 12 hours in the work of Kennelly and de Boer (1986). Thus, it would appear from the results presented here in relation to those of Kennelly and de Boer (1986) that the Jet-Sploding treatment used in this study was adequate for protecting dry matter and crude protein from ruminal degradation, provided the Jet-Sploding temperature was properly regulated.

Dry matter and CP disappearance from nylon bags was more rapid for barley, barley + oil, barley + JSCS and barley + wheat diets than for corn diets (Table 18). The effective degradability of DM was lower for the corn diets than for either of the four barley based diets ($P<0.05$). The analysis of variance procedure showed that there were differences ($P<0.01$) in the effective degradability of CP but the Bonferroni's test did not detect which means were different. However, the data suggest that the effective degradability of CP followed a pattern similar to that of the effective degradability of DM. The lower degradability of corn diets as compared to

Table 18. Effect of diet on the least square means for dry matter (DM) and crude protein (CP) disappearance from nylon bags at 0, 4, 8 and 36 hours and on the effective degradability of DM (EDDM)† and CP (EDCP)†

	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat
DM disappearance at:					
0 hr (%)	23.77ab (0.906)‡	27.37bc (0.906)	20.83a (0.906)	24.31bc (0.906)	28.69c (0.906)
4 hr (%)	29.11 (1.35)	50.76 (1.35)	37.95 (1.35)	42.71 (1.35)	52.86 (1.35)
8 hr (%)	35.21a (1.62)	65.26cd (1.62)	56.57b (1.62)	59.15bc (1.62)	70.00d (1.62)
36 hr (%)	83.22 (1.53)	86.77 (1.53)	83.95 (1.53)	88.76 (1.53)	87.33 (1.53)
CP disappearance at:					
0 hr (%)	28.96 (1.53)	28.48 (1.53)	22.23 (1.53)	28.39 (1.53)	28.44 (1.53)
4 hr (%)	34.93 (1.79)	37.40 (1.79)	31.54 (1.79)	35.34 (1.79)	33.65 (1.79)
8 hr (%)	35.10 (3.07)	45.90 (3.07)	41.55 (3.07)	42.39 (3.75)	53.83 (3.07)
36 hr (%)	64.25a (2.16)	82.66b (2.16)	76.81b (2.16)	86.12b (2.16)	81.65b (2.16)
EDDM (%)	35.51a (1.08)	59.54c (1.08)	50.54b (1.08)	55.64bc (1.08)	62.33c (1.08)
EDCP (%)	34.09 (2.48)	44.87 (2.48)	38.67 (2.48)	43.03 (2.48)	48.35 (2.48)

a,b,c Means in the same row with different letters are significantly different ($P<0.05$).

†Calculated using the equations of Orskov (1982) at an outflow rate of 0.08 h^{-1}.

‡Numbers in parentheses are the standard error of the least square means.

barley or barley + wheat diets would be expected as others have shown reduced ruminal digestion of starch and nitrogen when corn is compared to barley and wheat (Kay et al. 1972; Spicer et al. 1987).

The addition of canola oil to the barley diet appeared to result in a less rapid disappearance of DM and N from nylon bags and a reduced effective degradability of DM ($P<0.05$) (Table 18). A similar trend was noted for effective CP degradability but Bonferroni's test could not detect differences at the $P=0.10$ level of significance. The addition of JSCS to the barley-based diets did not change the effective degradabilities of DM or CP ($P>0.05$) when compared to the barley-only diet.

Deacon et al. (1988) reported that when samples were ground through a 1 mm screen, the degradability of DM and CP of whole, untreated canola seed was higher than that of canola meal whereas the degradability of DM and CP in Jet-Sploded canola seed was less than that of canola meal. In the present study, there was no improvement in the bypass value of the complete feed when ground JSCS was used as a protein source. Results of the evaluation of unground seeds indicated that the Jet-Sploded product used in this study was less degradable than canola meal (Table 17) but considering that there was no effect in the ground, complete diets it would be reasonable to assume that this difference was from a failure of the Jet-Sploding treatment to adequately disrupt the seed coat. This is also supported by the observation that the seeds from the end of the Jet-Sploding run, which had more broken seed coats, were more rapidly degraded in the rumen than were the seeds used in the growth trial.

Kovalczyk et al. (1976) reported that free fatty acids reduced proteolysis in the rumen. This may explain the reduction in effective degradability when canola oil was added to the barley diet. The JSCS did not

appear to have this effect, and this could possibly have been due to a lower availability of in-seed fats, even though the samples were ground.

IV. Comparison of daily calf performance with calculated available energy and protein relative to NRC requirements

For the purposes of this discussion energy and protein utilization refer to the number obtained when daily requirements for energy (Mcal NEG) and protein (g) were subtracted from daily intakes of energy and protein. Daily requirements for digestible energy (DE), net energy for maintenance (NEM), net energy for growth (NEG), crude protein (CP), undegradable intake protein (UIP) and degradable intake protein (DIP) (Table 21) were calculated using actual calf gains at 100, 150 and 180 kg (Table 22) and NRC (1989) requirements for DE, NEm, NEg, CP, UIP and DIP. Daily intakes of the nutrient fractions were calculated using actual daily feed intakes (Table 22), experimentally determined values for DE, CP, UIP and DIP, values calculated using NRC (1989) values for DE, NEM, NEG, CP, UIP and DIP in the individual feed ingredients and values for NEM and NEG as calculated using experimental values for DE and NRC (1989) equations for NEM and NEG (Table 19 and 20).

As would be expected from the low experimental values for DE, calves showed a negative energy utilization when NEM and NEG in the feed was calculated using experimental DE values (Table 23). However, when NRC (1989) values for NEM and NEG in the individual feed ingredients were used to calculate NEM and NEG the net energy utilization values were positive at all three weights. Thus the calculated energy intake was sufficient to support slightly more growth than was actually observed. This may have been due to the high level of concentrate feeding in the present study, as this would likely result in more fat deposition and hence a higher requirement for energy

Table 19. Summary of energy values for experimental diets as measured in vivo and as calculated from NRC (1989) tables

Diet	DE (Mcal/kg)		NEM (Mcal/kg)		NEG (Mcal/kg)	
	Measured†	NRC‡	Calculated§	NRC‡	Calculated§	NRC‡
Corn	3.003	3.68	1.57	2.05	0.974	1.40
Barley	2.572	3.52	1.25	1.99	0.685	1.35
Barley + oil	2.972	3.74	1.53	2.09	0.954	1.44
Barley + JSCS	3.132	3.75	1.67	2.09	1.056	1.43
Barley + wheat	3.064	3.67	1.62	2.04	1.013	1.39

†Measured in vivo at 12-13 weeks.

‡Calculated using NRC (1989) values for individual feed ingredients.

§Calculated using experimentally determined DE values and equations on page 9 of NRC (1989).

Table 20. Summary of crude protein (CP), rumen undegradable protein (UIP) and rumen degradable protein (DIP) for experimental diets as determined in situ and as calculated from NRC (1989) values

	CP (%)		UIP (%)		DIP (%)	
Diet	Analyzed	NRC†	In Situ‡	NRC†	In Situ‡	NRC†
Corn	16.63	16.0	10.96	6.73	5.67	9.27
Barley	15.61	16.0	8.61	4.83	7.00	11.17
Barley + oil	16.07	16.0	9.86	4.83	6.21	11.17
Barley + JSCS	15.51	16.0	8.84	5.79	6.67	10.21
Barley + wheat	16.11	16.0	8.32	4.45	7.79	11.55

†Calculated using NRC (1989) values for individual feed ingredients.

‡Effective degradability of N was determined (Section III) assuming a rumen escape rate of 8% per hour.

Table 21. Summary of calf requirements for energy and protein at 100, 150 and 180 kg liveweight

Liveweight (kg)	ADG† (kg/d)	NEM‡ (mcal/d)	NEG‡ (mcal/d)	CP§ (g/d)	UIP§ (g/d)	DIP§ (g/d)
100	1.14	2.72	2.05	505	470	97
150	1.50	3.69	3.17	655	437	199
180	1.66	4.23	3.80	806	402	298

†Average of daily gains for calves fed corn, barley, barley + oil and barley + JSCS diets.

‡Daily requirements calculated using equations on page 8 of NRC (1989) and actual calf gains.

§Calculated using NRC (1989) requirements and actual calf gains. A linear relationship between calf gains and protein requirements was assumed.

Table 22. Summary of actual daily gains and (ADG) feed intakes (ADF) on experimental diets at 100, 150 and 180 kg liveweights

	Liveweight					
	100 kg		150 kg		180 kg	
Diet	ADG (kg)	ADF (kg)	ADG (kg)	ADF (kg)	ADG (kg)	ADF (kg)
Corn	1.12	2.96	1.45	4.25	1.69	5.43
Barley	1.15	2.99	1.49	4.88	1.65	5.57
Barley + oil	1.19	3.00	1.54	4.54	1.66	5.37
Barley + JSCS	1.11	3.07	1.52	4.97	1.64	5.40
Barley + wheat	1.16	3.02	1.44	4.57	1.40	4.98

Table 23. Summary of daily net energy utilization† at 100, 150 and 180 kg liveweight using NRC (1989) or calculated‡ values for NEM and NEG

Daily Net Energy Utilization (Mcal/d) at:	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat
100 kg liveweight					
NRC (1989)	+0.23	+0.14	+0.40	+0.48	+0.30
Calculated	-0.85	-1.49	-0.88	-0.53	-0.69
150 kg liveweight					
NRC (1989)	+0.26	+0.92	+0.82	+1.41	+0.67
Calculated	-1.32	-1.85	-1.14	-0.26	-0.85
180 kg liveweight					
NRC (1989)	+0.91	+0.85	+1.02	+1.03	+0.24
Calculated	-1.14	-2.30	-1.31	-0.77	-1.39

†Calculated using NRC (1989) values for energy requirements (Table 21), actual intakes of experimental diets (Table 22) and NRC (1989) or calculated values for NEM, NEG in experimental diets (Table 19). Daily Net Energy Utilization = Daily Energy Requirements - (Feed Intake x Energy Content of Diet).

‡Calculated using experimentally determined values for DE and equations from NRC (1989).

per unit of liveweight gain. Conversely, when experimental values for DE are used to calculate the NEM and NEG content of the diets calculated energy intakes were insufficient to support even the observed growth rates. Thus, calf performance as compared to NRC (1989) energy requirements suggests the digestible energy values obtained from the digestion trial are low, as was also suggested by compsiron with other reports in the literature.

The estimates of undegradable intake protein in the experimental diets were 53 to 104% greater when calculated using the determined in situ values than when calculated using NRC (1989) values for the percent undegradable protein in the individual feed ingredients (Table 20). The net daily protein utilization values relative to requirements for undegradable intake protein were negative at all three liveweights when NRC (1989) estimates of undegradable feed protein were used. When experimentally determined values for undegradable feed protein were used only the net utilization at 100 kg liveweight gave large negative values (Table 24). Crude protein utilization values were negative only at 100 kg liveweight, whereas degradable intake protein values were positive at all weights examined.

It is difficult to determine where the discrepancy lies between NRC (1989) calculated protein utilization and experimentally determined values for protein utilization. NRC (1989) values for undegradable feed protein are estimates determined by different laboratories over a wide range of conditions, whereas the values determined in the present study were estimated using steers on a basal diet of alfalfa hay. As protein degradability of plant protein sources is higher when the basal diet is forage rather than grain (Orskov 1982) it is likely that our estimate of undegradable intake protein is lower than that which would be truly applicable for calves fed on high concentrate rations. Also, the diets were ground prior to incubation so

Table 24. Summary of daily utilization† of crude protein (CP), rumen undegradable protein (UIP) and rumen degradable protein (DIP) at 100, 150 and 180 kg liveweight using NRC (1989) or experimental‡ values for CP, UIP and DIP

Daily Protein Utilization (g/d) at:	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat
100 kg liveweight					
NRC					
CP	- 41	- 27	- 25	- 14	- 22
UIP	-470	-327	-325	-292	-336
DIP	+172	+237	+238	+216	+252
Experimental					
CP	- 13	- 38	- 23	- 29	- 19
UIP	-148	-213	-174	-204	-220
DIP	+ 71	+112	+ 89	+104	+137
150 kg liveweight					
NRC					
CP	+ 25	+126	+ 71	+140	+ 76
UIP	-150	-201	-218	-149	-234
DIP	+195	+346	+308	+308	+329
Experimental					
CP	+ 52	+107	+ 75	+116	+ 81
UIP	+ 29	- 17	+ 11	+ 2	- 57
DIP	+ 42	+143	+ 83	+132	+157
180 kg liveweight					
NRC					
CP	+ 63	+ 74	+ 53	+ 58	- 9
UIP	- 37	-133	-143	- 89	-180
DIP	+205	+324	+302	+253	+277
Experimental					
CP	+ 97	+ 63	+ 57	+ 32	- 4
UIP	+193	+ 78	+127	+ 75	12
DIP	+ 10	+ 92	+ 35	+ 62	+ 90

†Calculated using NRC (1989) values for protein requirements (Table 21), actual intakes of experimental diets (Table 22) and NRC (1989) or calculated values for CP, UIP and DIP (Table 20). Daily Protein Utilization = Daily Protein Requirmeent - (Daily Feed Intake x Protein Content of Diet).

‡Experimentally determined values for effective rumen degradable and undegradable protein.

this may have increased degradability values by increasing the surface area available for microbial action.

The requirements for CP, UIP and DIP at the actual daily gains observed in the experiment were calculated assuming that the linear relationship between daily gains and protein requirement extends beyond the maximum daily gains of 1.0 kg/d listed by NRC (1989). In early (100 kg) growth the large negative values for undegradable protein utilization as determined using both NRC (1989) and experimental values for undegradable feed protein would indicate that protein intake was inadequate for growth at this stage. However, actual observed daily gains do not support this conclusion, so it is possible that NRC (1989) estimates for undegradable intake protein are higher than what is actually required. This is not surprising, in view of the fact that the requirement for undegradable protein at this weight is 93% of the total requirement for crude protein. Another possibility is that the linear relationship between average daily gains and undegradable protein requirement does not extend beyond the NRC maximum daily gain of 1.0 kg and that at higher daily gains more fat is deposited, so protein required would be less than that predicted from the linear relationship. This might be expected to be a factor at the higher weights rather than at the 100 kg weight.

V.

Carcass Trial

Treatment did not affect ($P>0.05$) carcass weight, dressing percent, kidney fat weight or kidney fat weight expressed as a percent of carcass weight (Table 25). As was intended by experimental design, carcass weights differed ($P<0.01$) for the two slaughter groups (Table 26) but not among treatment groups. There was no effect ($P>0.05$) of slaughter group on dressing

Table 25. Effect of diet on the least square means for carcass weight, dressing percentage, kidney fat and kidney fat as a percent of carcass weight

	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat
No. of calves	9	9	9	9	9
Live slaughter weight (kg)	202.86 (1.991)†	201.16 (1.991)	200.82 (1.991)	200.48 (1.991)	200.64 (1.991)
Carcass weight (kg)	107.55 (1.643)	104.00 (1.653)	102.56 (1.653)	104.64 (1.653)	105.48 (1.653)
Dressing %	52.92 (0.562)	51.67 (0.562)	50.98 (0.562)	52.21 (0.562)	52.61 (0.562)
Kidney fat (kg)	0.581 (0.052)	0.502 (0.052)	0.530 (0.052)	0.573 (0.052)	0.580 (0.052)
Kidney fat (% carcass wt)	0.544 (0.048)	0.482 (0.048)	0.519 (0.048)	0.554 (0.048)	0.555 (0.048)

†Numbers in parentheses are the standard error of the least square means.

Table 26. Effect of live slaughter weight on the least square means for carcass weight, dressing percentage, kidney fat and kidney fat as a percent of carcass weight

	Slaughter Weight	
	180 kg	210 kg
No. of calves	10	35
Live slaughter weight (kg)	185.60A (1.571)†	216.79B (0.840)
Carcass weight (kg)	95.89A (1.304)	113.80B (0.697)
Dressing %	51.66 (0.443)	52.50 (0.237)
Kidney fat (kg)	0.541 (0.0411)	0.566 (0.0223)
Kidney fat (% carcass wt)	0.564 (0.0378)	0.498 (0.0206)

A,B Means in the same row with different letters are significantly different ($P<0.01$).

†Numbers in parentheses are the standard error of the least square means.

percent, kidney fat weight or kidney fat weight expressed as a percent of carcass weight (Table 26).

Other authors have found that dressing percentages are similar on corn and barley based diets (Beauchemin 1980; Latrille et al. 1983; Guertin et al. 1987a). No studies were found concerning the effects of wheat on carcass parameters in young calves but work with older animals (Oltjen et al., 1966) would indicate no significant effects on dressing percentage.

Results of trials with younger calves (<136 kg liveweight) have also shown that adding fat to calf starters had no effect on dressing percentage (Gardner and Wallentine 1972; Wrenn et al. 1979; Fisher 1980). In the present trial, adding oil (canola oil or JSCS) to the barley-based diets had no effect on kidney fat weight. This contrasts with results of Gardner and Wallentine (1972) and Fisher (1980) who found that adding fat to calf starters increased kidney fat deposition. However, differences may have existed in the percent of fat in the dry matter of the kidney fat depots (Kerz et al. 1982). Alternatively, these authors showed that differences in percentage fat in the kidney fat between Holsteins fed on a high plane of nutrition and those on a low plane of nutrition were not as great as the differences found in the subcutaneous depots at liveweights similar to the slaughter weights in the present work. Thus it is possible that at these slaughter weights differences in diets or plane of nutrition will not be reflected in the kidney fat depots, as this earlier maturing depot (Callow 1961; Berg and Butterfield 1968) may be already filled to physiological capacity.

Diet had no effect ($P>0.05$) on the chemical composition of the l. dorsi muscle at the 12th rib or on the rib eye area at the 13th rib (Table 27). As would be expected, calves slaughtered at the heavier (210 kg) weight had larger ($P<0.01$) rib eye areas than those slaughtered at the lighter (180 kg)

Table 27. Effect of diet and slaughter group on the least square means for chemical composition of the dry matter of the l. dorsi muscle at the 12th rib and on rib-eye area at the 13th rib

Diet	Slaughter Group	12th rib No. of calves	12th rib % CP	12th rib % fat	12th rib % ash	13th rib No. of calves	13th rib Rib-eye area (cm^2)
Corn	1	2	91.17 (1.103)	7.77 (0.778)	4.73 (0.094)	2	31.90 (3.538)
	2	6	88.71 (0.637)	8.16 (0.449)	4.67 (0.054)	7	46.89 (1.891)
	X†	8	89.94 (0.637)	7.96 (0.449)	4.70 (0.054)	9	39.39 (2.006)
Barley	1	2	89.53 (1.103)	9.57 (0.778)	4.77 (0.094)	2	35.29 (3.538)
	2	7	90.99 (0.590)	6.53 (0.416)	4.74 (0.040)	7	47.09 (1.891)
	X	9	90.26 (0.626)	8.05 (0.441)	4.63 (0.053)	9	41.19 (2.006)
Barley + oil	1	2	91.22 (1.103)	6.78 (0.778)	4.63 (0.094)	2	28.54 (3.538)
	2	7	90.50 (0.590)	7.77 (0.416)	4.64 (0.050)	7	42.94 (1.891)
	X	9	90.86 (0.626)	7.27 (0.441)	4.63 (0.053)	9	35.74 (2.006)
Barley + JSCS	1	2	88.29 (1.103)	7.70 (0.778)	4.54 (0.094)	2	42.65 (3.538)
	2	7	90.32 (0.590)	7.21 (0.416)	4.77 (0.050)	7	44.35 (1.891)
	X	9	89.30 (0.626)	7.46 (0.441)	4.66 (0.053)	9	43.50 (2.006)
Barley + wheat	1	2	90.36 (1.103)	7.65 (0.778)	4.59 (0.094)	2	40.14 (3.538)
	2	7	88.92 (0.590)	8.04 (0.416)	4.77 (0.050)	7	41.97 (1.891)
	X	9	89.64 (0.626)	7.85 (0.441)	4.61 (0.053)	9	41.06 (2.006)
Slaughter group 1	X	10	90.11 (0.493)	7.89 (0.348)	4.65 (0.042)	10	35.70 (1.582)
Slaughter group 2	X	34	89.89 (0.268)	7.54 (0.189)	4.69 (0.023)	35	44.65 (0.846)

†Combined data for slaughter groups 1 and 2.

weight. Slaughter group did not affect (P>0.05) the chemical composition of the l. dorsi muscle at the 13th rib.

Beauchemin (1980) found no difference in rib eye area, physical composition of the 12th rib or chemical composition of the l. dorsi muscle when calves were fed diets based on either whole corn or rolled barley. Guertin et al. (1987a) have also reported that diets based on whole corn, whole barley or rolled barley did not affect the physical composition of the 9th-10th-11th rib section or the chemical composition of the muscle in the 12th rib. Work with beef steers (Oltjen et al. 1966) would also indicate that when compared to corn, wheat results in comparable values for marbling score, rib-eye area and fat over the rib-eye. Similarly, fat additions to calf starters were shown to have no effect on the chemical composition of the rib-section or the semitendenosis muscle (Gardner and Wallentine 1972) or of the carcass (Wrenn et al. 1979; Stiles et al. 1973), although Bouchard et al. (1980) showed an increase in the percent dissectable fat at the 12th rib when 3 or 6% fat was added to calf starters.

There existed a significant (P<0.05) interaction between diet and slaughter group for percent fat in the l. dorsi muscle and for rib-eye area (Appendix Table J). It appears that the rib eye area for calves on diets containing barley plus JSCS or barley + wheat increased less from 180 to 210 kg slaughter weight than did the rib-eye areas of calves on the other diets, due to the higher rib-eye areas of calves fed barley + Jet-Sploded Canola Seed or barley plus wheat in the 180 kg slaughter group. For percentage fat in the l. dorsi muscle the interaction occurred when percent fat in samples from calves fed barley-only diets dropped from 9.57% at 180 kg to 6.33% at 210 kg whereas for the other diets percent fat was similar for both slaughter groups. Such a drop in fat percentage would not be expected when slaughter weight is

increased (Brekke and Wellington 1969; Waldman et al. 1969; Waldman et al. 1971). However only 2 animals per treatment were slaughtered at 180 kg so with this low number it is likely that the results were due to individual variation rather than a true diet x slaughter group interaction.

Diets containing barley and barley + wheat were similar in fatty acid composition (Table 28). Corn-based diets had higher proportions of C18:1 and lower proportions of C18:2 than did diets containing barley or barley + wheat. Adding oil as JSCS to the barley-based diet increased the proportions of C18:0, C18:1 and C18:3 and decreased the proportions of C16:0 and C18:2. Differences between diets containing canola oil and those containing JSCS were likely due to the hydrogenation of canola oil in the refining process (Vaisey-Genser and Eskin, 1982).

Values for the proportions of C18:2 and C20:4 in the extracted fat of the l. dorsi muscle reported in the present study (Table 29) are lower than values of 25.7 and 7.3% reported by Seewald et al. (1987) for the same muscle in grain fed calves slaughtered at 123 kg liveweight. These authors reported lower values for the proportions of C16:1 and C18:1 (11 and 23.3%) than were found in the present work. These differences are most likely due to the effects of age and fattening on the fatty acid composition in the carcass (Waldman et al. 1968), as calves in this study were older than those in the study of Seewald and Eichinger.

There were no differences ($P>0.05$) in the fatty acid proportions in the fat extracted from the l. dorsi muscles of calves fed corn, barley or barley + wheat. Adding canola oil to the barley based diet decreased the proportion of C16:0 in the l. dorsi fat below that obtained with a diet of barley + wheat and tended to reduce the proportion of C16:0 below that obtained on a barley diet. The addition of JSCS reduced the proportion of this fatty acid below

Table 28. Fatty acid proportions† in the experimental diets

Fatty acid‡	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley wheat
C10:0	ND §	ND	ND	ND	ND
C12:0	ND	0.106	0.000	0.055	0.048
C14:0	0.226	0.635	0.778	0.296	0.339
C16:0	25.424	24.904	28.871	12.168	22.889
C16:1	0.137	0.510	0.175	0.760	0.126
C18:0	3.176	1.640	4.319	2.171	1.973
C18:1	29.768	19.900	42.324	48.856	17.741
C18:2	35.674	44.835	16.695	25.811	49.435
C18:3	1.590	4.779	1.432	6.388	4.356
C20:0	0.847	0.417	1.246	0.733	0.620
C20:1	1.344	0.741	1.612	1.340	1.107
C20:4	0.368	0.711	0.711	0.527	0.370
C22:1	1.275	0.191	0.568	0.126	0.159
C24:0	0.804	0.257	0.696	0.292	0.708
Unidentified					

†Expressed as a percentage by weight of total fatty acids.

‡First number denotes the number of carbon atoms, the number after the colon denotes the number of double bonds.

§Not detected.

Table 29. Effect of diet on the least square means for fatty acid proportions† in the l. dorsi muscle at the 12th rib

Fatty acid‡	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley wheat
No. of calves	8	9	9	9	9
C10:0	0.019 (0.034)§	0.061 (0.033)	0.013 (0.033)	0.020 (0.033)	0.035 (0.033)
C12:0	0.070 (0.017)	0.085 (0.016)	0.075 (0.016)	0.073 (0.016)	0.088 (0.016)
C14:0	2.09 (0.203)	2.23 (0.200)	2.22 (0.200)	2.19 (0.200)	2.42 (0.200)
C16:0	22.83abc (0.577)	24.64bc (0.567)	22.35ab (0.567)	21.83a (0.567)	24.80c (0.567)
C16:1	3.36ab (0.334)	4.38ab (0.328)	3.59ab (0.328)	3.12a (0.328)	4.39b (0.328)
C18:0	13.15 (0.678)	13.07 (0.665)	14.32 (0.665)	15.03 (0.665)	12.98 (0.665)
C18:1	39.11 (0.847)	37.89 (0.832)	39.34 (0.832)	39.21 (0.832)	38.09 (0.832)
C18:2	13.29 (0.818)	10.13 (0.803)	11.13 (0.803)	11.59 (0.803)	11.07 (0.803)
C18:3	0.339a (0.068)	0.482ab (0.067)	0.631bc (0.067)	0.810c (0.067	0.467ab (0.067)
C20:0	0.528 (0.101)	0.552 (0.099)	0.460 (0.099)	0.676 (0.099)	0.513 (0.099)
C20:1	1.11 (0.197)	1.47 (0.194)	1.40 (0.194)	1.10 (0.194)	1.03 (0.194)
C20:4	2.41 (0.293)	2.28 (0.288)	2.15 (0.288)	2.30 (0.288)	2.07 (0.288)
C22:1	0.439 (0.122)	0.715 (0.119)	0.750 (0.119)	0.483 (0.119)	0.556 (0.119)
C24:0	0.019 (0.015)	0.055 (0.015)	0.034 (0.015)	0.050 (0.015)	0.022 (0.015)
Unidentified	1.23 (0.284)	1.92 (0.279)	1.60 (0.279)	1.49 (0.279)	1.54 (0.279)

a,b,c Means in the same row different letters are significantly different ($P<0.05$).

†Expressed as a percentage by weight of total fatty acids.

‡First number denotes the number of carbon atoms, the number after the colon denotes the number of double bonds.

§ Numbers in parentheses are the standard errors of the least square means.

that obtained on diets of barley or barley + wheat, but not below that obtained on diets of corn or barley + canola oil. The addition of canola oil to the barley diet did not change ($P>0.05$) the proportion of C16:1 in the intramuscular fat as compared to diets containing corn, barley or barley + wheat but JSCS resulted in a reduction ($P<0.05$) in the proportion of this fatty acid when compared to a diet containing barley + wheat and tended to reduce the percentage when compared to a diet containing only barley. The C18:3 content of the extracted fat in the l. dorsi muscle of calves fed JSCS was similar ($P>0.05$) to that of calves fed canola oil and higher ($P<0.05$) than that of calves fed corn, barley or barley + wheat. The content of C18:3 was higher in calves fed canola oil than in those fed corn. Other changes in fatty acid proportions did not reach significance.

Dryden and Marchello (1973) found increased proportions of C18:1 and C18:2 in the subcutaneous and internal fat depots when 6% safflower oil was added to beef rations and Dinius et al. (1974) reported that when safflower oil was added to beef rations the content of C14, C14:1, C16 and C16:1 in the adipose tissue tended to decrease as that of C18:1 increased. Extruded soybeans have been shown to increase the proportions of C18:2 and C18:3 in the adipose tissue (Rule and Beitz 1986). However, neither Dryden and Marchello (1973) nor Rule and Beitz (1986) found that the fatty acid proportions in muscle lipids changed when safflower oil or extruded soybeans respectively were added to beef rations. In the present work, neither added canola oil nor JSCS affected the proportion of C18:1 in the l. dorsi muscle, despite higher levels of C18:1 in these diets. Similarly, although adding JSCS increased the amount of C18:2 in the diet there was no increase in the amount of C18:2 in the l. dorsi muscle. Thus, it appears from the present work and the reports of Dryden and Marchello (1973) and Rule and Beitz (1986) that the proportions

of C18:1 and C18:2 in this muscle do not respond to dietary changes in the proportions of the fatty acids present in the diet.

Animals slaughtered at 180 kg had higher ($P<0.05$) proportions of C20:0 and C24:0 in the fat of the l. dorsi muscle than did animals slaughtered at 210 kg (Table 30). No studies comparing directly the effects of age and/or carcass weight on these fatty acids were found elsewhere in the literature, but Ostrander and Dugan (1962) have reported higher levels in veal intramuscular fat than in beef intramuscular fat, so there is possibly an effect of age on these fatty acids.

Meat colour readings from the present trials (Table 31) are within the range of 36-52% reported elsewhere for grain fed calves (Beauchemin 1980; Bouchard et al. 1980; Wood and Frohlich 1981). Diet had no effect ($P>0.05$) on the colour of the meat at the brisket or at the 13th rib. This is in agreement with the results of Beauchemin (1980) and Guertin et al. (1987a) who found no difference in meat colour when corn or barley-based diets were fed. In contrast to the results of Bouchard et al. (1980), who found that 3 or 6% added fat resulted in a darker meat, neither canola oil nor Jet-Sploded canola seed additions in the present work had any effect on meat colour.

Although supplementary iron was not added to the diets in this trial, dietary iron concentrations (Table 4) were in excess of the NRC (1979) requirements. From work with milk fed calves (Bray et al. 1959; MacDougall et al. 1973) it would appear that these levels would be adequate for synthesis of both hemoglobin and myoglobin. Blood hemoglobin and hematocrit levels (Table 31) are in the normal range for hemoglobin (8-15 mg/100 ml) and hematocrit (35-37%) as reported by Benjamin (1978) and agree with hemoglobin values of 10-12 mg/100 ml and hematocrit values of 34-36% reported elsewhere for grain fed calves (Neidermeier et al. 1959; Kunz et al. 1969; Beauchemin 1980; Fisher

Table 30. Effect of slaughter group on the least square means for fatty acid proportions† in the l. dorsi muscle at the 12th rib

Fatty acid‡	Slaughter Group 180 kg	210 kg
No. of calves	10	34
C10:0	0.0235 (0.0264) §	0.0355 (0.0143)
C12:0	0.0834 (0.0130)	0.0734 (0.0071)
C14:0	2.164 (0.157)	2.309 (0.086)
C16:0	23.410 (0.447)	23.165 (0.243)
C16:1	3.953 (0.258)	3.578 (0.140)
C18:0	13.322 (0.525)	14.097 (0.285)
C18:1	38.013 (0.656)	39.428 (0.357)
C18:2	11.820 (0.634)	11.070 (0.344)
C18:3	0.594 (0.053)	0.498 (0.029)
C20:0	0.661a (0.078)	0.431b (0.043)
C20:1	1.299 (0.153)	1.147 (0.083)
C20:4	2.140 (0.227)	2.344 (0.123)
C22:1	0.649 (0.094)	0.528 (0.051)
C24:0	0.051a (0.012)	0.021b (0.006)
Unidentified	1.776 (0.220)	1.335 (0.120)

a,b Means followed by different letters are significantly different ($P<0.05$).

†Expressed as a percentage by weight of total fatty acids.

‡First number denotes the number of carbon atoms, the number after the colon denotes the number of double bonds.

§ Numbers in parentheses are the standard errors of the least square means.

Table 31. Effect of diet on the least square means for meat colour of the brisket and 13th rib, pH at the 13th rib and on blood hematocrit and hemoglobin 3-4 d prior to slaughter

	Diet				
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat
Meat colour at brisket†	47.75 ± 4.58‡ (9)§	45.67 ± 4.67 (8)	44.58 ± 4.58 (9)	44.75 ± 4.67 (8)	44.61 ± 4.58 (9)
Meat colour at 13th rib†	46.42 ± 3.40 (8)	42.17 ± 3.40 (8)	39.11 ± 3.33 (9)	44.75 ± 3.40 (8)	40.39 ± 3.33 (9)
pH at 13th rib	5.71 ± 0.118 (8)	5.67 ± 0.116 (9)	5.68 ± 0.116 (9)	5.68 ± 0.116 (9)	5.66 ± 0.116 (9)
Hematocrit (%)	30.33 ± 0.843 (9)	29.25 ± 0.843 (9)	30.48 ± 0.843 (9)	32.27 ± 0.843 (9)	30.55 ± 0.843 (9)
Hemoglobin (mg/100 ml)	11.14 ± 0.402 (9)	10.81 ± 0.902 (9)	11.69 ± 0.402 (9)	11.55 ± 0.402 (9)	11.59 ± 0.40 (9)

†Meat colour expressed as % reflectance; the higher the number, the less reflectance and hence the lighter the meat.

‡Least square means ± standard error of the least square means.

§ Numbers in parenthesis are the number of calves per treatment for each measurement.

1980).

Calves slaughtered at 180 kg liveweight had lighter-coloured meat at the 12th rib ($P<0.05$), lower hemoglobin values ($P<0.01$) and lower hematocrit values ($P<0.01$) than did calves slaughtered at 210 kg liveweight (Table 32). Beauchemin (1980) reported that grain-fed calves slaughtered at 166 kg had lighter coloured meat and lower hemoglobin values than did calves slaughtered at 204 kg. However, Beauchemin (1980) reported no difference in hematocrit values when slaughter weight was increased. The darker coloured meat at the heavier slaughter weight would be due to increased pigment concentration in the meat of heavier calves (Zupka et al. 1972; Sheper 1978).

Of the 45 carcasses graded at the slaughter house, only 11 received A grades (Table 33). This number did not differ among diets, with 2-3 carcasses per diet grading A. It was thought originally that increasing the slaughter weight from 180 to 210 kg would improve grades but this was not the case. Of the 34 carcasses that were given B or C grades, 32 were downgraded because of inadequate muscling and/or inadequate kidney or external fat. Only 2 were downgraded solely because of inadequate kidney or external fat. Thus it appears that at these slaughter weights carcasses are not of the proper conformation for Grade A veal.

VI. SENSORY EVALUATION

Hunter Lab value for the degree of lightness (L), degree of redness (a) and degree of yellow (b) in the cooked meat samples did not differ among the five grain treatments ($P>0.05$; Table 34). Meat samples from the milk fed calves had higher ($P<0.05$) L-values than did meat samples from the grain fed calves, indicating a lighter colour for the milk-fed veal. Although it is generally accepted that raw meat from milk-fed veal is lighter in colour than

Table 32. Effect of liveweight at slaughter on the least square means for meat colour of the brisket and 13th rib, pH at the 13th rib and on blood hematocrit and hemoglobin 3-4 d prior to slaughter

	Slaughter Weight	
	180 kg	210 kg
Meat colour at brisket†	48.30 ± 3.614‡ (10) §	42.61 ± 1.995 (33)
Meat colour at 13th rib†	46.30 ± 2.631a (10)	38.83 ± 1.475b (32)
pH at 13th rib	5.70 ± 0.091 (10)	5.66 ± 0.050 (34)
Hematocrit (%)	29.14 ± 0.665A (10)	32.01 ± 0.355B (35)
Hemoglobin (mg/100 ml)	10.73 ± 0.317A (10)	11.99 ± 0.170B (35)

A,B,a,b Means in the same row with different letters are significantly different (A,B $P<0.01$; a,b $P<0.05$).

†Meat colour expressed as % reflectance; the higher the numbers, the less reflectance and hence the lighter the meat.

‡Least square means ± standard error of the least square means.

§ Numbers in parentheses are the number of animals per slaughter group for each measurement.

Table 33. Effect of diet and slaughter weight on carcass grades†

Calf No.	Diet	SIGR (kg)	Grade	Comments‡
287	Corn	180	B2	K
6683	Corn	180	B1	MFK
6583	Corn	210	A2	-
7283	Corn	210	A1	-
1287	Corn	210	B1	M
6481	Corn	210	B2	M
2587	Corn	210	B2	MF
3087	Corn	210	A3	-
4287	Corn	210	B3	M
6383	Barley	180	B1	MFK
6786	Barley	180	B2	MF
7583	Barley	210	B2	M
9983	Barley	210	A2	-
6883	Barley	210	B2	M
6981	Barley	210	B2	MF
7081	Barley	210	B2	M
3387	Barley	210	B§	MF
4687	Barley	210	B2	M
6986	Barley + Oil	180	B3	M
6783	Barley + Oil	180	B1	MFK
6483	Barley + Oil	210	B3	M
7483	Barley + Oil	210	B1	M
6281	Barley + Oil	210	A1	-
2687	Barley + Oil	210	A3	-
2887	Barley + Oil	210	B3	MF
3487	Barley + Oil	210	B2	M
7381	Barley + Oil	210	B3	M

Table 33. (con't.)

Calf No.	Diet	SIGR (kg)	Grade	Comments‡
987	Barley + JSCS	180	A1	-
7383	Barley + JSCS	180	B2	M
7083	Barley + JSCS	210	B1	M
1487	Barley + JSCS	210	C1	MF
6381	Barley + JSCS	210	B2	M
6781	Barley + JSCS	210	B4	M
7181	Barley + JSCS	210	B2	MF
3687	Barley + JSCS	210	B1	M
4087	Barley + JSCS	210	A §	-
487	Barley + Wheat	180	B3	M
7186	Barley + Wheat	180	B1	M
1187	Barley + Wheat	210	B4	F
6983	Barley + Wheat	210	A1	-
6681	Barley + Wheat	210	A2	-
2287	Barley + Wheat	210	A1	-
2787	Barley + Wheat	210	B2	M
4187	Barley + Wheat	210	B4	M
4487	Barley + Wheat	210	B2	M

†Graded hide-off 24 hours post-slaughter according to Agriculture Canada Specifications.

‡Refers to the reasons given by graders for downgrading to a B or C grade. M = inadequate muscling or conformation; F = inadequate external fat cover for quality; K = inadequate kidney fat cover.

§Values for colour readings were missing so no colour classification (1-4) was given.

raw meat from grain-fed calves (Bray et al. 1959; Beauchemin 1980; Bouchard et al. 1980; Smulders and de Visser 1988), Wood and Froehlich (1981) have reported that cooked meat samples from grain fed calves were not darker than cooked meat samples from milk-fed calves. Small, negative "a" values indicate that the cooked meat samples had a slight grey tinge, and this was more prominent ($P<0.01$) in the samples of milk-fed veal (Table 34). Again this contrasts with the results of Wood and Froehlich (1981) who reported that differences between milk-fed and grain-fed veal samples for the degree of redness disappeared when the meat was cooked. The "b" values did not differ ($P>0.05$) between samples from milk-fed and grain-fed calves and this has been reported elsewhere for cooked meat samples (Wood and Froehlich 1981).

Appendix N shows the analysis of variance for the ratings of the sensory panel. Expressing the sum of squares for each component as a percentage of the total sum of squares indicates that a considerable portion of the variation in juiciness, flavour intensity and flavour pleasantness ratings was due to the evaluators or to interactions between evaluators and treatments (Figures 2-5). When the variation in tenderness ratings was expressed in this manner the evaluators became relatively less important as a source of variation while treatment and treatment x panel interactions accounted for more of the variation in ratings.

Other studies have also shown that a considerable portion of the variation in taste panel ratings is due to variation among judges. Hanning et al. (1957) reported that sensory tenderness ratings were quite variable among judges. Brisson et al. (1979) found that variations in judges ratings for flavour, texture and order of preference were more a function of variation among judges than variation among samples. Variation in tenderness ratings among judges was also quite high (Brisson et al. 1979) but differences among

Table 34. Effect of diet on the least square means of the Hunter-Lab readings for colour intensity (L), degree of redness (a), and degree of yellowness (b) taken on cooked meat samples

Hunter-Lab Readings	Diet					
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat	Milk
L	57.24 ± 1.44a† (4)‡	56.80 ± 1.13a (6)	57.93 ± 1.27a (5)	56.99 ± 1.13a (6)	58.93 ± 1.45a (5)	65.44 ± 1.27b (6)
a	-2.08 ± 0.389A (4)	-1.53 ± 0.306A (6)	-2.09 ± 0.344A (5)	-1.97 ± 0.306A (6)	-1.90 ± 0.391A (5)	-4.56 ± 0.344B (6)
b	10.01 ± 0.47 (3)	10.31 ± 0.314 (6)	10.53 ± 0.354 (5)	10.77 ± 0.314 (6)	10.86 ± 0.402 (5)	10.02 ± 0.354 (6)

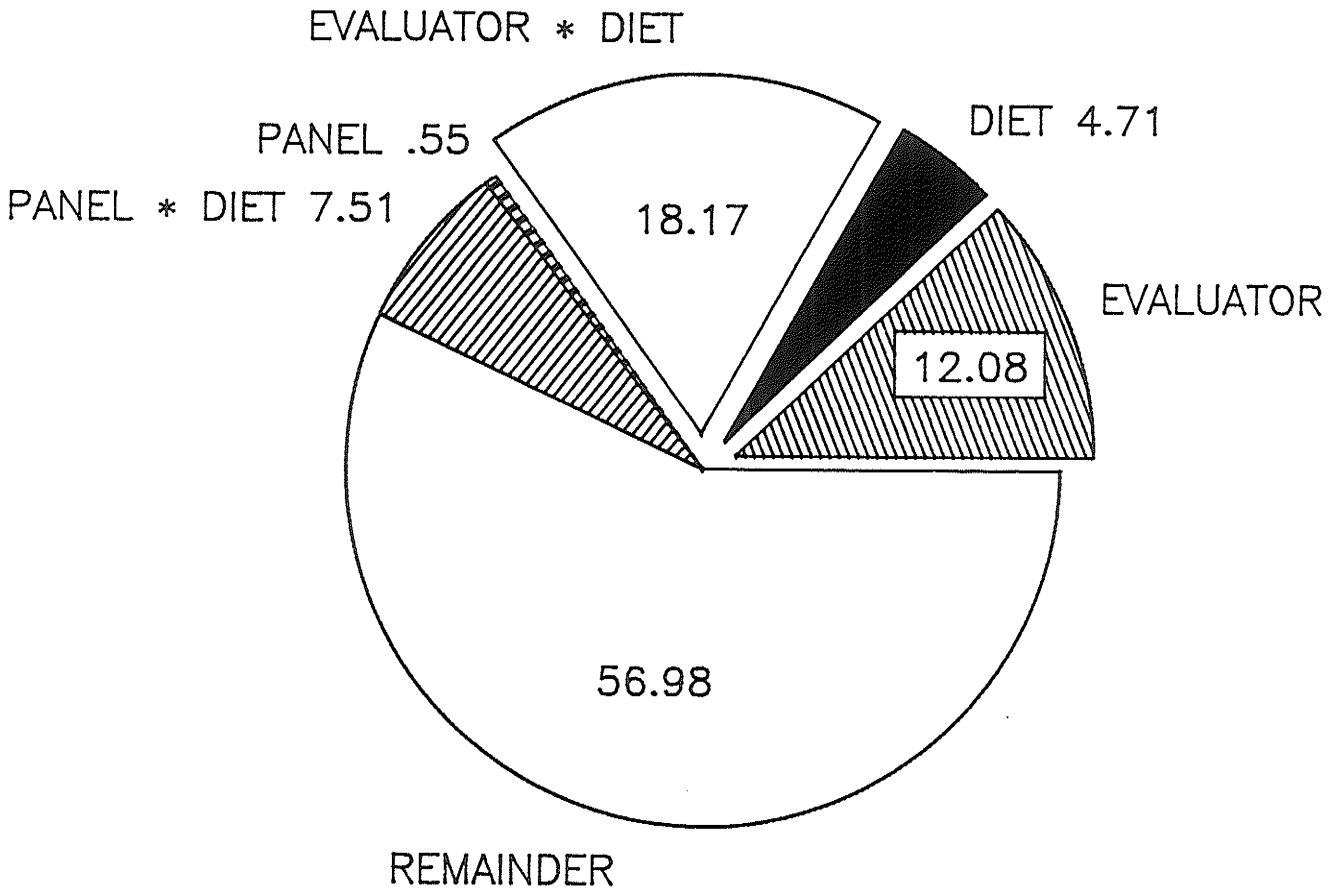
a,b Means in the same row with different letters are significantly different ($P<0.05$).

A,B Means in the same row with different letters are significantly different ($P<0.01$).

†Least square means ± standard error of the least square means.

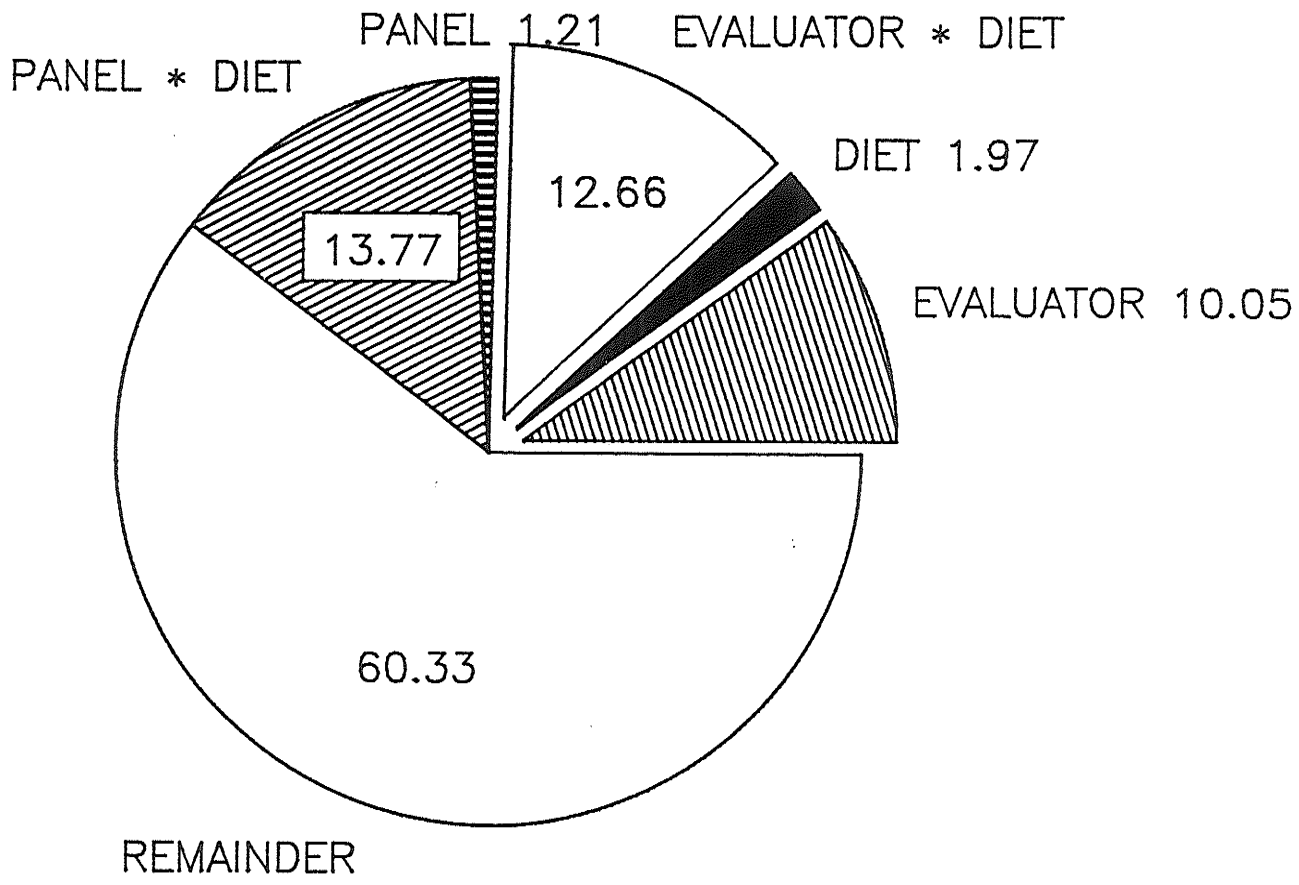
‡Numbers in parentheses are the number of observations in each cell.

FIGURE 2. COMPONENTS OF VARIANCE FOR TASTE PANEL RATINGS FOR FLAVOUR INTENSITY OF THE COOKED MEAT SAMPLES



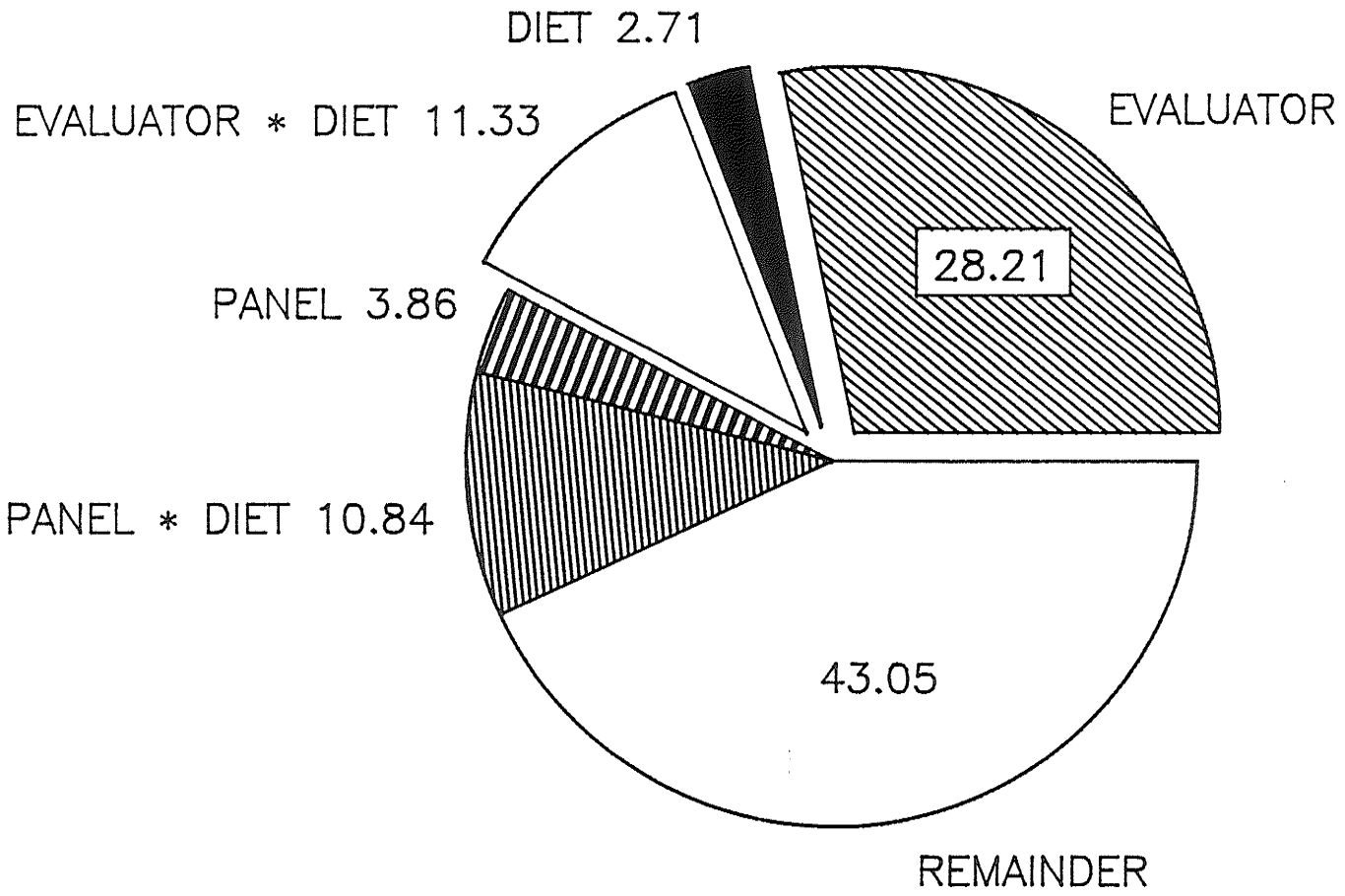
† The sum of squares for each component is expressed as a percentage of total sum of squares.

FIGURE 3. COMPONENTS OF VARIANCE FOR TASTE PANEL RATINGS FLAVOUR PLEASANTNESS OF THE COOKED MEAT SAMPLES †



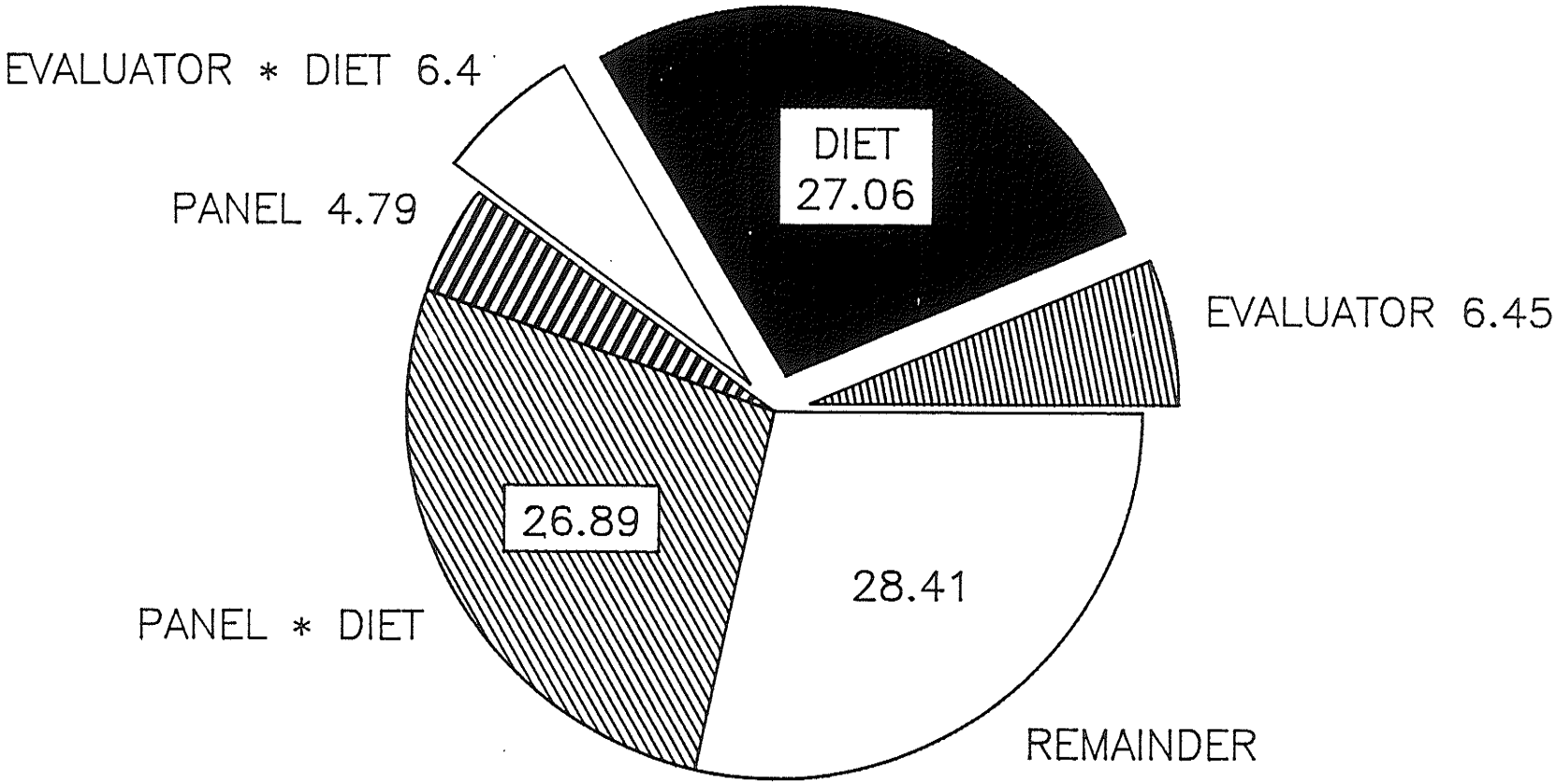
†The sum of squares for each component is expressed as a percentage of total sum of squares.

FIGURE 4. COMPONENTS OF VARIANCE FOR TASTE PANEL RATINGS FOR JUICINESS OF THE COOKED MEAT SAMPLES †



†The sum of squares for each component is expressed as a percentage of total sum of squares.

FIGURE 5. COMPONENTS OF VARIANCE FOR TASTE PANEL RATINGS FOR TENDERNESS OF THE COOKED MEAT SAMPLES†



†The sum of squares for each component is expressed as a percentage of total sum of squares.

treatments were large enough to reach significance in both studies (Hanning et al. 1957; Brisson et al. 1979).

In the present study judges were unable to detect differences among treatments for any trait except tenderness (Table 35). Milk fed veal was judged to be more tender ($P<0.05$) than veal from any of the grain fed calves except those fed barley + wheat. Among the grain fed calves, those fed wheat were judged to have the most tender meat ($P<0.05$). Meat from calves fed barley + JSCS was judged to be less tender ($P<0.05$) than meat from calves fed corn.

Hanning et al. (1957), Wood and Froehlich (1981) and Brisson et al. (1979) have also reported that only judges' ratings for tenderness reached statistical significance when meat from grain fed calves was compared to that from milk fed calves. Brisson et al. (1979) and Wood and Froehlich (1981) reported that milk fed veal was judged to be more tender than grain-fed veal but Hanning et al. (1957) reported that at 6 weeks of age meat from calves fed milk supplemented with copper and iron was judged to be more tender than was meat from calves fed unsupplemented milk, or limited milk or milk replacer plus hay and concentrate.

Volatile, drip or total losses from the meat during cooking did not differ ($P>0.05$) among diets (Table 36). This is in agreement with results of Hanning et al. (1957) and Brisson et al. (1979). The higher cooking losses for milk fed veal reported by Wood and Froehlich (1981) were not evident in this study. No differences among diets were observed for the percent press fluid ($P>0.05$). This is in agreement with the results of Hanning et al. (1957) and lends support to the results obtained from the taste panel evaluation of juiciness.

The Instron measurement of the force (in Newtons) required to rupture the

Table 35. Effect of diet on the least square means for panel evaluations for juiciness (JR), tenderness (TR), flavour intensity (FIR) and flavour pleasantness (FPR)

	Diet					
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat	Milk
No. of Observations	38	46	46	46	38	46
JR†	5.22 (0.375)‡	5.02 (0.364)	5.54 (0.364)	5.15 (0.364)	5.75 (0.375)	5.52 (0.364)
TR†	5.15b (0.299)	4.42ab (0.281)	4.73ab (0.281)	4.11a (0.299)	6.52c (0.299)	7.00c (0.281)
FIR†	5.93 (0.331)	5.72 (0.313)	5.52 (0.313)	4.98 (0.313)	5.08 (0.331)	5.42 (0.313)
FPR†	5.51 (0.271)	5.71 (0.252)	6.04 (0.252)	5.44 (0.252)	5.74 (0.271)	5.78 (0.252)

a,b Means in the same row with different letters are significantly different ($P<0.05$).

†Lower numbers denote a less favourable score.

‡Numbers in parentheses are the standard errors of the least square means.

Table 36. Effect of diet on the least square means for instrumental measurements of meat quality made on cooked meat samples

Parameter	Diet					
	Corn	Barley	Barley + oil	Barley + JSCS	Barley + wheat	Milk
No. of calves	5	6	6	6	5	6
Instron Force (N)	81.65ab (13.75)†	104.87ab (12.30)	126.16a (12.30)	103.62ab (12.30)	77.81ab (13.75)	73.51b (12.30)
% Press Fluid	40.51 (1.79)	40.39 (1.60)	42.67 (1.60)	38.84 (1.60)	42.21 (1.79)	42.30 (1.60)
% Drip loss‡	1.88 (0.30)	2.06 (0.27)	2.05 (0.27)	1.86 (0.27)	1.92 (0.30)	2.25 (0.27)
% Volatile loss‡	11.99 (1.01)	12.09 (0.90)	11.43 (0.90)	12.19 (0.90)	12.17 (1.01)	13.58 (0.90)
% Total loss‡	13.87 (1.06)	14.15 (0.95)	13.39 (0.95)	14.05 (0.95)	14.09 (1.06)	15.83 (0.95)

a,b Means in the same row with different letters are significantly different ($P<0.10$).

†Numbers in parentheses are the standard errors of the least square means.

‡Loss during cooking.

meat was higher for the calves fed barley + oil than for those fed milk ($P<0.05$; Table 36). No other differences reached significance ($P>0.05$), although numerically the trends were similar to those reported for the judges evaluation of tenderness (Table 36). Brisson et al. (1979) and Wood and Froehlich (1981) have also reported that instrumental measures of tenderness lend support to the taste panelists' conclusions regarding tenderness and that milk fed veal was more tender than grain fed veal. However, results from other studies (Hanning et al. 1957; Smulders and Visser 1987; Warner et al. 1988) do not support the conclusions that milk fed veal is more tender than grain fed veal.

Results are contradictory as to whether added fat affects the quality of veal meat. Johnson et al. (1988) reported that calves fed skim milk had less tender meat than did calves fed fat-supplemented skim milk but could demonstrate no effect of different fat levels on tenderness beyond the lowest level of fat inclusion. Furthermore, there was a 40-50 kg difference in liveweight between calves fed fat supplemented and unsupplemented diets. Seoane et al. (1978) reported that 18% low erucic acid rapeseed oil in milk replacers decreased the panelists' rating for tenderness when the meat from these calves was compared to meat from calves fed tallow supplemented milk, although the Warner Bratzler Shear values did not support this conclusion. Stiles et al. (1974) reported that 4% tallow in grain based diets resulted in a less tender meat as judged by a taste panel. The calves fed barley + canola oil in this study had higher Instron force values but values were not different ($P>0.05$) from those of the calves fed corn, barley, barley + JSCS or barley + wheat.

SUMMARY

I. GROWTH TRIAL

- Average daily gains from 6 weeks on test to slaughter did not differ ($P>0.05$) for calves fed corn, barley, barley + oil or barley + JSCS. Average daily gains were lower ($P<0.05$) for calves fed barley + wheat than for those fed barley + oil and tended to be lower ($P<0.10$) than for those fed barley + JSCS.
- The number of days required for calves to reach slaughter weight was similar ($P>0.05$) for calves fed corn, barley, barley + oil and barley + JSCS but calves fed barley + wheat required approximately 24 days longer to reach slaughter weight than did those fed barley + oil or barley + JSCS ($P<0.05$).
- Daily feed intake differed among the grain diets ($P<0.05$) but the means separation test was unable to distinguish which means were different. It appears that feed intake was lower on diets containing corn and barley + wheat than on diets containing barley, barley + oil or barley + JSCS.
- Feed efficiency ratios tended to differ among diets ($P<0.10$) but the means separation test could not pick up the trends. It would appear, however, that calves fed corn, barley + oil and barley + JSCS had more efficient gains than did those fed barley or barley + wheat.

II. DIGESTIBILITY TRIAL

- The apparent digestibility coefficients for dry matter, gross energy and crude protein did not differ ($P>0.05$) among the grain diets.
- The apparent digestibility of acid detergent fibre was similar ($P>0.05$) for diets containing corn, barley and barley + oil. The addition of JSCS to barley diets increased ($P<0.05$) the digestibility of acid detergent

fiber above that of diets containing barley only and the addition of wheat to the barley diet resulted in a higher ($P<0.05$) apparent digestibility of acid detergent fiber than was obtained for either the corn or barley-only diets ($P<0.05$).

- Rumen pH, rumen ammonia nitrogen levels, rumen volatile fatty acid proportions, total rumen volatile fatty acid levels and blood urea nitrogen levels at 1 and 3 hr post feeding were not affected by diet ($P<0.05$).

III. RUMEN DEGRADABILITY TRIAL

- Dry matter and crude protein disappearance in the rumen was more rapid for diets containing barley, barley + oil, barley + JSCS and barley + wheat than for diets containing corn.
- The effective degradability of dry matter was lower ($P<0.05$) for diets containing corn than for those containing barley, barley + oil, barley + JSCS and barley + wheat. The effective degradability of dry matter was lower ($P<0.05$) for the diet containing barley + oil than for diets containing barley or barley + wheat.
- The effective degradability of crude protein differed ($P<0.01$) among grain diets but the means separation test could not distinguish where these differences were. Numerically the patterns appeared to be similar to those for the effective degradability of dry matter.

IV. CARCASS TRIAL

- Carcass weight, dressing %, kidney fat weight, rib eye area at the 13th rib, and the chemical composition of the l. dorsi muscle at the 12th rib did not differ among diets ($P>0.05$).

- Adding canola oil or JSCS to the barley diets increased the proportion of C18:3 in the extracted fat of the l. dorsi muscle at the 12th rib. Calves fed diets containing JSCS had higher ($P<0.05$) levels of this fatty acid than did those fed corn, barley or barley and wheat and calves fed canola oil had higher levels of C18:3 ($P<0.05$) than did those fed corn but not higher ($P>0.05$) than those fed barley or barley + wheat.
- Adding canola oil to the barley diet decreased ($P<0.05$) the proportion of C16:0 in the l. dorsi fat below that obtained with a diet of barley + wheat and tended to reduce ($P<0.10$) the proportion of C16:0 below that obtained on a barley-only diet. The addition of JSCS reduced the proportion of the fatty acid below that obtained on diets of barley and barley + wheat but not below that obtained on diets of corn or barley + canola oil.
- The addition of JSCS to the barley diet reduced the proportion of C16:1 ($P<0.05$) in the extracted fat in comparison to a diet containing barley + wheat and tended to reduce the proportion of the fatty acid in comparison to a diet containing barley only ($P<0.10$).
- Meat colour at the brisket, meat colour at the 13th rib, pH at the 13th rib, and hematocrit and hemoglobin levels 3 d prior to slaughter were not affected by the various grain diets ($P>0.05$).

V. SENSORY EVALUATION

- The Hunter-Lab readings for colour intensity and degree of redness of the cooked meat were not different among the 5 grain diets but cooked samples of milk fed veal were lighter in colour ($P<0.05$) and more grey ($P<0.05$) than were any of the samples from the grain fed calves. The degree of yellowness of the cooked meat samples did not differ ($P>0.05$) among

diets.

- The variation in panel ratings for juiciness, flavour intensity and flavour pleasantness was more a function of evaluator and interactions between evaluator and diet than of diet alone. In the evaluation of tenderness however, evaluator and evaluator x diet interactions became less important and differences among diets reached significance ($P<0.05$).
- Milk fed veal was judged to be more tender ($P<0.05$) than veal from any of the grain fed calves except those fed barley + wheat. Meat from calves fed barley + wheat was judged to be more tender ($P<0.05$) than that from the other diets. Meat from calves fed barley + JSCS was judged to be less tender ($P<0.05$) than that from calves fed corn, with no differences between the meat of calves fed corn, barley or barley + canola oil.
- The Instron measurement of the peak force required to rupture the meat was higher ($P<0.05$) for those calves fed barley + canola oil than for those fed milk, but other differences did not reach significance ($P>0.05$).
- Other measurements of meat quality (press fluid %, volatile, drip and total cooking losses) did not differ ($P>0.05$) among diets.

GENERAL SUMMARY AND CONCLUSIONS

These results indicate that feeding diets containing rolled barley or rolled corn results in similar ADG for calves up to 210 kg liveweight, but feed efficiency is somewhat reduced on rolled barley diets because of the slightly lower DE content. However, replacing 50% of the barley with wheat would not be recommended as calves consuming diets containing wheat appeared to have reduced intakes and daily gains. Despite the greater DE content of the wheat diet, feed efficiency was similar on the barley and the barley + wheat diets. Furthermore, it appears that the barley + wheat diet affected performance mainly in the latter part of the growth trial, so the problem with feed intake might be intensified if the growth period were extended to 230 kg as is recommended in Quebec and Ontario. Adding either canola oil or JSCS to the barley diet appeared to improve feed conversion efficiency to that on a corn diet.

With the exception of minor changes in the proportions of C18:3, C16:0 and C16:1 in the lean at the 12th rib, carcass parameters were unaffected by diet. Only 2 to 3 carcasses from each dietary treatment received A grades and the reason most often given for downgrading to a B or a C grade was insufficient muscling. In general, meat from calves fed milk or barley + wheat was more tender than that from calves fed corn, barley, barley + oil or barley + JSCS. The data suggest that added oil, in the form of free canola oil or JSCS, may decrease tenderness of the meat. Cooked meat from milk-fed calves was lighter and more grey in colour than meat from grain fed calves.

LITERATURE CITED

Abdelgadir, I.E.O., J.L. Morrill, J.A. Stutts, M.B. Morrill, D.E. Johnson and K.C. Behnke. 1984. Effect of processing temperature on utilization of whole soybeans by calves. J. Dairy Sci. 67:2554-2559.

Ackerson, B.A., R.R. Johnson and R.L. Hendrickson. 1976. Effects of treatment of whole fat soybeans or soybean flour with formaldehyde to protect the polyunsaturated fatty acids from biohydrogenation in the rumen. J. Nutr. 106:1383-1390.

American Meat Science Association. 1978. Guidelines for cookery and sensory evaluation of meat. AMSA, Chicago, IL.

Anderson, H.R. 1975. The influence of slaughter weight and level of feeding on growth rate, feed conversion and carcass composition of bulls. Livestock Prod. Sci. 2:341-355.

Anderson, J.J., M. Khozloo and J.L. Walters. 1982. Effects of feeding whole cottonseed on intake, body weight, and reticulorumen development of young Holstein calves. J. Dairy Sci. 65:764-772.

Apple Computer Inc. 1985. Apple II Owner's Manual. Cupertine, CA. Apple Computer Inc. 192 p.

Asplund, J.M. 1961. Feeding dairy calves. 40th Annual University of Alberta Feeders' Day Report. p 17.

Association of Official Analytical Chemists. 1984. Official Methods of Analysis. (14th Ed.). A.O.A.C. Washington, DC.

Batra, T.R., W.R. Usborne, D.G. Grieve and E.B. Burnside. 1973. Genotype - environment interaction in calf production. II. Live measurements and carcass traits. J. Anim. Sci. 36:471-475.

Beauchemin, K. 1980. Alimentation et regie du veau lourd d'abattage nourri d'aliments d'allaitement on des grains. M.Sc. Thesis. University Laval, Quebec.

Benjamin, M.M. 1978. Outline of Veterinary Clinical Pathology. 3rd Edition. The Iowa State University Press, Ames, Iowa.

Berg, R.T. and R.M. Butterfield. 1968. Growth patterns of bovine muscle, fat and bone. J. Anim. Sci. 27:611-619.

Berg, R.T. and R.M. Butterfield. 1976. New Concepts of Cattle Growth. Macarther Press (Books) Pty. Ltd., Parramatta, Australia.

Blaxter, K.L., G.A.M. Sharman and A.M. MacDonald. 1957. Iron deficiency anaemia in calves. Br. J. Nutr. 11:234-246.

Bouchard, R., L.F. La Flamme, B. Lachance and G.L. Roy. 1980. Levels of protein and fat and type of protein in vealer rations. Can. J.

Anim. Sci. 60:523-530.

Bowman, A.L., R.G. Warner, J.K. Loosliand and G.H. Wellington. 1965. Relative importance of some nutritional components of milk replacers for veal production. J. Dairy Sci. 48(Suppl. 1):787 (Abstr.).

Bradley, N.W., R.M. Forbes, W.W. Alberta, G.E. Mitchell Jr. and A.L. Newmann. 1958. Use of chromic oxide method for determining digestible energy and protein in complete pelleted steer ration. J. Anim. Sci. 17:1199 (Abstr.).

Bray, R.W., E.H. Rupnow, R.M. Hanning, N.N. Allen and R.P. Niedermeier. 1959. Effect of feeding methods on veal production and carcass quality. II. Carcass grades, liver, hide, specific gravity, yield and chemical analysis of muscles. J. Anim. Sci. 18:732-737.

Brekke, C.J. and G.H. Wellington. 1969. Meat yields from Holstein veal calves. J. Anim. Sci. 29:6-10.

Brekke, C.J. and G.H. Wellington. 1972. Effect of animal weight on palatability of veal leg roasts. J. Anim. Sci. 35:937-940.

Bremner, I., J.M. Brockway, H.T. Donnelly and A..F. Webster. 1976. Anemia and veal calf production. Vet. Rec. 99:203-205.

Bremner, I. and A.C. Dalgarno. 1973. Iron metabolism in the veal calf. 2. Iron requirements and the effects of copper supplementation. Br. J. Nutr. 30:61-76.

Brisson, G.J., L. Grisé, M. Raymond, F. Castaigne et J. Goulet. 1979. Influence du régime alimentaire du veau de boucherie sur la composition de la carcasse, sur quelques proprietés organoleptizues et sur la composition de la viande. Université Laval, Quebec. 171 pp.

Bruce, V.M. and B.E. McDonald. 1977. Canadian Vegetable Oils and Some Implications for Human Nutrition. J. Can. Diet. Assoc. 38:90-97.

Burnside, E.B., T.R. Batra, G.K. MacLeod and D.G. Grieve. 1972. Genotype - environment interaction in calf production. I. Growth traits. J. Anim. Sci. 35:317-320.

Bush, R.S., J.W.G. Nicholson, T.M. MacIntyre and R.E. McQueen. 1978. A comparison of Candle and Tower rapeseed meals in lamb, sheep and beef steer rations. Can. J. Anim. Sci. 58:369-376.

Butterfield, R.M. 1966. The effect of nutritional stress and recovery on the body composition of cattle. Res. Vet. Sci. 7:168-179.

Butterfield, R.M., E.R. Johnson and W.J. Prior. 1971. A study of growth in calves. 2. Carcass tissues. J. Agric. Sci. Camb. 76:453-458.

Butterfield, R.M., W.J. Pryor and R.T. Berg. 1966. A study of carcass growth in calves. Res. Vet. Sci. 7:417-423.

Cabezas, M.T., J.F. Hentges Jr., J.E. Moore and J.A. Olson. 1965. Effect of diet on fatty acid composition of body fat in steers. J. Anim. Sci. 24:57-61.

Caffrey, P.J., C. Miller, P.O. Brophy and P.L. Kelleher. 1988. The effects of method of processing of starters, tallow inclusion and roughage supplementation on the performance of early weaned calves. Anim. Feed Sci. Tech. 19:231-246.

Callow, E.H. 1961. Comparative studies of meat. VII. A comparison between Hereford, Dairy Shorthorn and Fresian steers on four levels of nutrition. J. Agric. Sci. 56:265-282.

Callow, E.H. 1962. Comparative studies of meat. VIII. The percentage of fat in the fatty and muscular tissues of steers and the iodine number of the extracted fat, as affected by breed and level of nutrition. J. Agric. Sci. 58:295-307.

Chandler, P.T., E.M. Kesler, R.D. McCarthy and R.P. Johnston Jr. 1968. Effects of dietary lipid and protein on growth and nutrient utilization by dairy calves at ages 8 to 18 weeks. J. Nutr. 95:452-460.

Christian, K.E. and W.R. Harvey. 1985. User's guide for LSMLMW-mixed model least squares and maximum likelihood computer program. Ohio State University.

Crouse, J.D. and G.M. Smith. 1978. Relationship of selected beef carcass traits with meat palatability. J. Food Sci. 43:152-157.

Cummins, K.A., J.E. Nocek and C.E. Polan. 1982. Growth and nitrogen balance of calves fed rations of varying nitrogen degradability and physical form. J. Dairy Sci. 65:773-783.

Curnick, K.E., L.D. Muller, J.A. Rogers, T.J. Snyder and T.F. Sweeney. 1983. Addition of sodium bicarbonate to calf starter rations varying in protein percent. J. Dairy Sc. 66:2149-2160.

Daniels, L.B., S.E. Cantrell and J. Hornsby. 1973a. Digestibility and growth on rations containing processed and unprocessed soybeans. J. Dairy Sci. 56:824-827.

Daniels, L.B., R.M. Winningham and J.R. Hornsby. 1973b. Expansion-extrusion processed sorghum grain and soybeans in diets of dairy calves. J. Dairy Sci. 56:932-934.

Deacon, M.A., G. de Boer and J.J. Kennelly. 1988. Influence of Jet-Sploding^{R} and extrusion on ruminal and intestinal disappearance of canola and soybeans. J. Dairy Sci. 71:745-753.

Dinius, D.A., R.R. Oltjen, C.K. Lyon, G.O. Kohler and H.G. Walker Jr.

1974. Utilization of a formaldehyde treated casein-safflower oil complex by growing and finishing steers. J. Anim. Sci. 39:174-133.

Donnelly, P.E. and J.B. Hutton. 1976. Effects of dietary protein and energy on the growth of Fresian bull calves. I. Effects of level of feed intake and dietary protein content on body composition. N.Z. J. Agric. Res. 19:409-414.

Drevjany, L.A. 1986a. Bypass Protein and Iso-acids - Challenge of the 1990's. Highlights of Agric. Res. in Ontario. 9:16-21.

Drevjany, L.A. 1986b. Towards success in Heavy Calf Production. Ontario Ministry of Agriculture and Food. Kemptville College of Agricultural Technology.

Drevjany, L.A., E.E. Wheeler and G.S. Hooper. 1981. Techniques of efficient heavy calf production. Highlights of Agric. Res. in Ontario. 4:16-19.

Dryden, F.D. and J.A. Marchello. 1973. Influence of dietary fats upon carcass lipid composition in the bovine. J. Anim. Sci. 37:33-39.

Elam, C.J., P.J. Reynolds, R.E. Davis and D.O. Everson. 1962. Digestibility studies by means of chromium oxide, lignin and total collection techniques with sheep. J. Anim. Sci. 21:189-192.

Erwin, E.S., I.A. Dyer and M.E. Ensminger. 1956. Effects of chlortetracycline, inedible animal fat, stilbesterol and high and low quality roughage on performance in yearling steers. I. Feed consumption and rate of gain. J. Anim. Sci. 15:710-716.

Erwin, E.S., G.J. Marco and E.M. Emery. 1961. Volatile fatty acids analysis of blood and rumen fluid by gas liquid chromatography. J. Dairy Sci. 44:1768-1771.

Evans, G.W. and C.J. Habn. 1974. Copper and zinc binding components in the rat intestine. In: Protein-metal interactions. M. Friedman (Ed.). Plenum, New York. p. 285-297.

Fallon, R.J., R.E.V. Williams and G.M. Innes. 1986. The effects on feed intake, growth and digestibility of nutrients of including Ca soaps of fat in diets for young calves. Anim. Feed Sci. Tech. 14:103-115.

Fenwick, G.R. 1982. The assessment of a new protein source - Rapeseed. Proc. Nutr. Soc. 41:277-288.

Fiems, L.O., Ch. V. Boucqué, B.G. Cottyn and F.X. Buysse. 1985. Evaluation of rapeseed meal with low and high glucosinolates as a protein source in calf starters. Livestock Prod. Sci. 12:131-143.

Fiems, L.O., B.G. Cottyn, C.H.V. Boucqué and F.X. Buysse. 1987. Effect of formaldehyde treated soybean meal and urea in starters on nitrogen quality, degradability in sacco, sheep digestibility and

calf performance. Anim. Feed. Sci. Tech. 6:287-295.

Fischer, W.F., A. Giroux and M.R. L'Abbe. 1983. Effects of zinc on mucosal copper binding and on the kinetics of copper absorption. J. Nutr. 113:462-469.

Fisher, L.J. 1980. A comparison of rapeseed meal and soybean meal as a source of protein and protected lipid as a source of supplemental energy for calf starter diets. J. Anim. Sci. 60:359-366.

Fulton, W.R., T.J. Klopfenstein and R.A. Britton. 1979. Adaptation to high concentrate diets by beef cattle. 1. Adaptation to corn and wheat diets. J. Anim. Sci. 49:775-784.

Galyean, M.L., D.G. Wagner and F.N. Owens. 1979. Corn particle size and site and extension of digestion by steers. J. Anim. Sci. 49:204-210.

Gardner, R.W. 1968. Digestible protein requirements of calves fed high energy calf rations ad libitum. J. Dairy Sci. 51:888-897.

Gardner, R.W. and M.V. Wallentine. 1972. Fat supplemented grain rations for veal production. J. Dairy Sci. 55:989-994.

Gardner, R.W., R.D. Kellogg and L.E. Orme. 1971. Protein and methionine sources in calf starters. J. Dairy Sci. 54:704 (Abstr.).

Garrett, W.M., Y.T. Yang, W.L. Dunkley and L.M. Smith. 1976. Increasing the polyunsaturated fat content of beef and lamb. J. Anim. Sci. 42:845-853.

Gorrill, A.D.L., J.W. Nicholson, D. Larmond and H.E. Power. 1975. Comparison of fish protein sources and milk by-products in milk replacers for calves. Can. J. Anim. Sci. 55:269-278.

Government of Canada. 1984. Canada Agricultural Products Standards Act: Veal Carcass Grading Regulations. Canada Gayette Part II, Vol. 118:TIX1-TIX14.

Grandadam, J.A., J.P. Scheid, A. Jobard, H. Dieux and J.M. Boisson. 1975. Results obtained with Trenbalone Acetate^{R} in conjunction with estradiol 17β in veal calves, feedlot bulls, lambs and pigs. J. Anim. Sci. 41:969-977.

Grieve, C.M. and K.S. Winchell. 1970. Feeding Holstein dairy calves. 40th University of Alberta Feeders Day Report. p. 26-27.

Grumpelt, B.P. 1987. Utilization of whole or extruded canola seed by sheep and dairy cattle. M.Sc. Thesis. University of Manitoba.

Guertin, G.D., B. Lachance, D. Petitclerc and G.J. St. Laurent. 1987. Effects of photoperiod and feeding whole corn, whole barley or rolled barley on growth performance of heavy veal calves. Can. J.

Anim. Sci. 67:1188-1189 (Abstr.).

Guertin, G., B. Lachance, D. Petitclerc and G.J. St. Laurent. 1987b. Effects of photoperiod and feeding corn or barley on diet digestibility in heavy veal production. J. Anim. Sci. 65 (Suppl. 1):475 (Abstr.).

Hanning, F., R.W. Bray, N.N. Allen and R.P. Neidermeier. 1957. Tenderness and juiciness of veal loin roasts and chops. A comparison of method of measuring those qualities. Food Tech. 11:612-614.

Heinrichs, A.J., D.L. Palmquist and H.R. Conrad. 1982. Feed intake patterns of cows fed high fat grain mixtures. J. Dairy Sci. 65:1325-1328.

Hentges, J.R. Jr., A.M. Pearson and C.A. Tucker. 1954. Waste beef fat in steer fattening rations and its effect upon the carcass. J. Anim. Sci. 13:970 (Abstr.).

Hirs, C.H.W. 1967. Determination of cystine as cystic acid. In: Methods in Enzymology. Vol XI. Hirs, C.H.W. Ed. Academic Press, New York. pp. 59-63.

Hornstein, I., P.F. Crowe and M.J. Heimberg. 1961. Fatty acid composition of meat tissue lipids. J. Food Sci. 26:581-586.

Huber, J.T. and O.F. Campos. 1982. Enzymatic hydrolysate of fish, spray dried fish soluble and soybean protein concentrate in milk replacers for calves. J. Dairy Sci. 65:2351-2356.

Ingalls, J.R. and M.E. Seale. 1971. Effect of continuous feeding of rapeseed meal on growth of dairy calves and subsequent first lactation yields. Can. J. Anim. Sci. 51:681-686.

Ivan and Grieve. 1976. Effects of zinc, copper and manganese supplementation of high-concentrate ration on gastrointestinal absorption of copper and manganese in Holstein calves. J. Dairy Sci. 59:1764-1768.

Jenkins, K.J., D.B. Emmons, E. Larmond and F.D. Sauer. 1982. Soluble, partially hydrolyzed fish protein concentrate in calf milk replacers. J. Dairy Sci. 65:784-792.

Jennings, T.G., B.W. Berry and A.L. Joseph. 1978. Influence of fat thickness, marbling and length of aging on beef palatability and shelf life characteristics. J. Anim. Sci. 46:658-665.

Johnson, P.L., L.A. Drevjany, O.B. Allen and G.M. Reasbeck. 1988. Supplementation of skim milk fed to veal calves: carcass characteristics, chemical, instrumental, and sensory parameters. Can. J. Anim. Sci. 68:1069-1077.

Jones, G.M., L.P. Jacobs and L.J. Martin. 1974. Feed consumption and

growth of dairy heifers and bull calves fed calf starters differing in protein content. Can. J. Anim. Sci. 54:315-324.

Jones, G.M., L.J. Martin and H.F. MacRae. 1972. Comparison of a high energy grain ration to a high fat milk substitute for veal production. Can. J. Anim. Sci. 52:586 (Abstr.).

Kaufmann, V.W. and W. Lupping. 1982. Protected proteins and protected amino acids for ruminants. In: Protein Contribution of Feedstuffs for Ruminants: Application to Feed Formulation. E.L. Miller, I.H. Pike and A.J.H. Van Es, eds. Studies in the Agricultural and Food Sciences. Butterworth Scientific, Washington, DC.

Kay, M., N.A. MacLeod and A. Pavlicevic. 1972. The value of different cereals in diets for growing steers. Proc. Nutr. Soc. 31:57A.

Kay, M., N.A. MacLeod, G. McKiddie and E.B. Philip. 1967. The nutrition of the early weaned calf. X. The effect of replacement of fish meal with either urea or ammonium acetate on growth rate and nitrogen retention in calves fed ad libitum. Anim. Prod. 9:197-201.

Kendall, E.M. 1988. Insacco rumen degradation, and digestibility in the lower digestive tract of ruminants of canola meal and soybean meal. M.Sc. Thesis. University of Manitoba.

Kennelly, J.J. 1983. Whole canola seed for lactating dairy cows. 62nd Annual Feeders Day Report. Agriculture and Forestry Bulletin, University of Alberta. p. 80.

Kennelly, J.J. and G. de Boer. 1986. Ruminal and intestinal disappearance of whole canola seed as influenced by Jet-Sploding temperature. 65th Annual Feeder's Day Report, University of Alberta. p. 82-83.

Kerz, A.F., J.T. Reid, G.H. Wellington, H.J. Agala, S. Sunpfendorfer, A.M. Maiga and A. Fortin. 1982. Growth and development of cattle as related to breed, sex and level of intake. Part 2. Characterization of the chemical development and lipogenic activity of subcutaneous, perirenal and omental adipose tissue sites. Cornell Univ. Agric. Exp. Sta. No. 23. 32 pp.

Kimberly, C.J. 1976. Effect of age of cattle on digestion of whole wheat or oats fed with clover hay. Aust. J. Exp. Agric. Anim. Husb. 16:795-799.

Koers, W.C., R. Britton, T.J. Klopfenstein and W.R. Woods. 1976. Ruminal histamine, lactate and animal performance. J. Anim. Sci. 43:684-691.

Kovalczyk, J., E.R. Orskov and J.J. Robinson. 1976. Effect of fat supplementation on voluntary food intake and rumen metabolism in sheep. Br. J. Nutr. 37:251-257.

Kovalczyk, J., J.J. Robinson and A. Otwinowska. 1982. The digestion in the small intestine of young bulls of the protein of rapeseed meal treated or untreated with formaldehyde. Anim. Feed. Sci. Tech. 7:225-232.

Kreikemeier, K.K., R.A. Stock, D.R. Brink and R.A. Britton. 1987. Feeding combinations of dry corn and wheat to finishing lambs and cattle. J. Anim. Sci. 65:1647-1654.

Kunz, W.D., R.W. Gardner and L.E. Orme. 1969. High fat grain rations for veal production. J. Dairy Sci. 52:912 (Abstr.).

Lachance, B., H. Lapreire, G. St. Laurent, and J. Rolland. 1984. Performance of veal calves fed various levels of an acid milk replacer and concentrates. Can. J. Anim. Sci. 64:1078 (Abstr.).

Lassiter, J.W., V. Allegood and C.H. McGaughey. 1966. Chromic oxide as an index of digestibility of all concentrate rations for sheep. J. Anim. Sci. 25:44-47.

Latrille, L., J.P. Pare, G. St. Laurent and C. Pomar. 1983. Heavy veal production with Holstein calves raised by multiple suckling or milk replacers and fattened with whole corn, barley or oats. Can. J. Anim. Sci. 63:643-653.

Lawrie, R.A. 1985. Meat Science. 4th edition. Pergammon Press (Aust.) Pty. Ltd., Potts Point, Australia.

Leibholz, J. 1972. The effect of nitrogen intake, sulphur intake and dietary nitrogen source on the performance of the early weaned calf. Aust. J. Exp. Agric. Anim. Husb. 12:561-565.

Leibholz, J. 1975. Molasses in early weaning rations for calves. Aust. J. Exp. Agric. Anim. Husb. 15:587-590.

Leibholz, J. 1980. Urea and meat meal in the diets of ruminant calves -the sites of digestion and the nitrogen requirements for microbial protein synthesis. J. Agric. Res. 31:163-177.

Leibholz, J. and H.S. Kang. 1973. The crude protein requirement of the early - weaned calf given urea, meat meal or soybean meal with and without sulphur supplementation. Anim. Prod. 17:257-265.

Leibholz, J. and R.W. Naylor. 1971. The effect of urea in the diet of the early-weaned calf on weight gain, nitrogen and sulphur balance and plasma urea and free amino acid concentrations. Aust. J. Agric. Res. 22:655-662.

Link, B.A., K.W. Bray, R.G. Cassens and R.G. Kauffman. 1967. Influence of age on lipids in skeletal muscle. J. Anim. Sc. 26:898 (Abstr.).

Lucas, H.L. 1952. Algebraic relationships between digestion coefficients determined by the conventional method and by indicator methods. Science 116:301.

MacDougall, D.B., I. Bremner and A.C. Dalgarno. 1973. Effect of dietary iron on the colour and pigment concentration of veal. J. Sci. Food Agric. 24:1255-1263.

MacGreggor, C.A., C.J. Sniffen and W.H. Hoover. 1978. Amino acid profiles of total and soluble protein in feedstuffs commonly fed to ruminants. J. Dairy Sci. 61:566-573.

MacGuire, R.L., N.W. Bradley and C.O. Little. 1966. Effects of frequency of feeding on excretion of chromic oxide, crude protein and gross energy and on nutrient digestibility by steers. J. Anim. Sci. 25:185-191.

MacLeod, N.A., A. MacDearmid and M. Kay. 1972. A note on the use of field beans (Vicia faba) for growing cattle. Anim. Prod. 14:111-113.

Marchello, J.A., F.D. Dryden and W.H. Hale. 1971. Bovine serum lipids. 1. The influence of added animal fat to the ration. J. Anim. Sci. 32:1008-1015.

Marchello, J.A., F.D. Dryden and D.E. Ray. 1968. Variation in the lipid content and fatty acid composition of three bovine muscles as affected by different methods of extraction. J. Anim. Sci. 27:1233-1238.

Marsh, W.H., B. Fingerhut and H. Miller. 1965. Modified procedure for determination of blood urea N. Technicon Method #AA11-1. Clin. Chem. 11:624-627.

McFarlane, J.M., G.L. Morris, S.E. Curtis, J. Simon and J.J. McGlone. 1988. Some indicators of welfare of crated veal calves on three dietary iron regimes. J. Anim. Sci. 66:317-325.

Menard, M.P., C.C. McCormick and R.J. Cousins. 1981. Regulation of intestinal metallothinonein biosynthesis by dietary zinc. J. nutr. 111:1353-1361.

Miller, W.J., J.L. Carmon and H.L. Dalton. 1959. Influence of high levels of plant and animal fats in calf starters on growth, feed consumption and palatability. J. Dairy Sci. 42:153-158.

Miller, K.P., R.D. Goodrich, J.E. Garrett and J.C. Meiske. 1983. Sources of supplemental nitrogen for young Holstein steers. J. Anim. Sci. 57(Suppl. 1):455 (Abstr.).

Mir, Z., G.K. MacLeod, J.G. Buchanan-Smith, D.G. Grieve and W.L. Grovum. 1984. Methods for protecting soybean and canola proteins from degradation in the rumen. Can. J. Anim. Sci. 64:853-865.

Mollenberg, L., T. Ehlers, S. Jacobssen, S. Johnsson and I. Olsson. 1975. The effect of parenteral iron supply on haematology, health, growth and meat classification in veal calves. Acta. Vet. Scand. 16:197-204.

Moran, E.T. Jr. 1986. Manipulation of fat characteristics in animal products. In: Recent advances in Animal Nutrition. D.W. Haresign and D.J.A. Cole, Ed. Studies in the Agricultural and Food Sciences. Butterworths, London.

Morgan, C.A. and R.C. Campling. 1978. Digestibility of whole barley and oat grains by cattle of different ages. Anim. Prod. 27:323-329.

National Research Council (NRC). 1979. Nutrient requirements of dairy cattle. No. 3., 5th edition. National Academy of Sciences, Washington, DC: National Academy Press.

National Research Council (NRC). 1980. Mineral tolerence of domestic animals. Washington, DC: National Academy Press.

National Research Council (NRC). 1989. Nutrient requirements of dairy cattle. 6th edition. National Academy of Sciences, Washington, DC: National Academy Press.

Nicholson, J.W.G., A.D.L. Gorrill and P.L. Burgess. 1971. Loss in digestible nutrients when ensiled barley is fed whole. Can. J. Anim. Sci. 51:697-700.

Niedermeier, R.P., N.N. Allen, R.D. Lance, E.H. Rupnon and R.W. Bray. 1959. Effect of feeding methods on veal production and carcass quality. 1. Rate of gain, stomach capacity, Vitamin A, iron and hemoglobin values. J. Anim. Sci. 18:726-731.

Nishimuta, J.R., D.G. Ely and J.A. Boeing. 1973. Nitrogen metabolism in lambs fed soybean meal treated with heat, formalin and tannic acid. J. Nutr. 103:49-53.

Nordin, M. and R.C. Campling. 1976. Effectof the amount and form of roughage in the diet on digestibility of whole maize grain in cows and steers. J. Agric. Sci. Camb. 87:213-219.

Oestreicher, P. and R.J. Cousins. 1985. Copper and zinc absorption in the rat: mechanism of mutual antagonism. J. Nutr. 115:159-166.

Oltjen, R.R., A.S. Kozak, P.A. Putnam and R.P. Lehmann. 1967. Metabolism, plasma amino acid and salivary studies with steers fed corn, wheat, barley and milo all concentrate rations. J. Anim. Sci. 26:1415-1420.

Oltjen, R.R., P.A. Putnam, E.E. Williams Jr. and R.E. Davis. 1966. Wheat versus corn in all concentrate cattle rations. J. Anim. Sci 25:1000-1004.

Ono, K., B.W. Berry and L.W. Douglas. 1986. Nutrient composition of some fresh and cooked retail cuts of veal. J. Food Sci. 51:1352-1357.

Orskov, E.R. 1982. Protein nutrition in ruminants. Academic Press

Inc. (London) Ltd., London.

Orskov, E.R., B.J. Barnes and B.A. Lukins. 1980. A note on the effect of different amounts of NaOH application on digestibility by cattle of barley, oats and maize. J. Agric. Sci. (Camb.) 94:271-273.

Orskov, E.R., C. Fraser and J.C. Gordon. 1974. Effect of processing of cereals on rumen fermentation, digestibility, rumination time and firmness of subcutaneous fat in lambs. Br. J. Nutr. 32:59-69.

Orskov, E.R., C.Fraser and I. MacDonald. 1972. Digestion of concentrates in sheep. 4. The effects of urea on digestion, nitrogen retention and growth in young lambs. Br. J. Nutr. 27:491-501.

Ostrander, J. and L.R. Dugan Jr. 1962. Some differences in composition of covering fat, intermuscular fat and intramuscular fat of meat animals. J. Amer. Oil. Chem. Soc. 39:178-181.

OTT, E.A., W.H. Smith, R.B. Harrington and W.M. Bisson. 1966a. Zinc toxicity in ruminants. I. Effect of high levels of dietary zinc on gains, feed consumption and feed efficiency of lambs. J. Anim. Sci. 25:414-418.

OTT, E.A., W.H. Smith, R.B. Harrington and W.M. Bisson. 1966b. Zinc toxicity in ruminants. II. Effect of high levels of dietary zinc on gains, feed consumption and feed efficiency of beef cattle. J. Anim. Sci. 25:419-423.

Owens, F.N., W.M. Knight and K.O. Nimrick. 1973. Intraruminal urea infusion and abomasal amino acid passage. J. Anim. Sci. 37:1000-1009.

Palmquist, D.L. 1984. Use of fats in diets for lactating cows. In: Fats in Animal Nutrition. J. Wiseman ed., Butterworths, London.

Papas, A., J.R. Ingalls and L.D. Campbell. 1979. Studies on the effects of rapeseed meal on thyroid status of cattle, glucosinolate and iodine content of milk and other parameters. J. Nutr. 109:1129-1139.

Parrott, J.C. III, S. Mehen, W.H. Hale, M. Little and B. Theurer. 1969. Digestibility of dry rolled and steam processed flaked barley. J. Anim. Sci. 28:425-428.

Pavlicevic, A., N.A. MacLeod and M. Kay. 1972. The effect of processing barley on its digestion in the rumen of growing steers. Proc. Nutr. Soc. 31:56A.

Pinkerton, F., G.T. King and R.E. Leighton. 1972. Performance and carcass characteristics of young Holstein males fattened on all-concentrate diets. Feedstuffs. 43(52):39-45.

Prasad, D.A. and J.L. Morrill. 1976. Effect of processing soybeans on

their use by calves. J. Dairy Sci. 59:329-332.

Preston, T.R.. F.G. Whitelaw and N.A. MacLeod. 1964. The nutrition of the early weaned calf. VI. The effect of supplemental lysine and methionine on the utilization of groundnut protein. Anim. Prod. 6:17-24.

Preston, T.R., F.G. Whitelaw, N.A. MacLeod and E.B. Philip. 1965. the nutrition of the early weaned calf. VIII. The effect on nitrogen retention of diets containing different levels of fish meal. Anim. Prod. 7:53-58.

Prior, W.J. and E.R. Johnson. 1971. A study of growth in calves. III. Energy and nitrogen retention efficiencies of growth of carcass tissues. J. Agric. Sci. Camb. 27:459-463.

Puls, R. 1981. Veterinary Trace Mineral Deficiency and Toxicity Information. Agriculture Canada Pub. 5139.

Richards, M.P. and R.J. Cousins. 1975a. Mammalian zinc homeostasis: requirement for RNA and metallothionein synthesis. Biochem. and Biophys. Res. Comm. 64:1215-1223.

Richards, M.P. and R.J. Cousins. 1976b. Metallothionein and its relationship to the metabolism of dietary zinc in rats. J. Nutri. 106:1591-1599.

Riss, T.L., P.J. Bechtel, R.M. Forbes, B.P. Klein and F.K. McKeith. 1983. Nutrient content of special fed veal rib-eyes. J. Food Sci. 48:1868-1871.

Roy, J.H.B. 1980. The Calf. 4th ed. (Studies in Agric. and Food Sci.). Butterworths, London.

Rule, D.C. and D.C. Beitz. 1986. Fatty acids of adipose tissue, plasma, muscle and duodenal digesta of steers fed extruded soybeans. J. Amer. Oil Chem. Soc. 63:1429-1436.

SAS Institute Inc. 1986. SAS User's Guide: Statistics. 1986 Edition. Cary, NC. SAS Institute Inc. 584 p.

Sauer, W.C. 1976. Factors affecting amino acid availabilities for cereal grains and their components for growing monogastric animals. Ph.D. Thesis.

Schneider, B.H. and W.P. Flatt. 1975. The Evaluation of Feeds Through Digestibility Experiments. University of Georgia Press, Athens, Georgia.

Schurman, E.W. and E.M. Kesler. 1974. Protein to energy ratios in complete feeds for calves at ages 8 to 8 weeks. J. Dairy Sci. 57:1381-1384.

Seewald, M., H.M. Eichinger and H. Scherz. 1987. Fat content and fatty

acid pattern in muscle and adipose tissue from differently reared calves. Meat Sci. 19:101-109.

Seoane, J.R., A.D.L. Gorrill, E. Larmond, R.G. Stevenson and J.W.G. Nicholson. 1978. Effects of feeding milk replacers containing low-erucic acid rapeseed oil on growth, nutrient digestibility, meat quality and histological changes in tissues of veal calves. Can. J. Anim. Sci. 58:465-470.

Sharma, H.R. and J.R. Ingalls. 1973. Comparative value of soybean, rapeseed and formaldehyde-treated rapeseed meals in urea-containing calf rations. Can. J. Anim. Sci. 53:273-278.

Sharma, H.R., J.R. Ingalls and T.J. Devlin. 1980. Apparent digestibility of Tower and Candle rapeseed meals by Holstein bull calves. Can. J. Anim. Sci. 60:915-918.

Sharma, H.R., J.R. Ingalls and J.A. McKirdy. 1972. Nutritive value of formaldehyde-treated rapeseed meal for dairy calves. Can. J. Anim. Sci. 52:363-371.

Sharma, H.R., J.R. Ingalls and J.A. McKirdy. 1978. Replacing barley with protected tallow in rations of lactating Holstein cows. J. Dairy Sci. 61:574-583.

Sharma, H.R., J.R. Ingalls and R.J. Parker. 1974. Effects of treating rapeseed meal and casein with formaldehyde on the flow of nutrients through the gastrointestinal tract of fistulated Holstein steers. Can. J. Anim. Sci. 54:305-313.

Sharma, H.R., B. White and J.R. Ingalls. 1986. Utilization of whole rape (canola) seed and sunflower seeds as sources of energy and protein in calf starter diets. Anim. Feed Sci. Tech. 15:101-112.

Shehata, A.Y., J.M. Deman and J.C. Alexander. 1970. A simple and rapid method for the preparation of methyl esters of fats in milligram amounts for gas chromatography. Can. Inst. Food Tech. J. 3:85-89.

Sheper, J. 1978. Meat colour and meat quality of slaughter calves with reference to effects of slaughter weights, extent of fattening and sex. Fd. Sci. Tech. Abstr. 10:65917 (Abstr.).

Shingoethe, D.J. and M. Ahrar. 1979. Protein solubility, amino acid composition and biological value of regular and heat-treated soybean and sunflower meals. J. Dairy Sci. 62:925-931.

Shingoethe, D.J., G.L. Beardsley and L.D. Muller. 1974. Evaluation of commercial rapeseed meal and Bronowski variety rapeseed meal in calf rations. J. Nutr. 104:558-562.

Shingoethe, D.J., H.H. Voelker and F.C. Ladens. 1982. High protein oat grain for lactating dairy cows and growing calves. J. Anim. Sci. 55:1200-1205.

Smith, G.C., T.R. Dutson, R.L. Hostetler and Z.L. Carpenter. 1976. Fatness, rate of chilling and tenderness of lamb. J. Food Sci. 748-756.

Smith, G.C., Z.L. Carpenter, H.R. Cross, C.E. Murphey, H.C. Abraham, J.W. Savell, G.W. Davis, B.W. Berry and F.C. Parrish, Jr. 1984. Relationship of USDA marbling groups to palatability of cooked beef. J. Food Qual. 7:289-308.

Smulders, F.J.M. and I.J.R. Visser. 1988. The influence of diet on muscle-quality characteristics of veal. J. Anim. Sci. 65(Suppl. 1):284-285 (Abstr.).

Spicer, L.A., C.B. Theurer, J. Sowe and T.H. Noon. 1986. Ruminal and post-ruminal utilization of nitrogen and starch from sorghum grain, corn and barley based diets by beef steers. J. Anim. Sci 62:521-530.

Stake, P.E., M.J. Owens and D.J. Shingoethe. 1973. Rapeseed, sunflower and soybean meal supplementation in calf rations. J. Dairy Sci. 56:783-788.

Stanley, D.W. and H.S. Swatland. 1976. The microstructure of muscle tissue - a basis for meat texture measurement. J. Texture Studies. 7:65-75.

Starcher, B.C., J.C. Glauber and J.G. Madaras. 1980. Zinc absorption and its relationship to intestinal metallothionein. J. Nutr. 110:1391-1397.

Steele, R.G.D. and J.H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., New York.

Stiles, R.P., D.G. Grieve and W.A. Gilles. 1974. Effects of three protein levels, with and without added fat on the performance and carcass characteristics of heavy veal calves. Can. J. Anim. Sci. 54:79-86.

St. Laurent, G.J. and G.J. Grisson. 1967. Changes in the colour and pigment content of skeletal muscles of veal calves due to age and to iron and desferrioxamine supplementation when measured by biopsy technique. J. Anim. Sci. 26:1283-1287.

St. Laurent, G.J. and G.J. Brisson. 1968. Effect of dietary iron and desferrioxamine on blood hemoglobin and on pigment content and colour of muscles in veal calves. J. Anim. Sci. 27:1527-1531.

St. Laurent, G.J. and G.J. Brisson. 1972. Nutritive value for a FPC for young calves. Can. J. Anim. Sci. 52:585 (Abstr.).

Stobo, I.J.F., J.H.B. Roy and H.J. Gaston. 1967. The protein requirements of the ruminant calf. II. Further studies on the effect of protein content of the concentrate mixture on the performance of calves weaned at an early age. Anim. Prod. 9:23-33.

Stock, R.A., D.R. Brink, R.A. Britton, F.K. Goedeken, M.H. Sindt, K.K. Kreikemeier, M.L. Bauer and K.K. Smith. 1987. Feeding combinations of high moisture corn and dry-filled grain sorghum to finishing steers. J. Anim. Sci. 65:290-302.

Stone, J.B. and A.S. Wood. 1973. Rapeseed meal as a protein source in the starter concentrate for replacement calves. Can. J. Anim. Sci. 53:327-332.

Timbers, G.E., D.J. Buckley, M. Klock and M. Lalonde. 1986. An interactive personal computer program for texture analysis. Engineering and Statistical Research Institute. Agric. Can. Ottawa, Ontario.

Toland, P.C. 1976. The digestibility of wheat, barley or oat grain fed either whole or rolled at restricted levels with hay to steers. Aust. J. Exp. Agric. Anim. Husb. 16:71-75.

Toland, P.C. 1978. Influence of some digestive processes on the digestion b cattle of cereal grain fed whole. Aust. J. Exp. Agric. Anim. Husb. 18:29-33.

Trotta, A.O., E.M. Kesler and G.L. Hargrave. 1984. Percent and solubility of protein in complete feeds for Holstein calves to age 12 weeks. J. Dairy Sci. 67:2560-2565.

Vander Wal, P., P.L.M. Berende and J.E. Spriestma. 1975a. Effect of anabolic agents on performance of calves. J. Anim. Sci. 41:978-985.

Vander Wal, P., E.J. Van Weerden, J.E. Sprietsma and J. Huisman. 1975b. Effect of anabolic agents on nitrogen retention of calves. J. Anim. Sci. 41:986-993.

Varner, L.W. and W. Woods. 1975. Influence of wheat variety upon in vitro and in vivo lactate levels. J. Anim. Sci. 41:900-905.

Van Weerden, E.J. 1984. Carcass quality of veal calves given anabolic agents. In: Manipulation of Growth in Farm Animals. Current Topics in Vet. Med. Anim. Sci. Brussels, Dec. 982. J.F. Roche and D.O. Callaghan, Ed. p. 112-121.

Veen, W.A.G. and H.A. Vahl. 1984. The influence of the degradability of concentrate protein in the rumen and of the lysine content of the concentrate on growth and feed efficiency in early-weaned calves. Neth. J. Agric. Sci. 32:107-108.

Veira, D.M. and G.K. MacLeod. 1980. Effects of physical form of corn and urea supplementation on the performance of male Holstein calves. Can. J. Anim. Sci. 60:931-937.

Veira, D.M., G.K. MacLeod, J.H. Burton and J.B. Stone. 1980a. Nutrition of the weaned Holstein calf. I. Effect of dietary protein level on rumen metabolism. J. Anim. Sci. 50:937-944.

Veira, D.M., G.K. MacLeod, J.H. Burton and J.B. Stone. 1980b. Nutrition of the weaned Holstein calf. II. Effect of dietary protein level on nitrogen balance digestibility and feed intake. J. Dairy Sci. 50:945-951.

de Visser, H., S. Tamminga and L.G.M. Van Gils. 1982. Further studies on the effect of fat supplementation of concentrates fed to lactating cows. 1. Effect on feed intake, feed intake patterns and milk production and composition. Neth. J. Agric. Sci. 30:347-352.

Waldern, D.E. 1970. Simple starter rations for early weaned calves. Unpublished data. Canada Dept. Agric. Research Station. Agassiz, BC.

Waldern, D.E. and L.J. Fisher. 1978. Effect of steam processed barley, source of protein and fat on intake and utilization of starter rations by dairy calves. J. Dairy Sci. 61:221-228.

Waldman, R.C., G.G. Suess and V.H. Brungardt. 1968. Fatty acids of certain bovine tissue and their association with growth, carcass and palatability traits. J. Anim. Sci. 27:632-635.

Waldman, R.C., W.J. Tyler and V.H. Brungardt. 1969. Estimation of body composition in young calves. J. Anim. Sci. 29:426-428.

Waldman, R.C., W.J. Tyler and V.H. Brungardt. 1971. Changes in the carcass composition of Holstein steers associated with ration energy levels and growth. J. Anim. Sci. 32:611-619.

Warner, R.D., D.C. Morris, J.W. Taylor, J.R. Currie, G.M. Gaunt, T.G. Truscott and R. Stafford. 1988. Influence of rearing and age at slaughter on carcass and meat quality of veal calves. Proc. Aust. Soc. Anim. Prod. 17:350-353.

Wensing, Th., A.I. Abdebrahim and A.J.H. Schotman. 1986. Some aspects of extra iron supply in veal calf fattening. Vet. Res. Comm. 10:283-296.

Wheeler, E.E., D.M. Veira and J.B. Stone. 1980. Comparison of tower rapeseed meal and soybean meal as sources of protein in pelleted calf starter rations. Can. J. Anim. Sci. 60:93-97.

White, T.W., F.G. Hembry and W.L. Reynolds. 1972. Influence of grinding, supplemental nitrogen and roughage on the digestibility of corn. J. Anim. Sci. 34:672-676.

Whitelaw, F.G., T.R. Preston and R.D. Ndumbe. 1961a. The nutrition of the early weaned calf. I. The effect on nitrogen retention of diets containing different levels of groundnut meal. Anim. Prod. 3:121-127.

Whitelaw, F.G., T.R. Preston and G.S. Dawson. 1961b. The nutrition of the early-weaned calf. II. A comparison of commercial groundnut meal, heat treated groundnut meal and fish meal as the major

protein source in the diet. Anim. Prod. 3:127-133.

Whitelaw, F.G., T.R. Preston and N.A. MacLeod. 1963a. The nutrition of the early weaned calf. III. Protein solubility and amino acid composition as factors affecting protein utilization. Anim. Prod. 5:131-145.

Whitelaw, F.G., T.R. Preston and N.A. MacLeod. 1963b. The nutrition of the early weaned calf. V. The effect of protein quality, antibiotics and level of feeding on growth and feed conversion. 5:227-235.

Williams, C.H., D.J. David and O. Iismaa. 1962. The determination of Cr_2O_3 in faeces samples by atomic absorption spectophotometry. J. Agric. Sci. Camb. 59:381-385.

Winter, K.A. 1976. Protein levels in urea-supplemented starter rations for young calves. Can. J. Anim. Sci. 56:817-821.

Winter, K.A. and B. Lachance. 1983. Management and feeding of young dairy animals. Agriculture Canada. Pub. #1432E.

Wood, D.F. and D.A. Froehlich. 1981. Sensory evaluation of grain fed versus milk fed veal. Proc. Eur. Mtg. Meat Res. Workers. 27:531-533.

Wood, N.S. and J.B. Stone. 1970. Digestibility, nitrogen retention and caloric value of rapeseed and soybean meals when fed at two dietary levels to calves. Can. J. Anim. Sci. 50:507-512.

Wrenn, T.R., J. Bitman, S. Kahl, J.R. Weyant and D.L. Wood. 1979. Feeding cholesterol and tallow to young calves. J. Dairy Sci. 62:746-753.

Wrenn, T.R., J.R. Weyand, C.H. Gordon, H.K. Goering, L.P. Dryden, J. Bitman, L.F. Edmonson and R.L. King. 1973. Growth, plasma lipids and fatty acid composition of veal calves fed polyunsaturated fats. J. Anim. Sci. 37:1419-1427.

Yu, Y. 1978. Effect of treating full-fat whole soybeans with dry heat or formaldehyde on digestibilities of nitrogen and polyenoic acids. J. Dairy Sci. 61:128-131.

Zerbini, E. and C.E. Polan. 1984. Protein sources for growth of ruminating Holstein bull calves. J. Dairy Sci. 67(Suppl. 1):128 (Abstr.).

Zupka, Z., I. Barry and J. Prochazka. 1972. Change in carcass quality of cattle between 100 and 500 kg liveweight. Fd. Sci. Tech. Abstr. 4:115-144.

Appendix A. Implant age, slaughter group, season of marketing and source of calves on test

Calf No.	Diet	Implant Wt. (kg)	Slaughter Group (kg)	Marketing Season	Source†
287	Corn	100	180	Summer	U
6583	Corn	80	210	Summer	O
6683	Corn	100	180	Summer	O
7283	Corn	80	210	Fall	O
1287	Corn	80	210	Fall	U
6481	Corn	80	210	Fall	O
2587	Corn	80	210	Winter	U
3087	Corn	80	210	Winter	U
4287	Corn	80	210	Winter	U
6383	Barley	100	180	Summer	O
6786	Barley	100	180	Summer	U
7583	Barley	80	210	Fall	O
9983	Barley	80	210	Fall	O
6883	Barley	80	210	Fall	O
6981	Barley	80	210	Winter	O
7081	Barley	80	210	Winter	O
3387	Barley	80	210	Winter	U
4687	Barley	80	210	Winter	U
6986	Barley + Oil	100	180	Summer	U
6483	Barley + Oil	80	210	Summer	O
6783	Barley + Oil	100	180	Summer	O
7483	Barley + Oil	80	210	Fall	O
6281	Barley + Oil	80	210	Fall	O
2687	Barley + Oil	80	210	Winter	U
2887	Barley + Oil	80	210	Winter	U
3487	Barley + Oil	80	210	Winter	U
7381	Barley + Oil	80	210	Winter	O
987	Barley + JSCS	100	180	Summer	U
7383	Barley + JSCS	80	180	Summer	O
7083	Barley + JSCS	100	210	Fall	U
1487	Barley + JSCS	80	210	Fall	U
6481	Barley + JSCS	80	210	Fall	O
6781	Barley + JSCS	80	210	Fall	O
7181	Barley + JSCS	80	210	Winter	O
3687	Barley + JSCS	80	210	Winter	U
4087	Barley + JSCS	80	210	Winter	U
487	Barley + Wheat	100	180	Summer	U
7186	Barley + Wheat	100	180	Summer	U
1187	Barley + Wheat	80	210	Fall	U
6983	Barley + Wheat	80	210	Fall	O
6681	Barley + Wheat	80	210	Fall	O
2287	Barley + Wheat	80	210	Winter	U
2787	Barley + Wheat	80	210	Winter	U
4187	Barley + Wheat	80	210	Winter	U
4487	Barley + Wheat	80	210	Winter	U

†U-University herd, O-Manitoba dairy farms.

Appendix B. Raw data for calf weight gains, total feed consumption and the number of days from 6 weeks on test to slaughter

ID	TRT	SLGR	WTGAIN	FEED	DAYS
287	1	1	120	339.47	133
6583	1	2	151	413.98	119
6683	1	1	110	274.90	84
7283	1	2	168	475.48	126
1287	1	2	157	466.70	126
6481	1	2	163	469.36	133
2587	1	2	138	401.79	119
3087	1	2	151	353.90	98
4287	1	2	155	399.38	112
6383	2	1	134	392.80	126
6786	2	1	120	444.20	147
7583	2	2	139	434.54	105
9983	2	2	164	453.09	140
6883	2	2	152	462.83	140
6981	2	2	154	470.96	119
7081	2	2	137	414.21	105
3387	2	2	147	399.38	98
4687	2	2	151	409.14	119
6986	3	1	143	418.75	140
6483	3	2	144	409.44	119
6783	3	1	103	293.09	84
7483	3	2	156	448.73	126
6281	3	2	160	433.33	112
2687	3	2	163	424.31	112
2887	3	2	163	401.60	112
3487	3	2	155	368.02	105
7381	3	2	157	418.10	119
987	4	1	131	364.56	112
7383	4	1	118	320.61	98
7083	4	2	159	492.65	133
1487	4	2	163	536.97	154
6381	4	2	139	422.10	105
6781	4	2	153	452.84	126
7181	4	2	132	376.07	105
3687	4	2	161	390.51	126
4087	4	2	155	377.67	105
487	5	1	116	385.74	133
7186	5	1	134	405.20	161
1187	5	2	154	423.48	133
6983	5	2	106	455.01	133
6681	5	2	162	532.13	147
2287	5	2	161	460.66	126
2787	5	2	153	450.67	119
4187	5	2	163	429.94	133
4487	5	2	164	431.99	133

Appendix C. Sample ballot for panelists evaluation of meat juiciness, flavour intensity, tenderness and flavour pleasantness

Name: _____ Date: _____

Take 1 cube of meat and evaluate Juiciness, then Flavour Intensity.

Juiciness: The amount of liquid released after 2 chews between the molar teeth.

	Juiciness		Flavour Intensity
8	Extremely juicy	8	Extremely intense
7	Very juicy	7	Very intense
6	Moderately juicy	6	Moderately intense
5	Slightly juicy	5	Slightly intense
4	Slightly dry	4	Slightly bland
3	Moderately dry	3	Moderately bland
2	Very dry	2	Very bland
1	Extremely dry	1	Extremely bland

Take 1 cube of meat and evaluate Tenderness, then Flavour Pleasantness.

Tenderness: The amount of work required to masticate a sample that is ready for swallowing.

	Tenderness		Flavour Pleasantness
8	Extremely tender	8	Extremely pleasant
7	Very tender	7	Very pleasant
6	Moderately tender	6	Moderately pleasant
5	Slightly tender	5	Slightly pleasant
4	Slightly tough	4	Slightly unpleasant
3	Moderately tough	3	Moderately unpleasant
2	Very tough	2	Very unpleasant
1	Extremely tough	1	Extremely unpleasant

Appendix D. Analysis of variance of growth and feed consumption data from start to 6 weeks on test†d

Parameter	Source	df	Type III MS	F-Value	Pr>F‡
Age at start	D	4	13.1016	21.6	0.0914
	Error	39	6.0613		
Weight at start	D	4	23.9801	1.45	0.2373
	Error	39	16.5865		
Weight at 6 weeks	D	4	13.4464	0.45	0.7709
	Wt 0	1	1258.4039	42.22	0.0001
	Error	38	29.8077		
ADG to 6 weeks	D	4	0.0076	0.45	0.7709
	Wt 0	1	0.0571	3.38	0.0737
	Error	38	0.0169		
Milk replacer consumption	D	4	0.0014	0.38	0.8242
	Wt 0	1	0.0053	1.47	0.2322
	Error	38	0.0036		
Starter consumption	D	4	0.0129	1.18	0.3357
	Wt 0	1	0.2824	25.81	0.0001
	Error	38	0.0109		
Total DM consumption	D	4	0.0156	1.36	0.2668
	Wt 0	1	0.1290	0.07	0.7942
	Error	38	0.0115		
Feed:Gain ratio	D	4	0.8060	0.43	0.7853
	Wt 0	1	0.1290	0.07	0.7942
	Error	38	1.8699		

†Age at start and weight at start of test analyzed using diet (D) as the main effect; all other parameters analyzed using diet (D) as the main effect and initial weight (Wt 0) as a covariate.

‡Level of significance.

dOne calf was omitted from the analysis because of illness during this period.

Appendix E. Analysis of variance of growth and feed consumption data from 6 weeks on test to slaughter using Diet (D) as the main effect, slaughter group (S) as the blocking effect and initial 6 week weight (In Wt) as a covariate

Parameter	Source	df	Type III MS	F-Value	Pr>F†
Slaughter weight	D	4	7.0341	0.28	0.8896
	S	1	7570.2825	300.14	0.0001
	DxS	4	2.9679	0.12	0.9753
	In Wt	1	6.0401	0.24	0.9753
	Error	34	25.2226		
Weight gain on test	D	4	33.9166	0.45	0.7736
	S	1	7232.1439	95.37	0.0001
	DxS	4	9.6222	0.13	0.9717
	In Wt	1	3335.5667	43.99	0.0001
	Error	34	75.8342		
Days to slaughter	D	4	654.0848	4.55	0.0048
	S	1	0.0014	0.00	0.9975
	DxS	4	323.7543	2.25	0.0841
	In Wt	1	3937.2031	26.67	0.0001
	Error	34	143.8764		
Average daily gain	D	4	0.0586	3.01	0.0313
	S	1	0.4129	21.25	0.0001
	DxS	4	0.0166	0.86	0.4999
	In Wt	1	0.0177	0.91	0.3469
	Error	34	0.0194		
Total feed consumed	D	4	3298.7528	2.13	0.0989
	S	1	38393.4051	24.75	0.0001
	DxS	4	1468.1423	0.95	0.4492
	In Wt	1	12178.6216	7.85	0.0083
	Error	34	1551.3245		
Average daily feed	D	4	0.1425	2.81	0.0406
	S	1	0.2902	45.16	0.0001
	DxS	4	0.0797	1.57	0.2043
	In Wt	1	0.6832	13.47	0.0008
	Error	34	0.0507		
Feed:Gain ratio	D	4	0.2705	2.51	0.0600
	S	1	0.0987	0.92	0.3455
	DxS	4	0.0900	0.84	0.5124
	In Wt	1	0.1663	1.54	0.2227
	Error	34	0.1078		

†Level of significance.

Appendix F. Analysis of variance for DM, GE, ADF, CP and TL digestibility coefficients

Source	DDM	DGE	DADF	DCP	DTL
Diet					
df	4	4	4	4	4
Type III MS	117.5683	124.5685	166.1899	80.8228	339.2464
F-Value	3.10	3.01	1.02	1.76	2.03
P>F†	0.0373	0.0414	0.4176	0.1763	0.1274
Composite					
df	1	1	1	1	1
Type III MS	121.7242	203.3254	929.9540	755.3333	368.9376
F-value	3.21	4.91	5.73	16.37	2.20
P>F	0.0874	0.0378	0.0261	0.0006	0.1525
Diet x Composite					
df	3	3	3	3	3
Type III MS	70.311	68.0923	272.8527	3.6632	21.5529
F-Value	1.86	1.65	1.68	0.0006	0.13
P>F	0.1679	0.2093	0.2014	0.9705	0.0420
Error					
df	21	21	21	21	21
Type III MS	37.87	41.39	162.27	46.13	167.39

†Level of significance.

Appendix G. Analysis of variance for DM, GE, ADF, CP, TL digestibility coefficients†

Source	DDM	DGE	DADF	DCP	DTL
Diet					
df	4	4	4	4	4
Type III MS	70.4108	70.1527	523.5895	68.7923	404.1161
F-Value	1.76	1.60	5.53	1.38	2.33
P>F‡	0.1788	0.2144	0.0040	0.2789	0.0928
Error					
df	19	19	19	19	19
Mean square	40.02	43.76	94.63	49.93	173.22

†Data analyzed for only those calves consuming Composite 2 of the Cr_2O_3.

‡Level of significance.

Appendix H. Analysis of variance for dry matter (DM) and crude protein (CP) disappearance from canola meal, mill samples† and samples from the end of the run‡ after 0, 4 and 8 hours rumen incubation in nylon bags

Parameter	Source	df	Type III MS	F-Value	Pr>F §
DM disappearance at:					
0 hours	Diet	2	679.48	58.10	0.0040
	Steer (Diet)b	3	11.70		
4 hours	Diet	2	1034.78	100.26	0.0018
	Steer (Diet)	3	10.32		
8 hours	Diet	2	1380.16	25.72	0.0129
	Steer (Diet)	3	53.66		
CP disappearance at:					
0 hours	Diet	2	529.04	27.34	0.0119
	Steer (Diet)	3	29.35		
4 hours	Diet	2	1562.57	143.01	0.0011
	Steer (Diet)	3	10.93		
8 hours	Diet	2	1928.82	33.30	0.0089
	Steer (Diet)	3	57.92		

†Sample of canola seeds used in the growth trial.

‡Sample of canola seeds from end of run, when temperature was regulated properly.

§ Level of signficance.

bError term for diet effect.

Appendix I. Analysis of variance for dry matter (DM) and crude protein (CP) disappearance from experimental diets after 0, 4, 8 and 36 hours rumen incubation in nylon bags and for the effective degradability of CP (EDCP)† and DM (EDDM)†

Parameter	Source	df	Type III MS	F-Value	Pr>F‡
DM disappearance at:					
0 hours	Diet	4	38.61	14.87	0.0055
	Steer (Diet)§	5	2.60		
4 hours	Diet	4	375.51	2.17	0.2085
	Steer (Diet)	5	172.81		
8 hours	Diet	4	716.26	15.39	0.0051
	Steer (Diet)	5	46.55		
36 hours	Diet	4	21.99	1.20	0.4127
	Steer (Diet)	5	18.28		
CP disappearance at:					
0 hours	Diet	4	32.36	5.17	0.0504
	Steer (Diet)	5	6.26		
4 hours	Diet	4	18.78	0.27	0.8880
	Steer (Diet)	5	70.53		
8 hours	Diet	4	187.18	3.79	0.0884
	Steer (Diet)	5	49.45		
36 hours	Diet	4	290.98	20.82	0.0026
	Steer (Diet)	5	13.97		
EDDM	Diet	4	224.11	95.56	0.0003
	Steer	1	138.37	59.00	0.0015
	Error	4	2.35		
EDCP	Treatment	4	61.55	5.00	0.0740
	Steer	1	16.93	1.38	0.3059
	Error	4	12.30		

†Calculated using the equations of Orskov (1982) using an outflow rate of 0.08 h^{-1}.

‡Level of significance.

§Error term for DM and CP disappearance at 0, 4, 8 and 36 hours.

Appendix J. Analysis of variance for carcass weight, dressing %, kidney fat and kidney fat as a percent of carcass weight

Source	Carcass Weight	Dressing %	Kidney fat	Kidney fat (% carcass wt)
Diet				
df	4	4	4	4
Type III MS	21.2948	3.6990	7.8329	5.8981
F-Value	1.25	1.88	0.46	0.41
P>F†	0.3072	0.1353	0.7611	0.7988
Slaughter Group				
df	1	1	1	1
Type III MS	2495.4202	5.4207	4.7982	3.3478
F-Value	146.74	2.76	0.28	2.34
P>F	0.001	0.1056	0.5971	0.1355
Diet x Slaughter Group				
df	4	4	4	4
Type III MS	9.7714	3.0281	5.5625	4.2731
F-Value	0.57	1.54	0.33	0.30
P>F	0.6829	0.2116	0.8558	0.8769
Error				
df	35	35	35	35
Mean square	17.0061	1.9641	16.8553	14.3193

†Level of significance.

Appendix K. Analysis of variance for chemical composition of the 12th rib (DM basis) and rib-eye area of 13th rib

Source	12th rib			13th rib-eye area (cm^2)
	% fat	% CP	% Ash	
Diet				
df	4	4	4	4
Type III MS	0.7008	2.2174	0.0192	51.5466
F-Value	0.58	0.91	1.10	2.06
P>F†	0.6803	0.4689	0.3737	0.1074
Slaughter Group				
df	1	1	1	1
Type III MS	0.9437	0.3764	0.0161	622.6018
F-Value	0.78	0.15	0.92	24.86
P>F	0.3837	0.6967	0.3448	0.0001
Diet x Slaughter Group				
df	4	4	4	4
Type III MS	3.9594	5.6120	0.0197	69.0468
F-Value	3.27	2.31	1.12	2.76
P>F	0.0227	0.0780	0.3613	0.0430
Error				
df	34	34	34	34
Mean square	1.2119	2.4352	0.0175	25.0393

†Level of significance.

Appendix L. Analysis of variance for fatty acid proportions† in the l. dorsi muscle at the 12th rib

Fatty acid‡	Source	df	Type III MS	F-Value	Pr>F†
C10:0	D §	4	0.00230	0.33	0.8558
	Sld	1	0.00111	0.16	0.6926
	DxSl	4	0.00199	0.29	0.8852
	Error	34	0.00696		
C12:0	D	4	0.00037	0.22	0.9263
	Sl	1	0.000779	0.46	0.5027
	DxSl	4	0.000177	1.05	0.3972
	Error	34	0.00169		
C14:0	D	4	0.0906	0.37	0.8315
	Sl	1	0.1620	0.65	0.4244
	DxSl	4	0.4102	1.65	0.1832
	Error	34	0.2479		
C16:0	D	4	11.4258	5.72	0.0012
	Sl	1	0.4648	0.23	0.6326
	DxSl	4	1.9833	0.99	0.4248
	Error	34	1.9978		
C16:0	D	4	2.1412	3.21	0.0245
	Sl	1	1.0875	1.63	0.2105
	DxSl	4	0.5211	0.78	0.5457
	Error	34	0.6677		
C18:0	D	4	5.2208	1.90	0.1339
	Sl	1	4.6358	1.686	0.2033
	DxSl	4	0.1937	0.07	0.9906
	Error	34	2.7549		
C18:1	D	4	2.8285	0.66	0.6262
	Sl	1	15.4785	3.59	0.0665
	DxSl	4	4.3221	1.00	0.4192
	Error	34	4.3060		
C18:2	D	4	8.1920	2.04	0.1107
	Sl	1	4.3471	1.08	0.3055
	DxSl	4	4.5421	1.13	0.3583
	Error	34	4.0154		
C18:3	D	4	0.2003	7.25	0.0002
	Sl	1	0.0703	2.55	0.1199
	DxSl	4	0.0358	1.29	0.2918
	Error	34	0.0276		
C20:0	D	4	0.0402	0.65	0.6277
	Sl	1	0.4103	6.68	0.0142
	DxSl	4	0.0956	1.56	0.2082
	Error	34	0.0614		

Appendix L. (con't.)

Fatty acid‡	Source	df	Type III MS	F-Value	Pr>F†
C20:1	D	4	0.2424	1.04	0.4011
	S1	1	0.1996	0.77	0.3863
	DxS1	4	0.0593	0.25	0.9049
	Error	34	0.2331		
C20:4	D	4	0.1048	0.20	0.9349
	S1	1	0.3224	0.62	0.4347
	DxS1	4	1.2370	2.40	0.0694
	Error	34	0.5160		
C22:1	D	4	0.1175	1.32	0.2816
	S1	1	0.1129	1.27	0.2674
	DxS1	4	0.0706	0.80	0.5367
	Error	34	0.0888		
C22:4	D	4	0.0016	1.19	0.3327
	S1	1	0.0070	5.16	0.0296
	DxS1	4	0.0008	0.59	0.6715
	Error	34	0.00136		
Unidentified	D	4	0.3780	0.78	0.5465
	S1	1	1.4959	3.08	0.0881
	DxS1	4	0.1681	0.35	0.8445
	Error	34	0.4850		

†Expressed as a percentage by weight of total fatty acid.

‡First number denotes the number of carbon atoms, the number after the colon denotes the number of double bonds.

§D=Diet.

¶S1=Slaughter Group (180 vs. 210 kg).

Appendix M. Analysis of variance for Hunter-Lab^{R} readings for colour intensity (L), degree of redness (a) and degree of yellowness (b) taken on cooked meat samples

Parameter	Source	df	Type III MS	F-Value	Pr>F†
L	Diet	5	53.265	2.94	0.0008
	Panel	5	9.991	1.30	0.3050
	Error	19	7.680		
a	Diet	5	5.991	10.69	0.0001
	Panel	5	157.480	280.98	0.0001
	Error	19	0.5605		
b	Diet	5	0.579	0.98	0.4561
	Panel	5	17.424	29.51	0.0001
	Error	19	0.5905		

†Level of significance.

Appendix N. Analysis of variance for taste panel ratings for juiciness, flavour intensity, tenderness and flavour pleasantness

Juciness Rating

Source	DF	SS	% of TtlSS	MS	F	Prob
Evaluator	7	167.08	28.21	23.87	17.228	0.0000
Diet	5	16.03	2.71	3.21	1.673	0.1669
Eval. x Diet	35	67.08	11.33	1.92	1.383	0.0892
Panel	5	22.87	3.86	4.57	3.301	0.0072
Deit x Panel	23	64.20	10.84	2.79	2.015	0.0059
Remainder	184	254.93	43.05	1.39	-	-
Total		592.19	100.00			

Flavour Intensity Rating

Source	DF	SS	% of TtlSS	MS	F	Prob
Evaluator	7	71.16	12.08	10.17	5.571	0.0000
Diet	5	27.77	4.71	5.55	1.816	0.1353
Eval. x Diet	35	107.06	18.17	3.06	1.676	0.0158
Panel	5	3.23	0.55	0.65	0.353	0.8800
Diet x Panel	23	44.26	7.51	1.92	1.054	0.4007
Remainder	184	335.78	56.98	1.82	-	-
Total		589.26	100.00			

Tenderness Rating

Source	DF	SS	% of TtlSS	MS	F	Prob
Evaluator	7	72.31	6.45	10.33	5.963	0.0000
Diet	5	303.57	27.06	60.71	29.591	0.0000
Eval. x Diet	35	71.81	6.40	2.05	1.184	0.2360
Panel	5	53.77	4.79	10.75	6.208	0.0000
Deit x Panel	23	301.63	26.89	13.11	7.570	0.0000
Remainder	184	318.75	28.41	1.73	-	-
Total		1121.84	100.00			

Flavour Pleasantness Rating

Source	DF	SS	% of TtlSS	MS	F	Prob
Evaluator	7	51.77	10.05	7.40	4.381	0.0002
Diet	5	10.16	1.97	2.03	1.090	0.3829
Eval. x Diet	35	85.21	12.66	1.86	1.104	0.3297
Panel	5	6.22	1.21	1.24	0.737	0.5989
Diet x Panel	23	70.92	13.77	3.08	1.827	0.0156
Remainder	184	310.61	60.33	1.69	-	-
Total		514.89	100.00			

Appendix O. Analysis of variance for objective measurements of meat quality made on cooked meat samples

Parameter	Source	df	Type III MS	F-Value	Pr>F†
Instrom Force	Diet	5	2358.65	2.60	0.0527
	Panel	5	510.93	0.56	0.7272
	Error	23	907.46		
% Water Loss‡	Diet	5	12.96	0.84	0.5322
	Panel	5	26.20	1.71	0.1727
	Error	23	15.34		
% Drip Loss §	Diet	5	0.1247	0.29	0.9109
	Panel	5	0.6153	1.45	0.2432
	Error	23	0.4233		
% Volatile Loss §	Diet	5	3.04	0.62	0.6852
	Panel	5	3.25	0.67	0.6534
	Error	23	4.89		
% Total Loss §	Diet	5	4.102	0.77	0.5842
	Panel	5	5.485	1.023	0.4280
	Error	23	5.36		

†Level of significance.

‡As determined with the Carver Press.

§Loss during cooking.