C.1

PERFORMANCE OF SHEEP RAISED IN CONFINEMENT

WITH

SPECIAL EMPHASIS ON THEIR NUTRITIONAL REQUIREMENTS

by

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ABSTRACT

Four main experiments were carried out to study the nutrient requirements and management of sheep raised in confinement.

Experiment I was designed to study the reproductive performance and protein utilization of ewe lambs bred to lamb at approximately 14 to 16 months of age. Rapeseed meal was compared to soybean meal as a source of supplemental protein during the second half of gestation. Ewe weight gains and lamb birth weights were not affected by either the level or the source of protein. Neither dry matter nor protein digestibility were influenced by the stage of gestation of the ewe. No consistent results were obtained with regard to nitrogen retention of the ewes during the last half of gestation. The results suggest that 11% crude protein (CP) in the dry matter supplying approximately 68 g digestible crude protein (DCP) may be adequate for this class of ewes. The results also indicated that a level of 22% rapeseed meal may be included in the diet of gestating ewes without producing goitrogenic or other adverse effects.

Experiment II was conducted to assess the performance of ewe lambs during lactation when fed rapeseed meal or soybean meal together with low quality roughage. Weight changes of the ewes and the average daily gain of the lambs over the eight week lactation period were not affected by the level or the source of protein. The results suggest that 10% CP in the dry matter supplying approximately 92 g DCP may be adequate for the class of ewe studied. A level of 25% rapeseed meal may be included in the diet of lactating ewes.

In Experiment III wheat and barley were compared as energy sources in all-concentrate rations for lambs weaned at eight weeks of age. The cereal grains were fed in the whole, rolled, and pelleted forms together with a pelleted protein supplement. Digestiblity trials were also conducted to measure the digestibility of energy and protein as influenced by grain, process and level of intake. There was no difference in growth rate of lambs fed wheat or barley. Whole grains resulted in a faster rate of gain than the pelleted form. Digestibility of energy was not influenced by the method of processing. Protein digestibility was similar for the whole and rolled grains with a tendency for pelleting to depress digestibility of this nutrient. Increasing feed intake from maintenance to appetite resulted in a slight depression in nutrient digestibility. The results of this study suggest that processing of cereal grains for lambs is unnecessary from the standpoint of digestibility and would appear to be detrimental in terms of growth rate and feed conversion efficiency.

Experiment IV was designed to study the influence of level of protein supplementation of whole barley based rations for early weaned lambs. A series of digestibility studies were conducted to measure the digestibility of dry matter and protein during three periods of growth. Results of this study demonstrated that 16% CP in the ration of lambs from 20 - 29 kg liveweight was sufficient to produce the most economical gain during this period of growth. In the period from 29 - 36 kg the lambs receiving 14% CP in the ration gained faster and had the best feed conversion efficiency. During the final finishing period the results suggest that one could continue to feed a 14% CP ration. The digestibility of dry matter and crude protein were not influenced by stage of growth of the animal.

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A

INTRODUCTION

Lamb meat is faced with increasing competition from other meats and there are indications that the present level of consumption reflects a relative decline in demand for lamb as consumption of other red meats increases. A particular attraction to lamb production is that even with intensive systems involving relatively unsophisticated winter housing, a relatively small proportion of the total capital in the enterprise is invested in fixed equipment. Intensification of sheep production must be examined in this context. Mechanization in the sheep industry has been slow; while the use of confinement, or semiconfinement management systems, labour saving equipment, and specially constructed housing has increased rapidly in the production of cattle, poultry, and swine. Confinement rearing of sheep presents the opportunity to use labour saving equipment and to intensify production. Harvesting and feeding forage from highly productive tillable land will result in more complete utilization and greater production per acre than when lambs are pastured. Confinement feeding increases ease of handling, feeding, and control of parasites. It removes factors associated with weather and protects against predators. Lambs tend to finish more evenly and slow developing lambs are more easily identified.

The biological and economic efficiency of lamb production is dominated by the resources required to maintain the breeding ewe. Ewes fed in confinement can be fed according to their needs. However, proper nutrition of the ewe and lamb may be more critical under these conditions. Sanitation will be more critical since allowing a disease to start under these conditions could lead to its rapid spread. Confinement also presents the opportunity to make use of new knowledge about estrus synchronization and superovulation as methods of increasing the number of lambs born per ewe per year. By increasing the overall efficiency and lambing percentage, the sheep producer will be able to help meet the ever increasing operating costs of the sheep enterprise.

The experiments reported herein were conducted to study the performance of sheep raised under total confinement conditions with special emphasis on their nutritional requirements, using feeds readily available to sheepmen in British Columbia.

B

LITERATURE REVIEW

I. EWES

1. Nutrient requirements and utilization during pregnancy

Brody (1945) from a comprehensive study of the nitrogen requirements of different species indicated that the maintenance requirement of non - pregnant sheep was 3.6 g DCP/kg $W^{.73}$ daily. This corresponds to an intake of approximately 60 g DCP for 50 kg ewe and is similar to the NRC (1957) recommendation of approximately 54 g DCP for ewes of the same weight. These values are in close agreement to those suggested for ewes in early gestation (Phillipson 1959 and Thomson and Aitken 1959). For ewes in the later stages of gestation a requirement of 120 g DCP per day for 50 kg ewes has been accepted for many years.

(a) Protein requirement for maintenance

There is evidence that the maintenance requirement may be considerably lower than that suggested by Brody, (1945). Early results presented by Harris and Mitchell (1941) showed that approximately 23 g DCP daily may be adequate to maintain nitrogen equilibrum in 50 kg non - pregnant ewes. Robinson and Forbes (1966) investigated the nitrogen requirements of mature non - pregnant ewes.

Results showed that when the energy intake was slightly in excess of maintenance, mature ewes (57 kg) could be maintained in nitrogen equilibrium on a daily DCP intake of approximately 1.25 g/kg $W^{.73}$. This value, although only approximately 30% of that advocated by Brody (1945) and the NRC (1957) was in close agreement with other findings (Elliot and Topps 1964). However, it must be noted that the latter workers' results may not be directly comparable since they found that the level of DCP required for nitrogen equilibrium increased as the ratio of ground roughage to concentrate in the diet was increased. Similarly, Vercoe and Hall (1965) demonstrated that protein requirement was dependent on energy intake and that both were important in the maintenance of liveweight, liveweight gain, and nitrogen balance in mature wethers. However, the results of Graham (1964) would suggest that results obtained with mature wethers cannot be applied directly to the breeding ewe which has just undergone the physiological stress of lactation.

Robinson and Forbes (1970) carried out a further investigation to study the protein and energy requirements of mature ewes during the post lactation period. The effect of altering the proportion of roughage to concentrate in the diet on these requirements was also studied. The results of the study indicated no effect of roughage-concentrate ratio on the amount of apparently digested nitrogen required to achieve nitrogen equilibrium. The requirement of apparently digested nitrogen obtained in this study was over 50% higher than that reported by the same workers in an earlier study (Robinson and Forbes 1966). There was a difference in energy intake between the two studies and the authors emphasized the importance of defining protein requirements within the context of energy.

(b) <u>Protein requirement for pregnancy</u>

Various estimates of the protein requirements of pregnant animals have been make from nitrogen balance data. In the case of pigs, a positive nitrogen balance was obtained throughout the pregnancy period on a daily intake of 193 g CP (Lenkeit <u>et al</u>. 1965), while increasing the daily intake to 662 g CP increased nitrogen retention after the 70th day of gestation. The authors postulated that there is a phase during the last month of gestation in which nitrogen retention increases considerably if the necessary protein is provided in the diet. Whereas, over the first two-thirds of pregnancy, retention is at a low level and nitrogen given in excess of the low requirement is excreted in the urine. The significance of this increased retention is not clear since it is counterbalanced immediately after parturition by a considerable loss of urinary nitrogen.

Considering sheep, several experiments have been carried out on the performance and nitrogen utilization of housed ewes during pregnancy. Early work indicated that successful reproduction could be achieved on daily intakes as low as 50 g DCP (Klosterman etal. 1951; 1953). However, these findings have not been generally accepted.

Whiting and Slen (1958) studied the influence of energy and protein levels on lamb production in a large feeding trial. The workers found that increasing the energy content of the ration in early pregnancy increased the liveweight gain of the ewes but did not influence the birthweight of the lambs. However, increasing energy in late pregnancy did not influence liveweight gain of the ewes and tended to depress the birthweight of twin lambs. By increasing the DCP content of the ration by 50% liveweight gain of the ewes and birthweight of single lambs was not influenced but significantly increased birthweight of twin lambs and six week weight of singles. The minimum average protein requirement for pregnant ewes based on the results of this trial was 90 g/ kg total digestible nutrients (TDN) for maximum lamb production. The diversity, therefore, between recommended standards and levels reported to give satisfactory results in feeding trials suggested that further research was necessary to establish more precisely the protein requirements of the ewe during pregnancy.

An investigation was therefore undertaken by Robinson and Forbes (1967) to study the minimum requirements for protein and its utilization during the second half of pregnancy. Late pregnancy is the most critical stage since the morphological growth data of Wallace (1948) showed that the nutrient requirements of the products of conception were negligible during early pregnancy. The interacting effect of energy on nitrogen utilization as discussed by Chalmers (1961) was also recognized and levels of energy were included in the study. Four levels of DCP intake ranging from approximately 27.5 to 110 g DCP per day for a 68 kg ewe and two levels of energy, maintenance plus 25% and maintenance plus 50%, were adopted. These levels would represent mean CP intakes per day of 3.0, 4.1, 5.5, and 7.2 g/kg $W^{.73}$ and ME intakes of 113 and 134 kcal/kg $W^{.73}$.

When nitrogen balance studies were carried out at 10-12, 14-16, and 18-20 weeks of gestation, the stage of pregnancy had no significant effect on the apparent digestibility of either dry matter or protein. However, the apparent digestibility of dry matter (DM) and CP decreased with decreasing protein intake, while a high energy intake caused the apparent digestibility of DM to increase and that of CP to decrease.

Nitrogen retention increased from mid to late pregnancy in ewes on the higher energy and protein treatment, however, nitrogen retention was not affected by the number of fetuses carried. Therefore, nitrogen intake required for maximum efficiency just before parturition was equivalent to 77 g DCP per day for a 68 kg ewe. This is approximately 35% lower than generally accepted by Thomson and Aitken (1959) and

Phillipson (1959). The corresponding level of nitrogen retained was 0.286 g/kg $W^{.73}$ per day (6.2 g for a 68 kg ewe) and was considerably higher than that reported by Klosterman et al. (1953) for a similar nitrogen intake.

Several experiments have been carried out on the performance and nitrogen utilization of housed Scottish Blackface ewes during pregnancy. McClelland and Forbes (1968) studied the effect of DCP and metabolizable energy (ME) intake on the performance of ewes weighing 51 kg during the last six weeks of gestation. Three intakes of DCP; 68, 91, and 113 g daily were each studied with three intakes of ME; 1200, 1600, and 2000 kcal per day. It was found that lamb birth weight was significantly affected by protein intake and the effect seemed to be more pronounced at the lowest energy intake.

In a concurrent nitrogen balance trial (McClelland and Forbes 1969) in which the same quantities of DCP were given and at an energy intake of 1600 kcal ME per day, neither lamb birthweight nor nitrogen retention was significantly affected by protein intake. There was evidence however, that the maximum efficiency of nitrogen retention was achieved on an intake of approximately 69 g DCP per day.

In view of these results McClelland and Forbes (1971) decided that a further trial should be carried out to study protein utilization on intakes below and above this level at which maximum efficiency was achieved in the earlier experiment. The intakes adopted were 45, 68, and 91 g DCP per day and each were given with the standard ME intake of 1600 kcal per day which was found to be adequate in the previous experiments. The average liveweight of the ewes was 51.5 kg. Results showed no significant differences between the treatments in liveweight gains of the ewes, lamb birthweight, or ewe net body weight change (the difference between liveweight gain over the experimental period and liveweight loss at lambing). When metabolism trials were conducted during weeks 15-16 and 19-20 of gestation, no differences in the apparent digestibility of nutrients were observed as the results of advancing stage of pregnancy. However, the apparent digestibility of CP increased significantly with the increase in CP intake. The workers showed a significant linear relationship between DCP intake and nitrogen retention. That is, daily nitrogen retention increased by 0.19 g/kg $W^{.73}$ for every 1 g/kg $W^{.73}$ of apparent digested nitrogen intake per day. The highest mean intake of apparently digested nitrogen in this study was 0.76 g/kg $W^{.73}$ per day, while in their earlier experiment 1.05 g gave maximum retention and 0.78 g gave maximum efficiency (McClelland and Forbes 1969). For a 50 kg ewe these represent intakes in the range of 94 to 114 g DCP per day. And since the intakes studied in this experiment were lower (38 to 82 g DCP daily), this probably accounts for the inability to establish levels of maximum nitrogen retention and efficiency.

(c) Protein requirements of ewe lambs

There appears to be a lack of information concerning nutrient requirements and nutrient utilization in young growing pregnant ewes. Mating of females in their first year may accentuate the problems of arriving at these requirements because of the difficulties associated with the partition of nutrients between the dam and the fetus. Provided the overall nutrition of the young female is adequate, the long term reproductive performance is not impared by early breeding (Coop and Clark 1955; Yalcin and Bichard 1964), but there is a lack of information on the effect on utilization of nutrients.

Of the various nutrients, protein may be of special importance for this type of animal.

Robinson et al. (1971) have studied the utilization of protein during pregnancy by ewes bred to lamb at 13 months of age. The overall mean daily dry matter offered of approximately 1.2 kg was within the voluntary intake of all the animals. Assuming a mean requirement of ME for maintenance for the young growing animal at this stage, of 86 cal/ kg $W^{.73}$ per day, (Forbes and Robinson 1969); the level was approximately 1.5 times maternal maintenance.

Results showed that as protein content of the diet increased from 12.3 to 16.5%, liveweight gain of the ewes was stable, while lamb birthweights were depressed. This is difficult to explain in view of the significant increase in the overall nitrogen retention. However, the decrease in lamb birthweight resulted in a decrease in dam weight loss at parturition and an increase in maternal liveweight gain. This suggests that the partition of protein to the maternal body increased as the CP concentration of the diet was increased. The authors went on to report that nitrogen retention increased from the 50th day of gestation compared to an increase only after the 100th day in mature ewes, (Graham 1964; Robinson and Forbes 1967; Robinson et al. 1970).

The increase in nitrogen retention in early gestation appears to be comparable to that obtained by Elsley et al. (1966) with pregnant gilts and may suggest an acceleration in maternal lean tissue deposition due to the onset of gestation in growing pregnant animals.

The levels of protein intake fall within the range studied by Robinson and Forbes (1967) and Robinson et al. (1970) in mature ewes. There was approximately a 40% higher level of nitrogen retention in the young pregnant females as compared to the mature ewe at 95 days, with no differences at five days prepartum. Assuming this is not a breed difference, the high level of nitrogen retention in early gestation in the young females (occurring as it does at a time when the fetal growth is small), emphasizes the high requirement of nutrients for maternal growth.

2. Nutrient requirements and utilization during lactation

Early experiments in this area (Slen and Whiting 1952a; 1952b; 1952c) have shown that a level of 7% protein (59 g DCP daily) in the ration fed to mature ewes during pregnancy and lactation was inadequate for normal lamb and wool production. However, levels of protein in the ration above 10 percent (104 g DCP daily) resulted in no greater production than a 10% level. Other experiments indicate similar results (Jordan 1950; Klosterman et al. 1951; Van Horn et al. 1951). In most of these experiments essentially isocaloric rations were used.

(a) Effect of nutrition during gestation on lactation performance

Whiting and Slen (1958) studied the effect of the energy content of the ration on the protein requirements of ewes for lamb production. When the energy content of the ration was increased during late pregnancy and early lactation (DCP intake between 54 and 109 g DCP and digestible energy (DE) intake approximately 2.7 and 3.7 Mcal), body weight gains of the ewes were not affected; birth and six week weights of single lambs and birth weights of twin lambs were not affected. When the protein content of the rations was increased (from 73 to 91 to 109 and from 54 to 64 to 73 g DCP intake daily in the two experiments respectively), there was no increase in body weights of the ewes or birthweights of the single lambs, but there was an increase in the birthweights of twin lambs. Increasing the protein content of the rations increased the six week weights of single and twin lambs. The results of these experiments suggested that the minimum average protein requirement for pregnant and lactating ewes was approximately 100 g DCP/kg of TDN intake for maximum lamb production.

The recommended allowances for protein for ewes of 68 kg liveweight in early lactation given by the NRC (1968) and Morrison (1959) are approximately 115 and 150 g DCP per day respectively. The ARC (1965) based their recommendations on factorial estimates and suggested a minimal allowance of 165 g DCP daily in early lactation for ewes weighing 50 kg and producing approximately 1 kg of milk per day.

Hogue (1967) concluded from a review of North American recommendations and the results of Gardner and Hogue (1964), (1966) that daily CP intakes of 161 and 185 g DCP were required for single and twin suckling ewes respectively in early lactation. Some of the diversity in recommendations is likely to result from differences in the level of milk production and the extent to which body reserves are altered during pregnancy and lactation. The latter would have a considerable effect on the estimates obtained from practical feeding trials.

Robinson and Forbes (1970) investigated the effects of diets during lactation. The overall experiment included 64 ewes which were offered 16 diets comprising 4 levels of DCP (110.0, 82.5, 55.0, and 27.5 g DCP per 68 kg ewe per day) and two levels of energy (3270 and 2725 kcal ME per ewe per day) during gestation. During lactation, half the ewes on each pregnancy treatment were given high energy and low energy (5450 and 3815 kcal ME per ewe per day). Milk quality and quantity were also measured.

Results showed no significant differences in digestibility coefficients between protein intakes during the pregnancy phase (Robinson and Forbes 1967). This may suggest a rapid adjustment of the rumen microflora when the diets were changed after parturition. This suggestion is in general agreement with the results of Lloyd et al. (1956) who indicated that a period of approximately 10 days is sufficient for the digestibility coefficients of DM and CP to adjust to a constant level after extreme changes in dietary nutrient intakes.

None of the dietary treatments during gestation had a significant effect on milk nitrogen output. This trend would appear contrary to the findings of Robinson and Forbes (1968) who found small responses in milk production when expressed on a metabolic body weight basis as a result of feeding different levels of protein and energy during gestation. They did however, obtain results indicating a higher nitrogen content of the milk on the higher energy intake. This is in agreement with findings of Rook and Line (1961) which indicates that the protein content of bovine milk increases with increasing DE intake.

Gardner and Hogue (1963) studied the overall interrelationship of energy levels fed to ewes before and after lambing. They summarized their results as follows:

1. Varying TDN levels from 75% to 125% of NRC (1957) during the last six weeks of gestation did not affect single lamb birthweights but feeding higher levels significantly increased twin birthweights.
2. Feeding higher TDN levels during gestation significantly increased the average 90-day weight of twin lambs.
3. Feeding higher lactation levels to ewes increased the weaning

weights of both single and twin lambs.

4. Ewes with single lambs approximately maintained their body weight from six weeks prepartum to weaning when fed 100% of NRC (1957) standards whereas ewes with twins required approximately 125% of NRC (1957) standards.

Results indicated that the NRC (1957) standard is satisfactory for ewes pregnant with single lambs. But levels for ewes pregnant with twin lambs should be increased, together with an increase in the total digestible nutrient standard during lactation for ewes with both single and twin lambs.

(b) Protein requirement in relation to milk production

Robinson and Forbes (1970) used two main criteria to assess the adequacy of dietary CP intake during lactation. These were, the level of milk nitrogen output and the level of body nitrogen retention. They used a value of 1 g digestible organic matter intake (DOMI) equal to 3.82 kcal ME (Blaxter and Wainman 1964) and estimated the protein and energy intakes during lactation required for a given level of milk nitrogen production and the associated level of body nitrogen retention. They showed significant correlations between milk nitrogen production and DCP intake during lactation, and between milk nitrogen production and ME intake during lactation. There were also significant correlations between DCP intake and nitrogen retention and between ME intake and nitrogen retention.

From these correlations the workers reported the DCP requirement, as calculated from the overall relationship between DCP intake, ME intake, and milk nitrogen production to be 7.9 g/kg $W^{.75}$ per day. This is equivalent to approximately 185 g DCP per day for a 68 kg ewe suckling a mean number of lambs of 1.85 and is considerably higher than the 114 g advocated by the NRC (1968).

With regard to the energy requirement of the same ewe, Robinson and Forbes (1970) suggested that when energy intakes during lactation fall below 200 kcal ME/kg $W^{.75}$ per day, there is little response in milk nitrogen output to alterations in protein intake. Conversely, as energy intake increases above this level, the greater is the response in milk nitrogen output.

Robinson and Forbes (1970) then calculated the energy requirement for zero body weight change in the ewe and reported the value of 220 kcal ME/kg $W^{.75}$ per day. When calculated for a 68 kg ewe, this corresponds to a total daily intake of 5210 kcal ME per day for the production of 2.3 kg of milk. This value compares favourably with an estimated requirement of 5416 kcal obtained by Hadjipieris et al. (1966) for ewes in early lactation but is slightly higher than that advocated by the NRC (1968).

The DE intake of lactating ewes has important effects on the volume of milk produced, milk energy yield per day, and lamb growth rate (Barnicoat et al.; Thomson and Thomson 1953; Gardner and Hogue 1963, 1964). A ration consisting of 111% (versus 94%) of NRC (1957) DE recommendations, fed to ewes suckling single lambs, increased milk production and 90 day lamb weights by 11 and 17% respectively without significantly affecting milk composition characters such as fat, protein, ash, dry matter, or energy value (Gardner and Hogue 1964). Wilson et al. (1970) indicated that the amount and composition of ewe's milk was not influenced by creep feeding the lamb. However, at different stages of lactation, responses in the ewe's milk yield and composition to creep feeding of the lamb, might depend on the energy level supplied to the ewe.

In further work, Wilson et al. (1971), studied the effects of lactation stage, energy level for the ewe, and creep feeding on the ewe's milk yield and compostion and rate and efficiency of lamb growth. In the experiment 30 Dorset x Merino F_1 two year old ewes suckling their first lambs, were offered a high, moderate, and low energy level corresponding to 125, 100 or 75% of the NRC (1957) recommendations. Mean initial ewe weight, lamb age and weight were 46.3 kg, five days and 5.2 kg respectively. The estimated DE values for the ewe ration and creep feed were 2881 and 3300 kcal/kg respectively and 12.0 and 14.6 percent protein. The week of lactation significantly affected milk quantity and percent of fat, total solids, solids-not-fat, protein, and energy. Amount of milk (estimated from hand milking the ewes at three hour intervals) and milk gross energy produced was greatest during the third week of lactation. Energy intake of the ewes significantly affected all milk characters except solids-not-fat, ewe weight change, and lamb gain. Creep feeding did not affect any of the ewe milk characters. None of the two-way interactions involving week of lactation, energy level, or pre-weaning lamb regime were significant for the milk or weight change characters indicating that the main effects were essentially additive. However, the lamb creep feed consumption was greatest and kcals of creep feed DE/g lamb gain was least for the ewes receiving the low energy ration. The latter values were obtained by dividing the mean daily creep DE consumed by the differences in lamb daily gain between creep and non-creep-fed groups. Means for the high, moderate, and low energy levels were 17.5, 15.8, and 14.6 kcal creep DE/g of lamb gain respectively. These values indicate that the ewe's energy intake tended to be inversely related to utilization effeciency of the lamb's creep-feed.

(c) Milk yield and composition

Milk production of the ewe is the major factor influencing rate of liveweight gain of the lamb; while the weight of milk rather than its nutritive value estimated from composition gives the best index of its ability to promote lamb growth, (Barnicoat et al. 1957). The factor most capable of influencing the quantity of milk produced is the plane of nutrition of the ewe. Adequate feeding during lactation maintains milk production in the important early stages of the lamb's existence. Liberal feeding during pregnancy helps to sustain milk flow, particularly in the later stages of lactation, and would presumably exert a dominant influence on the production of colostrum. Lambs can be weaned at two months of age without detriment to their rates of gain (Barnicoat et al. 1957).

Milk yields of ewes vary widely on account of factors determined by individuality. Breeding from ewes selected for lactation performances would not appear encouraging as a means of improvement, as heredity of characters determining milk production as judged by lamb gains is low. The influence of the sire on the milking qualities of its ewe progeny might prove more rewarding.

After studying the natural suckling behaviour of lambs Ricordeau et al. (1963) sought to determine a precise and practical method of estimating the milk production of ewes during the suckling period by weighing the lambs before and after suckling. The workers found that the suckling interval of lambs on the average was about 1.5 hours and is never more than three hours. There is little difference in behaviour of suckling lambs whether they are single or twins. The suckling frequency varies during the day and in relation to the weight of the lambs, but the most important factor is the age of the lambs.

They recorded the milk production of 14 ewes over two periods of 48 hours after double weighings carried out every two hours and every three hours. They found the estimation of milk production in 24 hours is valid when the weighings relate to a period of 12 hours, with suckling intervals of two or three hours.

Ricordeau and Boccard (1961) studied the relationship between growth of lambs and quantity of milk consumed. From data obtained from 97 ewes (58 suckling singles, 39 suckling twins), the results showed that the maximum correlation between milk consumed and growth is reached earlier for twin lambs (period 0-21 days) than for single lambs (0-35 days). The weight of the lambs between 28 and 35 days makes it possible to give an equally good estimation of the quantity of milk consumed during the corresponding period, as the knowledge of the birthweight and average daily gain of the lamb. In all cases the standard deviation of the differences between the quantity actually consumed and the quantity estimated is about 12%. During the first five weeks the rate of growth of single lambs does not depend essentially on their birthweight, as seems to be the case for twins. They found the feed efficiency to be 5.84 and 5.41 kg milk/kg gain for single and twin lambs respectively.

The median value of five author's estimates of the nitrogen content of ewe's milk is given by the Agricultural Research Council (1965) to be 0.94 g N/100 g of milk.

Using Persian Blackhead ewes ranging in age from two to ten years, milk composition and the effect of diet on content of milk fat and milk yield were investigated by Butterworth <u>et al</u>. (1968). Analysis of the milk of nine ewes for fat, protein, ash, and lactose (by difference) throughout a 12 week lactation gave average values of 5.9, 5.6, 1.0, and

4.8% respectively. Ewes fed on a high plane of nutrition gave significantly more milk containing higher fat than ewes fed on a low plane of nutrition. The fat values were 8.8 and 8.3% respectively. Ewes suckling twins gave significantly more milk than those suckling singles. Lambs suckling high plane ewes gained more weight than those suckling low plane ewes from birth to 12 weeks. Highly significant correlation coefficients were obtained between milk consumed by the lamb and its gain in weight.

McCance (1959) and Peart (1968 a) have demonstrated that milk production of ewes is substantially decreased when nutrient intake is restricted and Peart (1967, 1968 b) has shown that the total milk production of Blackface ewes is greatly influenced by the level of production attained in early lactation. Peart (1970) obtained results which indicated that the stage of lactation is an important factor governing the response to increased nutrition and that body condition of ewes at parturition acts as a buffer between nutrient intake and nutrient requirements for lactation. He also suggested that when body reserves of ewes are severely depleted, factors other than nutrient intake may become limiting to milk production. There was a similarity of milk yields and of liveweight change when feed was rationed during lactation weeks one and two, suggesting that the rate of conversion of body reserves to milk production is more critical than the total amount of reserves available during this period. However, when restricted feeding was extended into the third and fourth weeks of lactation, fat ewes suckling twin lambs were able to maintain substantially greater milk production than lean ewes with twins. These results support the findings of Forbes (1969) in contrast to those of Treacher (1971).

The efficiency of utilization of ewe's milk by the lamb was studied by Jagusch and Mitchell (1971). The authors found that the mean digestibility of energy of ewe's milk was 98.4%. They also concluded that the metabolizable energy requirement for zero energy gain was 145.2 kcal/kg$^{.75}$ per day and the efficiency of utilization of ME for maintenance and growth was 76.9%.

3. Use of rapeseed oil meal and low quality roughage

Rapeseed oil meal

Canada is the largest producer and exporter of rapeseed. Expansion of the industry has been large in recent years and is expected to continue. Canadian farmers grew about 5.5 million acres in 1970 with yields being between 400 and 450 kg per acre. The development of new rapeseed varieties, and particularly ones free of erucic acid, has been a success. In North America, an improved rapeseed meal could be expected to supply a significant portion of the protein supplement required by an expanding livestock industry. As facilities are developed for crushing the seed, feed mills will find rapeseed meal an attractive alternative to soybean meal. The improved quality and use of the meal will add impetus to livestock production.

Rapeseed oil meal became available for livestock feeding during World War II (1939-1945) but it was known that the meal contained a toxic principle 1-5 vinyl - thiooxazolidone (Astwood et al. 1949) and was somewhat unpalatable when fed to livestock. The Polish - type rapeseed meal, Brassica campestris contains lower levels of glucosinolates and erucic acid than that of the Argentine type Brassica napus. Early investigations conducted with turkeys showed severe thyroid enlargements as a result of feeding levels of the meal sufficient to meet the protein needs in practical grain based rations (Blakely and Anderson 1948).

Burkitt (1951) reported on the digestibility of rapeseed oil meal for sheep and mentioned it's unpalatable nature.

Bell and Weir (1952) found that supplementing marsh hay with rapeseed meal improved the _postpartum_ weights of gestating ewes and improved the quality of all the lambs and twins in particular as compared to those ewes fed marsh hay alone. No thyroid enlargements were noted.

Bezeau, Slen, and Whiting (1960) compared rapeseed meal with linseed meal as a source of protein for pregnant ewes and reported these to produce similar results when included in rations at comparable levels of up to 20% of the diet. At levels above 20% rapeseed meal was noted to be unpalatable and total feed intake decreased. While the potential goitrogenic effects of rapeseed meal have been well established, they do not appear to have been reported in sheep (Bell _et al_. 1967).

Impaired reproduction when reapessed meal is fed has been reported for rats (Manns and Bowland 1963 a; Schuld and Bowland 1968). A delay in sexual maturity, delayed estrus, and significantly reduced number of pigs weaned were observed by Manns and Bowland (1963 a) when 8% rapeseed meal was fed to gilts during growth and gestation. Litter size and weight at birth were not affected. The smaller litter size and weight at weaning have been considered to be due to a lactational inadequacy.

The adverse effects of dietary rapeseed meal on reproduction could be associated with an iodine deficiency that would show up in the offspring. Devilat and Skoknić (1971) conducted an experiment to study the effect of rapeseed meal as the main source of supplemental protein in the diets for pregnant and lactating gilts. Results indicated that gilts fed 12% rapeseed meal during pregnancy gained significantly less than those fed a similar amount of fishmeal protein.

Total litter size and weight at birth were similar for both treatments. However, only 49% of the piglets were born alive from the gilts fed the 12% rapeseed meal diet; thyroid glands of live and stillborn piglets were markedly enlarged and symptoms of iodine deficiency were clearly manifested. Most pigs died within 72 hours after birth and four of the 7 gilts lost their whole litter during this period. Of the total pigs born to rapeseed-meal-fed gilts, only 13.4% survived to three weeks. It was concluded from this study that rapeseed meal of the type fed when used as the main source of supplemental protein for gilts, may result in a severe iodine deficiency syndrome in litters when non-iodized salt is used in the diet.

Low quality roughage

It is generally recognized that legume forages contain more calcium, protein, and carotene than do non-legume forages and they have been shown to be superior in pregnant ewe rations, (Shrewsbury et al. 1942; Williams et al. 1950). However, the latter investigators reported little benefit from the administration of supplementary vitamin A to ewes receiving any one of several non-legume forages fed with complete mineral supplements.

The need for good fleshing in ewes during late gestation has been emphasized, (Hammond 1932; Thompson and Fraser 1949; and Wallace 1948). Since the differences in the TDN values of forages, varying widely in quality, are proportionately smaller than the DCP differences; attention was focused on the need for supplementary protein with non-legume roughages. Favourable effects due to the addition of protein to low-protein hays were observed (Bell et al. 1933; Burroughs et al. 1950).

II. SUCKLING LAMBS

1. Nutrient requirements from birth to eight weeks of age

The protein requirements of two to six week old lambs have not been firmly established. The utilization of protein by lambs of this age is apparently affected by several factors. Ranhotra and Jordan (1964) observed no significant increase in weight gains when six to eight week old suckling lambs were fed either a pelleted ration containing 16.5% protein or 13.5% protein. Conversely, Hinds et al. (1964) and McInnes and Briggs (1964) reported significantly greater gains among lambs fed rations containing 17 to 18% protein than when lower levels were fed. Three years later Glimp et al. (1967) suggested that pelleting creep feed may reduce the protein degradation in the rumen to a similar degree as heating the soybean meal, thus possibly explaining the lack of agreement between various reports.

Poe et al. (1969) reported that development of the lambs rumen is affected by the preweaning diet with greater reticulo - rumen growth occurring in lambs fed high forage than low forage creep rations. Jordan and Hanke (1970) conducted an experiment to determine the effect of level and source of protein supplement (soybean meal or urea) on weight gains of suckling lambs. The four experiments involving 281 suckling lambs three to four weeks of age fed ground corn alone or pelleted rations ranging from 9 to 14% CP equivelent, showed that daily feed consumption tended to be lower in the urea supplemented rations. The urea treatment had a significant effect on weight gains in only one replication, and in this case feed intake was reduced by about one-third. Level of protein, excluding urea fed lambs did not affect weight gains.

In the fourth experiment, ninety lambs weaned at four weeks of age and fed rations containing 9.8 to 17.5% CP showed that daily intakes of less than 100 g of CP equivalent per lamb significantly reduced average daily gain. But, amounts in excess of 100 g resulted in no further significant increase in gains. During the period from four to ten weeks of age, palatable rations containing 13.5 to 14% protein will result in intakes of 100 g of protein. Workers concluded that the main contribution of a creep ration is as a source of supplemental energy and that the ewe's milk provides adequate protein.

2. Rations for creep feeding lambs and their intake

Positive lamb growth responses from creep feeding have been observed, (Perry *et al*. 1958; Ross *et al*. 1961; Gardner and Hogue 1963). The latter authors also observed a significant interaction between lactation DE levels of the ewes (100 *versus* 125% of NRC 1957 recommendations) and type of creep feed (hay *versus* simple *versus* complex concentrate mixtures), indicating that the two effects were not additive. However, when the lambs were fed the same simple creep feed in a subsequent trial, the authors concluded that the amount of creep feed consumed was essentially equal regardless of the ewes' ration energy level (75 *versus* 100 *versus* 125% of recommendations). Later work by Wilson *et al*. (1970) indicated that the amount and composition of ewe's milk was not influenced by creep feeding the lambs.

III. FEEDER LAMBS

1. Performance of lambs fed all concentrate rations

Interest in mechanized feeding operations, rapid expansion of human population, and the resultant necessity of obtaining maximum nutrient yield per unit of available land has recently focused the attention of research people on the feeding of all concentrate rations to ruminant animals.

As early as 1897, researchers tried unsuccessfully to rear calves on rations devoid of roughages. Subsequent attempts by McCandlish (1923) were unsuccessful and postulated that fibrous materials were necessary in the diet of ruminants.

Mead and Regan (1931) were the first workers to conclude that roughage was not necessary in the diet for calves. By additions of cod liver oil and alfalfa ash to a basal ration of barley, oats, wheat bran, and linseed meal; they were able to secure continued normal growth of calves to 19 months of age. They considered lack of vitamin A and inadequate minerals to be the limiting factors in early research in this area.

Orskov et al. (1971 b) carried out an experiment to investigate the effect of feeding barley and a protein concentrate with and without hay to fattening lambs. The results showed that a level of 5% hay gave the greatest daily intake of concentrate, greatest growth rate, and most efficient feed conversion. However, these parameters were not significantly different from the lambs fed the all concentrate ration.

Recently, Nottle (1972) reported that when sheep were fed 100% whole wheat or whole oats towards the end of the fattening period, the lambs began to chew the wooden partitions of their pens.

Hudson et al. (1963) studied the response to an all concentrate ration fed to feeder lambs. When 96 lambs were fed for 70 days eight lambs died; five early losses showed no evidence of concentrate ration consumption while three others died from urinary calculi late in the trial. Average daily gain in the 70 day period was 195 g per day while the average feed consumption was 1.2 kg per day resulting in a very favourable feed conversion ratio of 1:5.6. Fifty carcasses showed a general lack of exterior finish despite good internal fattening and quality. Forty representative lambs slaughtered by a meat laboratory received federal grades including 7 prime, 23 choice, and 10 good. No adverse physiological effects were noted.

Keating et al. (1964) fed 28 lambs two all concentrate rations consisting of dry rolled milo or dry rolled barley. During the first 18 days of the 100 day trial, one lamb on the milo and three on the barley ration died. General sickness and scouring suggested that lambs on the barley ration were under greater stress. Lambs on the milo ration produced higher daily gains with significantly improved feed efficiency over the lambs on the barley ration. However, the gains were considerably lower than those reported by Hudson et al. (1963) for lambs on similar rations.

A complex study was undertaken by Botkin et al. (1965) to evaluate pellet size, concentrate levels and preparation methods for hay or barley when fed in mixed rations for fattening lambs. In the experiment on pellet size, 124 lambs were fed two commercially prepared complete pellets containing 70% hay and 30% barley. the rations differed only with respect to pellet size; that is 0.64 cm or 1.90 cm in diameter.

Results showed no appreciable difference in any trait studied between groups of lambs fed different size pellets. No difficulties were encountered with lambs in eating large pellets. This is in agreement with the work of Church et al. (1961) who reported no significant differences in lamb performance due to differences in pellet size varying from 0.64 cm to 1.27 cm.

In the first experiment on concentrate level, two pelleted rations, one containing 45% barley, 45% beet pulp, and 10% dehydrated alfalfa meal, and the other containing 70% alfalfa hay and 30% barley were fed to 144 lambs for 70 days. Results of this experiment showed that lambs receiving the high concentrate ration gained at a significantly slower rate than those on the high roughage feed. In terms of feed efficiency, dressing percentage, and carcass grade there was little difference between the two groups.

Lambs receiving the high concentrate pellets were difficult to keep on feed and some deaths occurred. The lower feed consumption of the higher concentrate fed lambs was in proportion to their gain, and was probably due to texture of the pellets and not to the ingredients. The pellets were extremely hard and many lambs showed signs of their teeth being worn very short by the end of the test. These lambs also scoured more readily than lambs fed the high roughage pellets.

Butcher et al. (1961) and Meyer and Hull (1964) found difficulty in feeding high concentrate rations to lambs.

In the second high concentrate experiment by Botkin et al. (1965), two rations of commercially prepared pellets, one of which contained 30% corn, 30% barley, 30% oats, and 10% dehydrated alfalfa; while the other containing 70% alfalfa hay and 30% barley were used. Results of the last fifty-six days on test showed rate of gain to be essentially the same for both groups. The lambs fed the high concentrate pellets ate less feed per day and used feed more efficiently. However, the improvement in feed conversion was insufficient to overcome the difference in feed cost. Contrary to the first experiment, no difficulty was encountered with keeping the lambs on feed with scours or with deaths.

In another experiment to study hay and barley preparation, eight rations were fed including whole, rolled, ground or pelleted barley mixed with alfalfa hay pellets or with ground alfalfa hay. In the first trial of this experiment, hay and barley each made up 50% of all rations. In the second trial all mixtures contained 60% hay and 40% barley. The rolled barley was steamed. The ground barley was put through a 0.5 cm screen; the pelleted barley used a 0.64 cm die, while the hay was either in the form of 0.64 cm pellets or chopped using a 5.08 cm screen.

Results of both trials showed that treatment significantly influenced rate of gain, feed efficiency, and feed cost per kg of gain. Effects of treatment on death loss, feed intake, dressing percentage, and carcass grade were not significant. In both trials lambs fed alfalfa hay pellets as part of the ration gained faster and more efficiently than those fed the ground form. These findings agree with findings of Fontenot and Hopkins (1965) comparing hay pellets with ground hay as part of a mixed ration. However, these data do not completely support the postulation of Meyer _et al._ (1959), that increased gains and efficiency of lambs resulting from feeding pellets are due to an increased feed intake. Nevertheless, they fed a ration of alfalfa hay only.

Results of trial one alone showed gains slightly lower (not significant) for lambs fed rations with barley pellets, than those lambs fed rations with barley prepared in any other way. In trial two, lamb gains were similar regardless of how the barley was prepared. In both trials feed efficiency and feed cost per 100 pounds of gain were significantly poorest for lambs fed rations containing barley pellets. Daily feed consumption was not affected to a great degree by method of barley preparation. Whole, rolled, and ground barley were not too different from each other with regard to any measure of lamb performance, although rations with rolled barley showed a slight advantage in feed efficiency and feed cost per kg of gain.

Meyer and Hull (1964) reported that while rolled and ground barley were essentially the same, there was a slight advantage for whole barley in feed efficiency. Jordan (1962) reported no difference in lamb performance between whole, steam rolled, or cold rolled barley.

In recent work McManus et al. (1972) studied the production responses to mineral buffer supplemented whole wheat grain feeding of lambs. Thirty-nine crossbred lambs off pasture and weighing 27 kg were group fed on lucerne chaff and whole wheat grain ad libitum in yards over a three week adaptation period. All animals were subsequently offered whole wheat grain plus 1.5% ground limestone ad libitum for 19 weeks. The addition of mineral buffer supplements of 1:1 Na_2HPO_4 and $NaHCO_3$ (buffer I) or 1:1:1:1 mixture of Na_2HPO_4, $NaHCO_3$, $KHCO_3$, and $Ca HPO_4$ (buffer II), as 2% of the grain offered resulted in significantly better feed intake and liveweight gains and decreased food conversion ratios as compared to those shown by control sheep fed on wheat grain and limestone. Administration of 2.5×10^6 IU injectable vitamin A to half the lambs over the first ten weeks of the experiment seemed to cause neither benefit nor harm.

2. Digestibility of all concentrate rations

In general, the digestion coefficients of feedstuffs used until recently were based on an extensive compilation by Schneider (1947) and Morrison (1956). The coefficients for concentrates were determined by difference and usually at low total concentrate levels in the ration, as compared to present fattening diets for ruminants. Observations by Hale et al. (1962) and Saba et al. (1964) obtained with a high concentrate or all concentrate ration suggest the digestion coefficients for protein and nitrogen-free-extract (NFE) are considerably lower for milo than for barley. The studies reported by Keating et al. (1965) provided additional information on the digestibility of all concentrate rations of milo and barley by ruminants. Digestion trials were conducted with cattle to determine digestibility of milo and barley in a 50% roughage ration (19% crude fiber) and an 85% concentrate ration (9% fiber). Digestion trials were also conducted with lambs to determine digestibility of all milo and all barley rations. With the 50% roughage ration digestion coefficients were similar for milo and barley; however, the TDN values were higher for milo. In the 85% concentrate rations, digestibility of protein and NFE of the barley ration was significantly higher than for the milo ration. The same relationship existed for TDN between the two grains. With lambs on all grain rations, digestibility of the NFE and gross energy were noticeably greater for milo than for barley. This is contrary to the results obtained with cattle and suggests that digestibility values for lambs and cattle are not interchangeable for high grain rations.

Nottle (1972) studied the digestibility of whole wheat when fed to sheep at two different levels (675 g and 785 g per day).

Data tended to show no difference in digestibility of any parameter due to an increase in the level of intake and does not support the general assumption that increasing the level of intake decreases digestibility due to an increased rate of passage. However, differences between the two feed intake levels was small and it is possible that one would not expect a difference in digestibility.

Orskov and Fraser (1972) in a recent report on the digestibility of whole and processed barley when fed to sheep, found that dry matter digestibility decreased from 78.2 to 74.9 and the DM required per kg liveweight gain increased from 2.56 to 2.80 kg as a result of rolling the whole grain before pelleting. This work was extended in a trial in which 12 lambs were given either whole barley or whole barley pelleted using a 7.8 mm die. The digestibility of the DM and organic matter was higher for the whole unprocessed barley diet. This may have been due in part to an increase in the fiber digestibility of the unprocessed ration and to a presumed survival of cellulolytic bacteria at the higher rumen pH.

3. Level of protein in all concentrate rations

Interest in protein and energy levels in fattening lamb rations increased after interactions between these two nutrients were shown. Bosshardt et al. (1946) compared caloric intake with protein utilization in growing albino rats; at a given level of protein intake, changes in caloric intake often resulted in changes in the apparent utilization of protein. Donaldson et al. (1955) showed that the energy to protein ratio in the diet of chickens influenced the caloric intake, feed efficiency, and growth rate, while Hill et al. (1956) concluded that energy intake of growing chicks is governed mainly by dietary energy concentration and to a lesser extent by protein level. Lofgreen et al. (1951) working with young dairy calves, found that the efficiency of utilization of protein in high protein rations, as measured by nitrogen balance, is markedly influenced by energy intake. Meyer (1958) when working with rats, reported that a low protein intake in relation to energy influences food intake indirectly through the apparent adverse ratio of the two nutrients. He also went on to state that as the energy portion of the diet is decreased food intake increases because the animal no longer needs to dispose of the excess energy as body fat or heat.

Jones et al. (1960) found differences in both average daily gain and carcass grade as well as feed efficiency between protein levels fed to 35 kg lambs. The average DCP on a dry matter basis of the high level was 11.2% *versus* 8.4% for the low level. The high level produced an average daily gain of 0.17 kg while the low protein level produced an average daily gain of 0.14 kg. The lambs on the higher level of protein tended to grade higher. Consumption was increased at the higher protein level. Differences in liveweight gain or grade between the energy levels, 90% and 120% of the minimal recommendations of Morrison (1957), were not statistically significant. The interactions between protein and energy on the average daily gain (ADG), carcass grade, and feed efficiency were significant. The high energy-high protein (HE-HP) groups gained faster and graded higher than any other groups but the low energy-high protein (LE-HP) groups were the most efficient. The HE-LP groups gained more slowly, were the least efficient, and had a lower grade than the other treatment groups. The estimated net energy (NE) intake figures expressed as percentages of expected or desired consumption show that all groups with the exception of the HE-LP group consumed 90% or more of the expected amounts. The HE-LP group consumed only 78.6% of the expected amount of net energy, while the LE-HP group gave the highest percentages of expected consumption. It would appear that as the energy level is increased, it is also necessary to increase the protein level to maintain feed consumption and growth rate of the animals.

More specifically, protein requirements of livestock are thought to be a function of many variables and not a specific figure for all conditions. Yet, requirements as listed in the various NRC publications are specific quantities expressed either as a percentage of the ration or as an amount per animal per day. This may be a simple way of expressing protein requirements but is probably an oversimplification of the facts. A major need exists in nutrition research to further qualify the nutrient requirements in terms of all the variables which may cause these requirements to vary. Once the quantitative importance of each of these variables is determined, the ability to formulate rations with predictable results will be enhanced.

Three of these variables are known to affect the amount of protein required in a ration. They are body weight, rate of body weight gain, and digestibility of protein in the ration. Preston (1966) attempted to integrate these 3 variables into a simple protein requirement for growing-finishing cattle and lambs. He reported the daily digestible protein requirequirements could be expressed by the following equations:

$$\text{cattle} \quad DP = 2.79 \text{ W kg}^{0.75} \; (1 + 1.905 \text{ G})$$
$$\text{lambs} \quad DP = 2.79 \text{ W kg}^{0.75} \; (1 + 6.02 \text{ G})$$

where DP is in grams; W $\text{kg}^{0.75}$ is the animal's metabolic body weight and G is the daily gain in kg. He suggests further that the above equations need to be modified such that body weight and weight gain can be replaced by carcass weight and gain of a specific composition such as percentage lean or fat.

Glimp et al. (1967) conducted an experiment to study the effects of reducing soybean protein solubility by dry heat on the protein utilization at two levels, (12.1 and 17.2%) of CP on rate and efficiency of gain and nutrient utilization in lambs 16-20 kg bodyweight and 42-56 days of age. He showed that heat treatment of soybean meal at 149 degrees centigrade for four hours had a significant effect on its utilization by growing lambs. Weight gains and feed efficiency of lambs fed the lower level of protein containing heat treated soybean meal were comparable to gains by lambs fed 17.2% rations containing commercially processed solvent extracted soybean meal. Heat treated soybean meal when fed in rations at a level to provide 17.2% CP did not improve lamb performance. The author went on to show that the digestibility of dry matter, gross energy, and cellulose, and the percentage of digestible nitrogen retained were similar for both levels of protein. However, increasing the protein content of the ration increased protein digestibility and increased nitrogen retention.

Black (1971) using entirely liquid diets which passed directly to the abomasum, determined the protein requirements of lambs weighing 8 to 30 kg. Liquid diets were used since it was thought that the true requirements of the lamb's body for protein depended on the extent of breakdown of protein in the rumen. This may be either underestimated or overestimated when solid diets of increasing protein content are fed.

The intersection of the line representing the linear increase in nitrogen retention in response to increases in protein intake and the horizontal line representing the maximum nitrogen retention was taken to be the optimum protein requirement as suggested by Hegsted (1964). He established the protein requirements for 7.8 kg lambs to be 4.84 g;

for 12.6 kg to be 4.31 g; for 20.8 kg to be 3.34 g and for 30.4 kg lambs to be 2.57 g of reference protein per 100 kcal of net energy. The reference protein requirement was established from a summation of the maximum protein retention and the endogenous protein losses, whereas, net energy was calculated from the metabolizable energy intake by the factors estimated by Walker and Jagusch (1969). The reference protein is defined as a theoretical protein used solely for tissue synthesis.

These results may be applied to either weaned or suckling lambs receiving any protein source.

Andrews and Orskov (1970) also studied the nutrition of the early weaned lamb. They reported that males grew 15% faster than females; the difference increasing with age and the amount of feed given. Growth rate responded linearly to increase in feeding level and curvilinearly to increase in dietary protein concentration. A significant interaction occurred whereby growth increased with higher protein concentrations as feeding level increased. At the highest feeding level (near ad libitum) the results suggest that the optimum dietary CP concentration for growth was about 17.5, 15.0, 12.5, and 12.5% at body weights of 20, 25, 30, and 35 kg respectively. The overall dietary CP concentration for growth between 16 and 40 kg body weight was about 17.0, 15.0, and 11.0% when the mean DE intake was 3.0, 2.6, and 2.1 Mcal/day. These results agree reasonably well with estimates of protein requirements for lambs given by the ARC (1965).

In further experiments concerning the nutrition of the early weaned lamb, the authors reported that there were significant increases in the rate of both nitrogen and fat retention with increases in the level of feeding from 70% of ad libitum to 85% of ad libitum to ad libitum.

There were also linear increases in the rate of protein deposition and decreases in fat deposition with increases in the concentration of CP from 10 to 20% in the dry matter. This effect was particularly marked at the high level of feeding. They also indicated that male lambs deposited more nitrogen and less fat than females. This was evident in both rate of depositon and of carcass composition at 40 kg liveweight.

(a) Effect of breed, sex and pre-weaning management on protein requirements

The extent to which the protein requirements of lambs are generally applicable to different breeds and environments has been tested (Orskov et al. 1972). The authors used three dietary concentrations of CP in an all concentrate ration to determine the variation, if any, in the requirements of early weaned and intensively fed lambs at six different centers in Great Britain. They showed that the optimum protein concentration of the pelleted rolled barley, white fish meal rations was in the region of 15 to 17% CP in the dry matter. However, the authors also pointed out that this may vary depending on the breed and sex of the lamb and on it's environment and management background from birth to the time it is placed on feed. For example, feed utilization differed significantly between breeds, Finn Dorset lambs having lower growth rates and poorer feed efficiency than Suffolk crosses. Female lambs had about 19% lower growth rates than male lambs. In terms of preliminary management differences, the lambs which suffered the longest growth check (defined as the interval between weaning and the time at which liveweight recovered to the weight the lamb was at weaning) at weaning (15.3 days) were those which were artificially-reared on cold milk substitutes ad libitum. It is apparent therefore, that the nutrient requirements of all classes of sheep is dependent on many factors which must be considered when making recommendations.

4. Rumen development of lambs fed all concentrate rations

It is well known that when ruminants are fed diets containing large amounts of easily fermentable carbohydrates (such as concentrated feed) they often die because of an overproduction of lactic acid in the first stomach. This disease is called lactic acidosis (Mackenzie 1967). It has been empirically stated and experimentally shown that animals can be accustomed to an all concentrate ration, by a gradual increase in the amount of carbohydrate rich diet (Ryan 1964), thus achieving an adaptation to the ration in such animals. Mechanisms for this adaptation were explained by microbial changes occurring in the rumen (Bryant and Burkey 1953; Hungate 1957; Maki and Foster 1957; and Palmquist and Baldwin 1966).

Hungate *et al*. (1952) suggested as an alternative mechanism of adaptation, that the microbial population has the ability to remove or neutralize the lactic acid in the rumen. In fact, higher activities of lactate - utilizing microorganisms were demonstrated in adapted rather than non-adapted animals. On the other hand, Mackenzie (1967) suggested that low levels of soluble carbohydrates maintained by protozoan activities in adapted animals prevented new multiplication of lactic acid formers upon the concentrated feed addition. By adding ground concentrated feed containing 19% CP to the non-adapted microbial population *invitro*, Nakamura *et al*. (1971) observed lactic acid accumulation whereas adapted populations were stable with respect to the acid production. Their conclusions for the mechanisms of adaptation to high concentrate feeds differs from those of Reid *et al*. (1957). They suggested that the mechanism of adaptation could be attributed to the large number of lactate - utilizing bacteria in the ruminal population, by which normal pH was maintained and therefore balanced flora existing without alteration. In Nakamura's experiment, however, pH during the initial phase of incubation with the all - hay population was higher than that with the hay - concentrate population, although in the former, floral change occurred later. High levels of easily fermentable carbohydrates would promote lactate formers, on the one hand, and on the other, by suppressing utilization of lactate. It should be emphasized that once an amount of carbohydrates continued to exist during the period, sufficient to induce multiplication of lactate formers, subsequent lactate accumulation could not be prevented even in the hay - concentrate population. Therefore, pH probably is an important factor for the change in microflora when animals are fed all concentrate rations.

Warner et al. (1959) summarized the factors to date governing the development of rumen. The rumen has an inherent growth potential which is in part related to body growth and unrelated to diet. Dry feed ingestion results in an increase in capacity, an increase in total rumen tissue, and a marked development of rumen papillae. The rumen expands in volume in approximate proportion to the weight of material it holds on a day to day basis. Hay consumption probably results in a greater expansion than concentrate consumption because of its slower rate of passage which results in a continual "piling up" (within limits) of residue. The muscle layer of the rumen develops in response to an increase in the weight of rumen contents which it must support and knead. Rumen papillae grow in response to stimulation by the volatile fatty acids derived from the rumen fermentation.

The fact that the order of effectiveness of the three principal acids is butyrate > propionate > acetate indicates that they elicit their effect by stimulating the blood flow in the mucosa and / or by being metabolized by the mucosa. The rumen papillae will be damaged unless an active fermentation (dry feed consumption) is maintained in the rumen. With these criteria in mind, there should be no reason to discriminate against high concentrate feeding of ruminants.

Warner et al. (1959) reported that when a 90% hay ration was fed to calves the papillae length was 4.1 mm as compared to 7.5 mm for calves receiving a 90% concentrate ration.

Kunkel et al. (1962) showed that pelleting a diet of sorghum grain, cottonseed hulls, and dry molasses had no effect on papillary length and that papillary length may be independent of body growth.

Slyter et al. (1970) fed all concentrate diets to steers and showed the ruminal pH values to be 6.0, 5.2, 5.8, and 6.1 for corn, wheat, barley, and milo respectively. Krough (1961) showed that when carbohydrates such as starch were fed in increasing amounts to sheep, originally given a roughage diet, at a certain level of intake the normal rumen population was quickly replaced by streptococci and lactobacilli and finally by yeasts and the animal became seriously ill. Eadie, Hobson, and Mann (1967), in a survey of the rumen flora of animals fed ad libitum on barley rations, found the rumen pH value was often low and suggested that the microbial population was rather unstable. Mann (1970) presented the results of a study on the effects on the rumen bacteria of overfeeding on barley of a heifer already adapted to a barley diet. He presented data to show that it is possible to feed large amounts of barley provided that the rate of increase is small so that the interrelationship between the various bacteria is not disrupted and the aciduric bacteria do not assume a dominant role. The rumen pH value fell as the amount of lactic acid increased. He found that the absence of protozoa contribute to high rumen bacterial counts at rumen pH values below 5.5. He also demonstrated that total volatile fatty acids (VFA) and the molar proportion of propionic acid both increased with decreasing pH value. Fonnesbeck et al. (1970) showed that when they fed three different rations containing 7.8, 9.8, and 11.8% protein there was no significant difference in the pH value of the rumen ingesta.

Recently McManus et al. (1972) reported that when mineral buffer supplemented whole wheat was fed to lambs on its own, the buffer supplements significantly raised the rumen pH values above control animals fed whole wheat grain plus 1.5% ground limestone ad libitum. The supplements also decreased the total rumen volatile fatty acid concentration and lowered the proportion of acetic acid while increasing that of propionic acid. Caproic acid was detected in significant quantities in the rumen of all sheep.

IV. EXPERIMENTAL METHODS AND CHEMICAL ANALYSIS

One method of doing physiological and nutritional studies with cattle or sheep is to make complete and separate collections of feces and urine for several consecutive days. Metabolism stalls used to achieve this have been described by Briggs and Gallup (1949); Erwin et al. (1956); Nelson et al. (1954); and Aschbacker (1970). In this regard, metabolism stalls are improved upon in terms of their construction to facilitate complete uncontaminated collection and ease of handling. Lloyd et al. (1956) showed that an adaptation period of ten days was necessary before ruminant animals could be placed on a metabolism trial. In a review of errors associated with the determination of nitrogen retention of sheep by nitrogen balance studies, Martin (1966) found that loss of ammonia from feces was negligable and the loss from urine depended on the temperature and pH at which it was collected. Collection at neutral pH resulted in losses of up to 9.7% of the urinary nitrogen as ammonia gas if an acid trap were not incorporated in the collection apparatus. The author showed the average loss of nitrogen when collecting urine at pH values below 2.0 was 1.33% when the ambient temperature was between 25 and 28^{o} C and 0.97% when it was between 15 and 18^{o} C.

The digestible energy value of a feedstuff is favoured over gross energy as a description of energy content. However, determination of this value by using a bomb calorimeter can be, as experienced by the author, time consuming, frustrating, and somewhat meaningless since the gross energy content of all feed values appear to be similar for all feeds. Digestible dry matter, because it may be simply and accurately determined, is at least indicative of feeding value. Moir (1961) pooled his own plus several other workers' data involving many different feedstuffs, digestibilities, and levels of intake fed to both cattle and sheep and obtained the regression: $y = 0.0462\ x - 0.158$ ($r = 0.981^{***}$) where y = DE in kcal/g DM intake and x = DM digestibility %. The regression did not deviate from linearity over the range 0.30 to 83% DM digestibility, and 1.24 to 3.65 kcal/g.

Graham (1969) derived an equation to predict metabolizable energy intake from digestible organic matter intake. The equation was derived by assuming that digestible organic matter (DOM) had a gross energy value of 4.40 ± 0.02 kcal/g (Armstrong et al. 1964). The equation was:

$M = 37.5I \times d - u$ where M is ME (kcal/day); I is organic matter intake (kg/day); d is digestibility of organic matter (%); and u is urinary energy for a fasting animal (approximately equal to 70 and 500 kcal/day for sheep and cattle respectively). This equation will provide an estimate of ME from percent DOM for any level of many diets given to sheep or cattle. However with diets containing more than 60% grain, estimates will be about 10% too low.

C

MATERIALS AND METHODS

I. GENERAL METHODS

1. Experimental Design

The main objective of the experiments reported herein was to study the management and nutrient requirements of sheep raised in total confinement. The sheep were fed rations consisting of feeds readily available in British Columbia.

Two pilot experiments were carried out with mature lactating ewes to obtain estimates of their requirements for protein and energy and to test procedures, facitilies, and equipment. These two experiments are reported in Appendices I and II.

Four main experiments were carried out. The objective of Experiment I was to study the reproductive performance and protein utilization of ewe lambs bred to lamb at approximately 14 to 16 months of age. Rapeseed meal was compared to soybean meal as a source of supplemental protein during the last half of gestation. Trials were undertaken to determine the digestibility of the rations fed and the nitrogen retention of the ewes at different stages of gestation.

The ewes from Experiment I were used to study the protein requirements during the lactation phase. (Experiment II) Rapeseed meal was again compared to soybean meal as a source of supplemental protein for the lactating ewe.

The object of Experiment III was to study the influence of energy source and physical form of all - concentrate rations for early weaned lambs. Wheat was compared to barley in either the whole, rolled or pelleted form. Digestibility studies were carried out on each ration at two levels of intake.

Experiment IV was designed to determine more precisely the level of protein supplementation necessary when feeding whole barley based rations to feeder lambs.

2. Feeding Trials

All the animals used in this study formed the entire flock housed on the campus of the University of British Columbia. The flock, numbering approximately 80 ewes, was primarily of Dorset Horn breeding including some registered polled Dorset Horns. Over the two years that this study was carried out, all ewes were bred to registered rams of the same breed. The management of the flock was considered to be similar to other flocks in the area.

With regards to both the ewe and lamb feeding trials, as many animals as possible were randomly assigned to treatments in any one experiment. Every effort was made to feed the animals so that they were in similar physical condition before the start of each experiment.

All animals were housed in one of two "cold type" buildings. The larger building was of essentially pole type construction with wood partioned pens inside. There was access to the perimeter pens from the outside which facilitated easy manure removal and from the inside by means of two alleys. Between the two alleys in the center was located further pen space. The pens had an earth floor and were bedded with wood shavings or sawdust as required. The watering bowls servicing each pen were of the overflow drain type, ensuring a constant supply of clean water to all animals. Adequate feed trough space (type dependent on the form of feed) was provided for each pen, so that all animals could eat at one time.

The other smaller building can be seen in the photograph below.

It was of solid wall construction with wall vents plus a 48 cm fan at one end to ensure adequate ventilation. The individual steel constructed pens were situated on either side of a central feed alley. The pens provided a floor area of approximately 2.7 square metres per pen. Running the full length of the building, under the pens, were two manure pits approximately 70 cm deep. The slatted floors were made of 5 cm square firlumber and were nailed 1 cm apart on two stringers.

The floor was made in 120 cm sections to fascilitate easy manure removal every 8 months. Fresh water was provided in each pen by means of nipple drinkers, using a low pressure system. The individual feeders were attached to the gates in front of each pen facing the central feed alley. Feeders were designed to minimize any feed being wasted.

A large quantity of feed was stored for each experiment to reduce any differences between batches of feed within any one experiment. A 5 mm die was used to pellet rations.

The roughage fed to the group-fed-ewes in the larger unit was long hay in baled form while that fed in the smaller unit was chopped using a 5.08 cm screen ("Haybuster", J.J. Manufacturing, Nebraska); each ewe being fed individually.

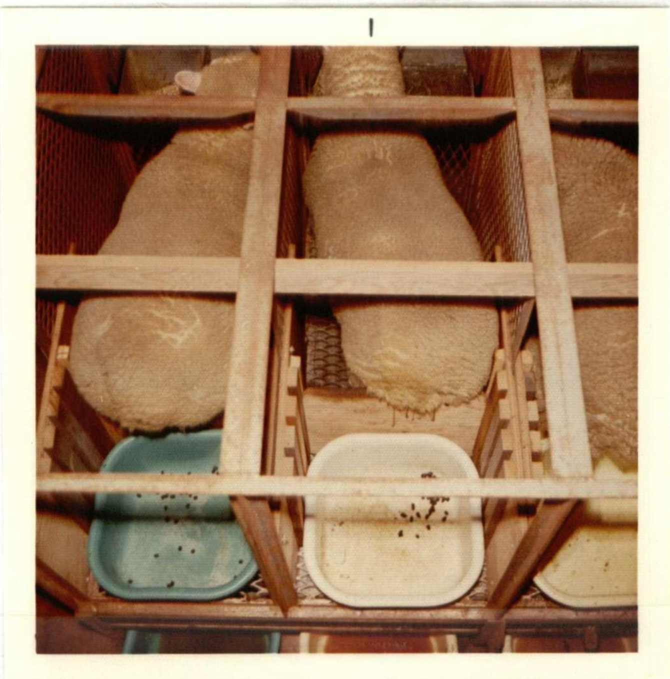
The feed intake of animals fed either in groups or as individuals was recorded daily. Animals were weighed at seven day intervals and recorded. Recorded and calculated data are given in the respective portions of the appendices. These data have been in turn condensed and included in the results and discussion sections of each experiment.

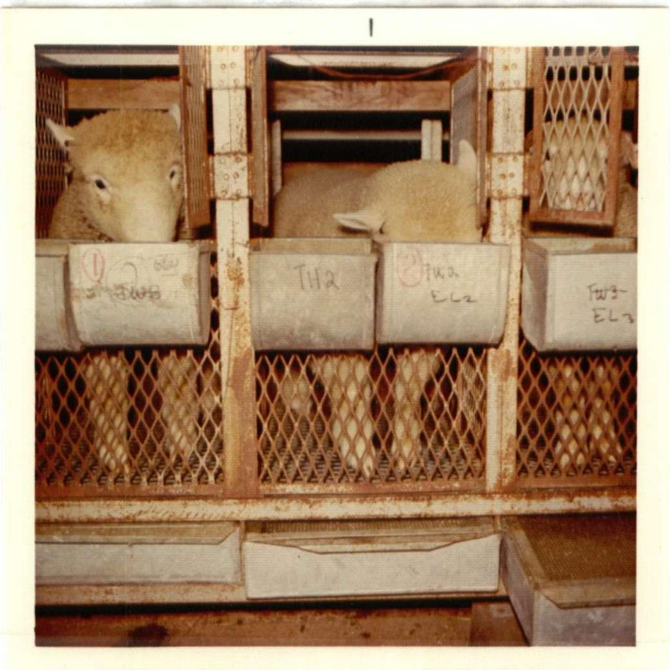
3. <u>Digestibility Trials</u>

Ram lambs which formed part of the feeding trials were used to determine digestibility and nitrogen retention of the feeder lamb rations. Representative ewes at different stages of pregnancy were used to determine digestibility and nitrogen retention of the ewe rations. In one case, however, non-pregnant ewes were used to establish "base line" digestibility and nitrogen balance.

Both lambs and ewes used for metabolism studies were allowed at least the ten day adaptation period to the ration and adjustment to its level of intake. In trials with feeder lambs the collection period lasted at least seven days while that for the ewes was at least five days in duration. An effort was made to feed and collect samples from the animals at approximately the same time each day.

The ram lambs were housed in metabolism cages as shown in the photograph below.





The ewes were housed in specially designed cages as shown in the photograph below.

Cages were designed and built by the author and his advisor, Dr. R. M. Tait. The features of the stall were: adjustable for both length and width, both front and rear openings for easy access, and the ability of the unit to be constructed and dismantled easily. It also combines desirable features of previously described cages such as: construction materials which provide long life, ease of cleaning, complete and total separation of feces and urine, convenience of feed and water containers, and mobility of the entire cage.

Abnormal stress created by uncomfortable stalls and rough handling can bias experimental results, therefore, it is necessary to give careful consideration to facilities used in metabolism studies. The stall built for this study took these factors into consideration. Ewes weighing from 40 to 75 kg were easily accommodated in this cage and appeared comfortable. Total and complete separation could be maintained even when using the different sizes of ewes.

Three factors being measured and recorded to determine the digestibility and nitrogen balance values for each lamb and ewe fed were total daily feed intake, total daily fecal output, and total daily urine output. The total feces and urine output were collected daily and measured. A representative sample of feces of approximately 10% by weight was dried at 85° C for 24 hours to determine the dry matter output per day. These samples were then stored until all daily samples from the trial were collected. These samples (representing the same percentage of total daily dry matter output) were pooled, thoroughly mixed, and ground through a one mm screen and stored pending analysis. A representative sample of urine of approximately 10% of the total daily output was combined with each successive days collection and stored at 3° C pending analysis. After each day's urine collection, concentrated H_2SO_4 was added to the narrow necked vessel at the rate of approximately 0.5% in order to ensure the optimum pH to prevent ammonia loss. A few drops of toluene were also added daily to further ensure ammonia loss was minimized.

II. CHEMICAL ANALYSES

Precautions were taken when analyzing samples of feed, feces, and urine to ensure that no contamination of samples occurred. Urine samples were passed through two layers of cheese cloth before analyzing.

The determination of digestibility and nitrogen balance was completed through the use of the following equations:

$$\text{Digestible Dry Matter (DDM \%)} = \frac{\text{DM intake} - \text{DM output}}{\text{DM intake}} \times 100$$

$$\text{Digestible Crude Protein (DCP\%)} = 100 \times \frac{(\text{DM intake} \times \text{\% CP in feed} - \text{DM output} \times \text{\% CP feces})}{\text{DM intake} \times \text{\% CP in feed}}$$

$$\text{Nitrogen Retention (g)} = \text{Feed N intake} - (\text{Feces N output} + \text{Urine N output})$$

$$\text{Absorbed N} = \text{Feed N intake} - \text{Feces N output}$$

$$\text{Efficiency of N Utilization (\%)} = \frac{\text{Retained N}}{\text{Absorbed N}} \times 100$$

Proximate values were computed on a dry matter basis. Chemical analyses of feeds, feces, and urine samples were performed according to AOAC (1965) methods. Acid detergent fiber values of feeds were determined by the method of Van Soest (1963) as modified by Waldern (1971).

III. STATISTICAL METHODS

The growth data of the feeder lamb experiment entitled, "The Influence of the Energy Source and Physical Form of All Concentrate Rations for Early Weaned Lambs", were subjected to an analysis of variance for a 2 x 3 factorial design. The digestibility data were analyzed as a 2 x 2 x 3 factorial. Duncan's multiple range test was used to determine significant differences (Steele and Torrie, 1960).

The ewe and suckling lamb performance data were subjected to analysis of variance with a single criterion of classification. Duncan's multiple range test was used to determine differences among means (Steele and Torrie, 1960).

D. EXPERIMENTAL

EXPERIMENT I Reproductive performance and protein utilization of ewe lambs bred to lamb at 14 to 16 months and fed rapeseed meal and low quality roughage.

1. Introduction

One of the main factors influencing the biological and economic efficiency of meat production from sheep is the number of viable lambs produced during the lifetime of the ewe. With the advent of more intensive systems of production, it is probable that breeding ewes prior to one year of age will become more widely adopted as a means of increasing overall efficiency.

Provided the overall nutrition of the young female is adequate, the long term reproductive performance is not impaired by early breeding (Coop and Clark 1955; Yalcin and Bichard 1964).

The experiment reported here was conducted to assess the reproductive performance and protein utilization of ewe lambs bred to lamb at approximately 14 to 16 months of age. Rapeseed meal was compared to soybean meal as a source of supplemental protein during the second half of gestation.

2. Materials and Methods

Twenty - seven polled Dorset Horn ewe lambs weighing approximately 45 kg were bred to rams of the same breed and housed in individual slotted floor pens 10 weeks prior to the onset of lambing.

All animals were individually fed 680 g of grass hay plus 340 g of one of three pelleted concentrate supplements. The composition of the supplements is given (Table 1).

TABLE 1. COMPOSITION OF CONCENTRATE SUPPLEMENTS

	Treatment (%)		
Ingredients	1	2	3
Barley	20	52	74
Soybean meal	--	--	23
Rapeseed meal	66	35	--
Dry Molasses	10	10	--
Minerals and Vitamins*	4	3	3

* 0.5% Cobalt - Iodized salt; 1.5 - 2.2% Limestone
1.0% vitamins (435,000 IU vitamin A; 87,000 IU vitamin D; and 1,700 IU vitamin E per kg)

The supplements for treatments 1 and 2 were based on rapeseed meal (Brassica campestris) and contained 28.7 and 20.7% protein on a dry matter basis, respectively. The supplement for treatment 3 was based on soybean meal and had a protein content of 22.4% which was intended to be comparable to treatment 2. The grass hay used as the basal feed for the three treatments had a protein content of 5.9% on a dry matter basis. On the basis of analysed values the protein levels in the total ration were 13.50, 10.83, and 11.40 for treatments 1, 2, and 3 on a dry matter basis respectively. All rations provided 2.6 Mcals of DE per ewe per day.

Digestibility and nitrogen balance trials were conducted with a total of 16 ewes distributed over the three treatments during weeks 9 to 14, 16 to 18, and 19 to 20 of gestation. All animals were weighed weekly except during the balance trials when weighings were carried out at the beginning and end of the seven day collection period.

Samples of feed, feces, and urine were collected, stored, and analyzed as described in the general methods section of this report.

3. Results and Discussion

Ewe performance as measured by ewe liveweight changes and lamb birthweights is summarized (Table 2).

TABLE 2. EWE PERFORMANCE

	Treatment			
	1	2	3	
Number of Ewes	9	9	9	
Ewe weights (kg)				
Five weeks *prepartum*	42.7	45.2	42.6	
prepartum	45.8	48.9	46.5	
Weight gain	3.1	3.7	3.9	N.S.
post partum weight	39.8	42.8	40.6	
Lamb birthweights (kg)	3.76	3.74	3.55	N.S.
	(7M,2F)	(6M,3F)	(3M,6F)	

Ewe weight gains over the five week *prepartum* feeding period were not significantly ($p>0.05$) affected by the level or the source of protein. In comparing treatments 1 and 2, the high level of rapeseed meal in the ration tended to decrease weight gain of the ewes.

This may support the findings of Hussar and Bowland (1959) and Manns and Bowland (1963 a) who reported a depression in growth rate and efficiency of feed utilization when rapeseed meal was included in the diets of rats and swine. This depression in growth and feed intake was found to be related to the level of isothiocyanates present in rapeseed meal. It must be noted that depressed feed intake was not a factor in the present study as feed intake was held constant for the three groups. Despite the tendency for a lower liveweight gain in the ewes receiving the high rape diet, there was no significant effect ($p > 0.05$) of diet on lamb birthweights. This does not support the observation of Robinson et al. (1971) that lamb birthweights tend to decrease with increased protein intake in the case of ewe lambs. However, the protein levels compared in the present experiment were below those used by Robinson et al. (1971).

Rapeseed meal resulted in lamb birthweights similar to those from the soybean treatment at comparable levels of protein intake (treatment 2 versus 3). The ration used for treatment 1 contained 22% rapeseed meal. Despite this high level, no gross evidence of goitrogenic effects were observed in either the ewes or the lambs. This observation supports the conclusion of Bell et al. (1967).

The digestibility coefficients for the rations and nitrogen balance data at three stages of pregnancy are summarized (Table 3).

Dry matter digestibility was not significantly ($p > 0.05$) affected by either the level of protein or the stage of pregnancy, however digestibility of the ration containing soybean meal was consistently higher than that of rations containing rapeseed meal. This difference was not significant ($p > 0.05$). The results of McClelland and Forbes (1971) and Robinson and Forbes (1967) also demonstrated no effect of gestation or protein level on the digestibility of dry matter.

TABLE 3. DIGESTIBILITY AND NITROGEN BALANCE

		Treatment		
		1	2	3
Apparent Dry Matter Digestibility %				
Week of Gestation	9 to 14	63.58	63.15	66.05
	16 to 18	64.01	63.67	65.07
	19 to 20	63.26	63.87	64.98
Apparent Crude Protein Digestibility %				
Week of Gestation	9 to 14	67.24	57.67	61.24
	16 to 18	65.42	58.37	61.75
	19 to 20	66.19	56.88	62.30
Nitrogen Retention g/ewe/day				
Week of Gestation	9 to 14	3.33	1.79	2.46
	16 to 18	2.79	3.35	3.77
	19 to 20	4.18	2.37	3.01

As was to be expected, apparent protein digestibility was significantly ($p<0.05$) greater at the higher level of protein. Soybean protein had a higher digestibility than that of rapeseed meal when compared at a similar level of intake; 85.58 and 75.92% respectively as determined by difference. Protein digestion was not influenced by stage of gestation in any treatment ($p>0.05$).

Nitrogen retention tended to increase from week 9 to 18 of gestation on all three treatments with no apparent effect of level of protein intake. At the lower level of protein intake, nitrogen retention tended to be lower during the last week of gestation compared with the 18th week. This was in contrast to the higher level of protein which resulted in a continued increase in nitrogen retention. The results are not in complete agreement with those of Robinson et al. (1971) who demonstrated a linear increase in nitrogen retention both with increasing protein level and advancing stage of pregnancy.

While these workers demonstrated a significant increase in nitrogen retention as pregnancy progressed, our data did not agree with this finding for all three treatments. In addition, within the present study there were unequal observations within the subclasses of stage of gestation for the three rations. For these reasons nitrogen retention for the three treatments was compared on the basis of one stage of gestation only (weeks 17 to 20), (Table 4).

TABLE 4. NITROGEN RETENTION G/EWE/DAY

	Treatment		
	1	2	3
range	2.06-7.11	-0.03-5.48	1.89-4.90
mean	4.04	2.80	3.71
standard deviation	1.79	2.49	1.23

While there was no significant ($p > 0.05$) difference between treatments, the values appear to show that ewes on the higher level of protein retained a greater amount of nitrogen (treatment 1 versus 2). Ewes receiving the soybean supplemented ration also tended to retain more nitrogen than those receiving rapeseed meal at a similar level of protein intake. This may have been due to the higher digestibility of the soybean protein, however the individual animal variation must be noted.

Protein utilization may have been influenced by the level of energy intake which appeared to be slightly below that required to permit net body weight gain in the ewe lambs during the later stages of gestation.

All lambs were healthy at birth and all ewes appeared to have an adequate milk supply at parturition. These results suggest that 11% crude protein in the dry matter supplying approximately 68 g DCP may be adequate for the class of ewes studied. Rapeseed meal would appear to be a suitable source of protein and may be used safely even at relatively high levels for pregnant sheep.

EXPERIMENT II Performance of ewe lambs during lactation when fed rapeseed meal and low quality roughage.

1. Introduction

If the long term reproductive performance of the ewe is not to be impaired by early breeding then it would seem important to study the performance of the ewe lambs (Experiment I) during their lactation phase. Milk yields of ewes are extremely variable even within a single flock of sheep. Treacher (1971) reported that mature Dorset Horn ewes produced 49.4 to 62.7 kg per ewe for the first six weeks of lactation. He also reported that the level of feeding during pregnancy or lactation had no effect on milk yields.

Rapeseed meal was compared to soybean meal as a supplemental source of protein for lactating ewes. An effort was made to obtain an estimate of the milk produced and it's quality.

2. Materials and Methods

Twenty - seven polled Dorset Horn ewe lambs weighing approximately 42 kg post partum were housed in individual slotted floor pens during the eight week lactation period. The ewes were individually fed 1021 g of grass hay and 500 g of one of three pelleted concentrate supplements (Table 1).

The supplements for treatments 1 and 2 were based on rapeseed meal and contained 32.42 and 20.45% crude protein on a dry matter basis respectively. The supplement for treatment 3 was based on soybean meal and had a protein content of 19.53% which was intended to be comparable to treatment 2.

TABLE I. COMPOSITION OF CONCENTRATE SUPPLEMENTS

	Treatment		
Ingredients	1	2	3
Barley	11	50	74
Soybean Meal	--	--	20
Rapeseed Meal	75	35	--
Dry Molasses	10	10	--
Minerals and Vitamins*	4	5	6

* 0.5% Cobalt - iodized salt; 2.2 to 2.5% limestone; 1.2 to 2.0% trace mineral mix; 1.0% vitamins, supplying 435,000 IU vitamin A, 87,000 IU vitamin D, and 1,700 IU vitamin E per kg.

The grass hay used as the basal feed for the three treatments had a protein content of 5.9% on a dry matter basis. The protein content of the total rations were 13.80, 10.08, and 9.79 for treatments 1,2, and 3 respectively, based on analyzed values (DM basis). All rations were designed to provide 4.0 Mcal DE per ewe per day.

The experiment was designed so that one half of the animals that received the higher level of rapeseed meal during pregnancy (Experiment I) received the lower level of rapeseed meal during lactation (treatment 1). The other half of the animals on the high level of rapeseed meal during pregnancy continued to receive the higher level during lactation (treatment 2). Conversely, half of those animals receiving the low level of rapeseed meal during pregnancy received the higher level during lactation (treatment 3); while the others continued to receive the low level during lactation (treatment 4). Those animals receiving soybean meal during pregnancy continued to get the soybean ration during lactation (treatment 5).

A creep feed ration consisting of 50% soybean meal and 50% rolled barley was offered to the lambs at approximately one week of age.

3. Results and Discussions

Ewe performance as measured by ewe weight change and lamb weaning weights in terms of both pregnancy and lactation treatment of the ewe is summarized (Table 2).

Due to the fact that there were small numbers of animals per treatment, the weight changes of the ewes and the average daily gain of their lambs could not be analyzed statistically. However, the mean values indicated only a small difference in the weight changes of the ewes on any of the treatments. The mean ADG values of the lambs also indicated only small differences between treatments. The lambs on treatments 1 and 2 appeared to start consuming creep feed later than those on any other treatment. This may be evidence to show that the level of protein offered to the ewe during pregnancy has a notable effect on the lactation phase of the ewe.

TABLE 2. EWE AND LAMB PERFORMANCE AND

CREEP FEED CONSUMPTION

	Treatment				
	1 HR-LR	2 HR-HR	3 LR-HR	4 LR-LR	5 LS-LS
Number of Ewes	5	5	5	4	9
Ewe weights (kg)					
postparum weights	39.3	38.8	42.4	43.4	41.5
56 day weight	41.1	39.9	42.1	42.4	42.2
weight changes	+1.8	+1.1	-0.3	-1.0	+0.7
Lamb weights (kg)					
birthweight	3.65	4.07	3.62	3.89	3.61
56 day weight	18.64	18.77	19.60	19.51	17.82
weight gain	14.99	14.70	15.98	15.62	14.21
average daily gain	0.268	0.263	0.285	0.279	0.254
	(2M,3F)	(5M)	(2M,3F)	(3M,1F)	(3M,6F)
Creep Feed Consumption of Lambs					
start of creep consumption (days)	30	28	24	23	23
start of creep consumption (kg)	10.2	10.6	9.0	9.2	8.6
total feed intake g	9619	7763	12,033	8341	8535
average daily intake g	370	431	376	253	259

A summary of ewe and lamb performance and creep feed consumption in terms of the lactation treatment of the ewe is summarized (Table 3).

TABLE 3. EWE AND LAMB PERFORMANCE AND CREEP FEED CONSUMPTION

	Treatment			
	1	2	3	
	High Rape	Low Rape	Low Soybean	
Ewe Performance	14% CP	10% CP	10% CP	
number of ewes	9	9	9	
post partum weight (kg)	41.7	41.4	41.5	
56 day weight	41.1	41.8	42.2	
weight change	-0.6	+0.4	+0.7	N.S.
milk production (kg/day)	1.02	1.08	1.18	
Lamb Performance				
birthweight (kg)	3.69	3.77	3.61	
56 day weight	18.90	19.07	17.82	
weight gain	15.21	15.30	14.21	
average daily gain	272	273	254	N.S.
Creep Feed Consumption	9	9	9	
age at start in days (10g+/day)	26	27	23	N.S.
weight at start (kg)	9.89	9.71	8.57	N.S.
total feed intake (kg)	9.66	9.05	8.54	
average daily intake (g)	310	295	260	N.S.
	(6M,3F)	(5M,4F)	(3M,6F)	

Weight changes of the ewes over the eight week lactation period were not significantly ($p > 0.05$) affected by the level or the source of protein. When comparing treatments 1 and 2 the ewes on the higher level of rapeseed meal tended to lose weight slightly. The ewes receiving the soybean supplemented ration tended to gain slightly more weight than those on rapeseed meal at a similar level of protein intake.

The average daily gain of the lambs was not significantly ($p > 0.05$) affected by either the level or the source of protein. However, it would appear that the source of protein had a greater affect on the ADG than did the level of protein fed to the ewe. The very similar ADG of the lambs on treatments 1 and 2 is probably reflected by the similar average daily creep feed intake of those lambs and not due to the feeding regime of the ewes. The lambs on treatment 3 tended to gain less and consume less creep feed than those ewes receiving the rapeseed protein. The lower creep feed intake of the lambs on treatment 3 compared to treatments 1 and 2 may have been due to a slightly greater amount of milk produced by the ewes on the soybean ration. The lambs on treatment 3 also started consuming creep feed sooner in terms of both age and weight, than those whose dams received rapeseed protein. The ration used for treatment 1 contained 25% rapeseed meal and despite this high level, no gross evidence of goitrogenic effects were observed in either the ewes or the lambs. This observation supports the conclusion of Bell _et al_. (1967). These results suggest that 10% CP in the dry matter supplying approximately 92 g DCP may be adequate for the class of ewes studied. Rapeseed meal would appear to be a suitable source of protein and may be used safely even at relatively high levels for lactating sheep.

Low quality forages such as those used in this experiment may be fed to lactating sheep provided they are adequately supplemented with a high protein concentrate mixture.

EXPERIMENT III The influence of the energy source and physical form of all concentrate rations for early weaned lambs.

1. Introduction

Grains or concentrate feeds are more valuable as energy sources per unit of weight than the best quality roughages. When there is a small differential in the costs of good quality roughage and grain, the grain will be the cheaper source of energy. High concentrate rations using barley have become popular for feeding cattle. Studies by Butcher et al. (1961) at the Utah Agricultural Experimental Station demonstrated that lambs can also be successfully fattened on a high concentrate diet if they can be kept on feed. The workers at Utah found it necessary to have feed available at all times and that the feed be pelleted in order to prevent sorting which they thought would lead to reduced intakes and nutrient imbalance. The workers compared two rations; a 27% barley, 60% alfalfa ration was compared to a 85% barley, 5% alfalfa ration. A significant advantage of the high barley diet was an improvement in feed efficiency. They also realized a significant increase in dressing percentage for the high barley diet. They found no detrimental effects of the high concentrate diet on any of the carcass characteristics studied. They did find however, that lambs on the high concentrate diet had a skeleton which was less developed. However, this was considered a possible advantage since it would increase the edible portion of the lamb carcass.

Carbohydrates that are fed to ruminants are largely degraded by rumen microorganisms to acetic propionic and butyric acids.

In ruminants a large proportion of the dietary energy is wasted as heat. This is due in part to the animal living on energy derived from these fatty acids. The relative proportions of the various fatty acids produced in the rumen affect their efficiency of use. In general, the more acetic acid produced relative to propionic and butyric, the lower the efficiency of utilization. Substitution of concentrate for roughage tends to lower the production of acetic acid relative to the others. The Utah workers examined the rumen fatty acid mixtures produced on the high and low concentrate diets and compared these to the feed efficiencies observed in the fattening lambs.

They found that as the amount of barley in the diet was increased up to a maximum of 85%, acetic acid production decreased and propionic acid increased. Interpretation of this trend indicates that the nutrients obtained from the barley diets are used more efficiently than an equal quantity of nutrients absorbed from the roughage diet. The feed efficiency data from the lamb fattening trial supported this; the figures showing that 32% more feed was required for each pound of gain from the roughage diet.

Orskov and Fraser (1972) conducted an investigation to determine whether the rolling of barley before pelleting is required for the most efficient utilization of the grain by lambs. Diets consisting of 91% barley, 7.5% white fish meal, and 1.5% limestone were fed. They found that dry matter digestibility decreased from 78.2 to 74.9 ($p < 0.01$) and the dry matter required per kg liveweight gain increased from 2.56 to 2.80 kg ($p \; 0.05$) as a result of rolling. This work was extended in a trial in which 12 lambs were given either whole unprocessed barley or whole barley pelleted through a 7.8 mm die.

The lambs given whole barley had a higher pH (6.2 versus 5.2) in the rumen and a higher proportion of acetic acid (53.1 versus 43.9) in the rumen liquor than those receiving pelleted barley. The proportion of butyric and higher acids was not significantly changed. The digestibility of dry matter (80.2 versus 78.9) and organic matter (83.5 versus 81.6) was higher for the whole unprocessed barley diet. This effect may have been due in part to an increase in the fiber digestibility and to a presumed survival of cellulolytic bacteria at the higher rumen pH.

The main purpose of the experiment reported here was to compare wheat and barley as the energy source in all concentrate rations for early weaned lambs. The grains were fed in three physical forms and digestibility of nutrients was determined at two levels of intake. A short discussion related to the influence of grain and its form on some rumen parameters is also included.

2. Materials and Methods

Forty - eight Dorset Horn lambs weaned at eight weeks of age and averaging 20.6 kg were assigned at random to treatments in a 2 x 3 factorially designed experiment. Wheat and barley were fed in the whole rolled and pelleted forms. The grains were supplemented with a commercial 32% pelleted protein supplement (Table 1).

The supplement was used at a level of 25% of the rations until the lambs reached approximately 30 kg liveweight at which time it was reduced to 15% of the ration and maintained at this level until the lambs were marketed at a weight of 45 kg. These levels of supplementation resulted in the barley rations having an initial CP level of 17.1% and a final value of 15.1%

TABLE 1. COMPOSITION OF SUPPLEMENT

Ingredient	kg
Wheat shorts	479
Cottonseed meal	181
Dry distillers solubles	91
Urea	32
Salt	36
Dicalciumphosphate	23
Limestone	32
Molasses	32
Premix*	23

*Vitamin A 325	70 g
Vitamin D_2 80	60 g
Copper sulphate	20 g
Cobalt sulphate	20 g
Manganese sulphate	300 g
Zinc sulphate	400 g
Prodine	36 g

plus wheat shorts to make 2.3 kg premix

The initial and final CP values for the wheat rations were 18.4 and 16.6% respectively. It is interesting to note that the whole barley used throughout the trials had an average bushel weight of 23.92 kg/bu compared to 26.93 kg for wheat.

While the lambs were suckling, they had access to creep feed based on barley. At eight weeks of age they were weaned directly onto the experimental rations which were fed twice daily to appetite.

After weaning, no roughage supplements were offered. Each group of lambs consisted of four entire males and four females.

In conjunction with the growth experiment, a series of digestibility trials were conducted to measure the apparent digestibility of dry and organic matter, gross energy, and protein. These values were determined for wheat and barley in the three physical forms and at feed intakes of 600 g and 1,000 g. Three male lambs weighing approximately 45 kg were used for each determination and the levels of intake represented approximately maintenance and appetite. The protein-mineral-vitamin supplement was fed at a level of 15% of the rations during the digestion trials. The total collection technique was employed using a 10 day preliminary period and a 10 day collection for each treatment.

Dressing percentage was calculated on representative lambs from the pelleted and whole, barley and wheat groups. These values were determined from the warm carcass weight and the liveweight just before being loaded on the truck for shipment. The lambs had been without feed for 16 hours prior to shipment.

A representative sample of rumen contents was taken at the time of slaughter and within two hours was passed through two layers of cheesecloth. The resulting fluid was centrifuged at 7,000 rpm for 20 minutes. The pH was read on the resulting supernatant. Also at the time of slaughter approximately 225 square cm of rumen wall were sampled from each animal and stored in formalin. Photographs were taken of the rumen wall samples as well as the rumen contents. Histological sections of the rumen wall samples were prepared.

3. Results and Discussions

(a) Lamb Performance

The average daily gain (ADG), feed conversion ratio (FCR), and feed intake and how they were affected by the type of grain and method of processing are summarized (Table 2).

TABLE 2. THE MAIN TREATMENT EFFECTS OF GRAIN AND PROCESS ON AVERAGE DAILY GAIN, FEED CONVERSION, AND FEED INTAKE

	Grain		Process		
	Barley	Wheat	Whole	Rolled	Pelleted
Number of lambs	24	24	16	16	16
ADG (g)	254	242	281a	250ab	213b
FCR	4.09	4.25	4.04	4.31	4.16
Feed intake (g DM/kg $^{0.75}$)	79	78	88	81	68

ab within comparison groupings; means followed by different letters are significantly ($p < 0.05$) different

There was no significant ($p > 0.05$) difference between the ADG of the wheat and barley fed groups. There was, however, a significant ($p < 0.05$) effect of processing with whole grains resulting in a faster rate of gain than pelleted grains. Rolled grains resulted in an intermediate rate of gain which was not significantly ($p > 0.05$) different from either the whole or pelleted forms. There was no significant ($p > 0.05$) interaction between the type of grain and method of processing with regard to ADG.

Feed conversion ratios (FCR) were group averages and could not be analyzed statistically. However, the mean values indicated only a small difference in the FCR of wheat compared to barley with a tendency for barley to be slightly superior. Similarily, the differences in FCR values for the three physical forms were small but there was a tendency for the whole grains to be utilized more efficiently.

Feed intake, expressed per unit of metabolic weight (g DM/kg $^{0.75}$) and representing the mean feed intake over the growth period was similar for wheat and barley. The method of processing appeared to influence this parameter, with feed intake being greatest for whole grains and least with the pelleted form. As with FCR values, feed intakes were group averages and were not subjected to statistical analysis.

The individual treatment results in terms of lamb performance are given (Table 3).

The effect of processing was similar for both wheat and barley, with ADG being significantly ($p<0.05$) greater for the whole grains than for the pelleted grains. There was no significant ($p>0.05$) difference between whole and rolled or rolled and pelleted forms for either grain. There was a similar trend with both grains for growth rate to be greatest for the whole grain and least for the pelleted form with rolled grains being intermediate. The FCR values did not show the same trend as growth rate, however, feed conversion efficiency tended to be superior for the whole barley group. Feed intake followed a similar trend to growth rate with this parameter being greatest for the whole grains and lowest for the pelleted form. This trend was similar for both wheat and barley.

TABLE 3. LAMB PERFORMANCE AS INFLUENCED BY WHEAT AND BARLEY IN THREE PHYSICAL FORMS

	Barley			Wheat		
	Whole	Rolled	Pelleted	Whole	Rolled	Pelleted
Number of lambs	8	8	8	8	8	8
ADG (g)	292a	251abc	219c	269ab	249abc	208c
FCR	3.85	4.43	2.98	4.22	4.20	4.34
Feed intake (g DM/kg $^{0.75}$)	88	84	86	87	78	70

abc means followed by different letters are significantly ($p < 0.05$) different

(b) Digestibility of Grains

Digestibility of gross energy and protein for the main treatment effects of process, grain, and level of feed intake are summarized (Table 4).

The digestibility of gross energy (GE) was not significantly ($p > 0.05$) affected by the method of processing. As was to be expected, the digestibility of energy of wheat was significantly ($p < 0.05$) greater than that of barley. As the level of feed intake was increased, there was a small but significant ($p < 0.05$) depression in the digestibility of energy. A significant ($p < 0.05$) interaction between grain and process was observed with regard to the digestibility of energy. This may be explained by the digestibility of rolled wheat being slightly higher than the other forms of wheat, and the rolled barley having a slightly lower value than the

TABLE 4. NUTRIENT DIGESTIBILITY COEFFICIENTS FOR THE MAIN TREATMENT EFFECTS

	Number of Animals	Digestibility Coefficients Gross Energy	Digestibility Coefficients Crude Protein
Grain			
Barley	18	82.1	80.5
Wheat	18	85.7*	84.8*
Process			
Whole	12	84.1	82.2 ab
Rolled	12	83.8	84.0 a
Pelleted	12	83.7	81.8 b
Level of Intake			
600 g	18	84.4	83.9
1000 g	18	83.3*	81.3*

* differences between means are significant ($p < 0.05$) F test

ab means followed by different letters are significantly ($p < 0.05$) different

other forms of barley. This result may have been influenced by the fact that some difficulty was experienced in keeping lambs on feed at the higher level of feed intake with the rolled wheat ration during the digestion trials.

The digestibility of protein was significantly ($p > 0.05$) influenced by the method of processing. Protein digestibility decreased when the grain was pelleted compared to rolled grains, while the value for whole grains was intermediate and not significantly ($p > 0.05$) different from the pelleted or rolled forms. Digestibility of protein was significantly ($p < 0.05$) lower for barley than for wheat. As was the case with energy, increasing the level of feed intake also resulted in a significant ($p < 0.05$) depression in the digestibility of protein.

The level x grain, level x process, and second order interactions were not significant ($p > 0.05$). There was a significant ($p < 0.05$) grain x process interaction which could be explained by the digestibility of protein for wheat being improved by rolling, compared to the whole grain. There was no such effect in the case of barley. As mentioned earlier, the difficulty experienced with the rolled wheat in the digestion study may have influenced this result.

The results of this experiment indicate that rapid liveweight gains and efficient feed conversion can be achieved by early weaned lambs fed all concentrate rations. The ADG of the barley fed group was 254 g and of the wheat fed group 242 g, while the FCR values were 4.09 and 4.25 for barley and wheat respectively. These results suggest that either barley or wheat are suitable energy sources in all concentrate rations for lambs and no digestive disturbances were encountered in any animals on either grain during the growth study. These findings confirm those of Orskov et al. (1971) who have reported rapid and efficient gains by early weaned lambs fed all concentrate diets. Despite the higher DE concentration of wheat compared to barley (3.64 versus 3.28 Mcals DE/kg DM), the lambs fed barley had a slightly superior growth rate at a similar level of feed intake. This suggests that the DE of barley was utilized with greater efficiency than that of wheat.

With regard to method of processing, the best growth rate and feed conversion efficiency was achieved with whole grains, and of the treatments tested, the whole barley group had the best performance. This result substantiates the observations of Hanke and Jordan (1963), Meyer and Hull (1964), Botkin et al. (1965), and Christensen (1967). The results do not agree with those of Lodge (1966), which indicated that rolling of barley improved the rate of gain and feed efficiency. In the experiment of Hanke and Jordan (1963), it was observed that pelleting barley depressed feed intake and had an adverse effect on ADG and FCR. This finding is substantiated by the results of the present experiment.

The superior growth rate of the whole grain fed lambs could in part be explained by a greater feed intake by these animals. The differences in feed intake were particularly noticable in the early stages of the experiment when whole grains appeared to be most acceptable and pellets least acceptable to the young lambs. It may be suggested that hard pellets could be responsible for the lower feed intake, however, it is the opinion of the author that the pellets used in this experiment were not unduly hard.

The digestibility of energy was not significantly ($p>0.05$) affected by the method of processing, indicating that lambs are capable of digesting whole grains as efficiently as the processed forms. This is in agreement with the results of MacRae and Armstrong (1969) who also reported no difference between the digestibility of whole and rolled barley. Orskov and Fraser (1972) have demonstrated whole barley to have a higher digestibility than pelleted barley for lambs. In the present experiment the whole grains tended to have a higher digestibility of energy than the pelleted form, however the difference was not significant ($p > 0.05$).

In order to ascertain if the digestibility of whole grains was influenced to a greater extent by the lower level of feed intake compared to the rolled or pelleted forms, the digestibility of nutrients was determined at two levels of feed intake. The statistical analysis of the main treatment effects indicated that there was no significant ($p > 0.05$) interaction between the method of processing and the level of intake. However, it is interesting to compare the digestibility of energy and protein for the three methods of processing at two levels of intake (Table 5).

TABLE 5. THE INFLUENCE OF LEVEL OF FEED INTAKE AND METHOD OF PROCESSING ON NUTRIENT DIGESTIBILITY

	Level of Feed intake		Depression in Digestibility %
	600 g	1000 g	
Digestibility of GE%			
whole	85.2	83.0	2.6
rolled	83.6	84.0	-*
pelleted	84.4	83.0	1.7
Digestibility of CP%			
whole	83.9	80.5	4.0
rolled	85.1	82.8	2.7
pelleted	82.4	80.1	2.8

* This result may have been influenced by some difficulty experienced in maintaining lambs on feed at high level of intake with rolled wheat during the digestion trials.

The results indicated that the digestibility of the nutrients was depressed at the higher level of intake with the exception of the digestibility of energy for the rolled grains. The problem associated with rolled wheat has been mentioned previously and may have influenced this result. The results (Table 4), also suggest that there was a tendency for the digestibility of nutrients of whole grains to be depressed to a slightly greater extent than those of the processed forms as a result of increasing the feed intake from maintenance to appetite. This was merely a tendency and was not statistically significant, therefore it would appear that the lambs were capable of digesting the whole grains with similar efficiency to the processed forms whether at the maintenance or appetite levels of feeding.

The effect of the type of grain and the method of processing on dressing percentage and certain rumen characteristics were assessed (Table 6).

TABLE 6. THE EFFECT OF GRAIN AND PROCESS ON DRESSING PERCENTAGE AND CERTAIN RUMEN CHARACTERISTICS

	Grain		Process	
	Barley	Wheat	Whole	Pelleted
Dressing Percentage	51.95	53.49	52.02	53.41
Rumen Characteristics				
Contents	no noticeable odor	pungent butyric acid odor	dry, some evidence of whole grains	wet, "soup-like" consistency
pH	5.55	5.56	5.14	5.97
papillae	no noticeable differences →		long, "leaf like"	short, "club like"

With regard to dressing percentage, the mean values indicated only a small difference between wheat and barley with a tendency for wheat to be slightly superior. An effect of processing was observed, with pelleted grains resulting in a slightly superior dressing percentage than whole grains.

The type of grain and the method of processing appeared to have some effect on certain rumen characteristics. Rumen contents of wheat fed lambs gave off a very pungent "butyric acid like" odor, while this was not the case with the barley fed lambs. Pelleted grains caused the rumen contents to have a wet (soup-like) consistency. This was not observed in the whole grain fed lambs; the contents being comparitively dry.

There was no difference between the rumen content pH values of the wheat and barley fed groups. However, the rumen contents of the lambs fed whole grains were considerably more acidic than those fed pelleted grains. There were no noticeable differences in the rumen papillae of barley compared to wheat fed groups. It is interesting to note, however, that those lambs fed whole grains had long, "leaf-like" papillae compared to the short "club-like" characteristic of pelleted grain fed lambs.

EXPERIMENT IV The influence of the level of protein supplementation of whole barley - based rations for early weaned lambs.

1. Introduction

There is considerable variation in the estimated protein requirements of young growing lambs. It is probable that much of this variation is a result of differences in the age and rate of gain of the lambs studied. Also most values have been obtained using low energy rations consisting of high proportions of roughage. Andrews and Orskov (1970) carried out one of the few experiments on protein requirements of early weaned lambs using all concentrate rations. They suggested that when these rations were fed *ad libitum*, the optimum crude protein concentration of the ration should be 17.5, 15.0, 12.5, and 12.5% at body weights of 20, 25, 30, and 35 kg respectively.

Now that the grain and the form of that grain has been established as the ideal ration for feeding lambs, it would seem necessary to establish more precisely the amount of protein supplementation necessary to give optimum economical gain and feed conversion.

The experiment reported here was therefore designed to assess the performance of early weaned lambs fed whole barley based rations with different levels of protein supplementation.

2. Materials and Methods

Fifty - four polled Dorset Horn lambs, weaned at eight weeks of age and averaging 20 kg were assigned at random to four treatments. The treatments consisted of whole barley plus a 32% protein pelleted supplement (as described in Experiment III) in order to obtain different levels of protein in the ration during three periods of growth (Table 1).

TABLE 1. LEVELS OF PROTEIN IN THE RATION DURING THREE PERIODS OF GROWTH

	Period		
	1	2	3
Treatment	20 to 29 kg	29 to 36 kg	36 to 45 kg
1	18	18	18
2	18	15.5	13
3	16	13.5	11
4	14	14	14

The barley and protein supplement contained 12.5% and 36.2% protein on a dry matter basis, respectively. In conjunction with the growth experiment, a series of digestibility studies were conducted to measure the apparent digestibility of dry matter and protein. These values were determined for the 18% protein ration when fed during the three periods of growth. Three male lambs were used for each determination and the levels of intake at 600 g, 900 g, and 1000 g represented appetite. The trials were carried out when the average of the three lambs weights were 25, 35, and 40 kg to represent growth periods 1, 2, and 3 respectively.

In a subsequent trial, three male lambs were used to determine the digestibility of 1000 g of whole barley when fed alone. When the protein level of any ration was below 13%, additional minerals and vitamins were supplied in addition to those supplied in the protein supplement.

3. Results and Discussion

The main effects of level of protein during three periods of growth on the average daily gain and feed conversion efficiency are presented (Table 2).

When comparing the ADG and FCR of all the lambs on all treatments during period 1 (20 - 29 kg) it would appear that the most efficient gain was obtained when the lambs received 16% CP in the ration. When the mean ADG of all lambs receiving 18% CP (treatments 1 and 2 combined) is compared to treatments 3 and 4 the greatest growth rate was achieved by those lambs receiving 16% CP in the ration. If FCR values are viewed in the same manner, the 16% CP is again the best ration. A 14% CP ration for fattening lambs during this initial stage would apparently be insufficient due to the fact that the lambs on this ration realized the lowest ADG and consumed the greatest amount of feed per unit gain.

In period 2 (29 to 36 kg) those lambs fed the 14% CP ration produced the most economic gain. It must be noted however that the lambs on this ration may have compensated for shortage of protein in their ration during the initial period of growth.

During the final finishing period from 36 kg to market weight, the results suggest that one could continue to feed 14% CP in an all concentrate ration. These levels compare favourably with those of Andrews and Orskov (1970).

TABLE 2. THE EFFECT OF THE LEVEL OF PROTEIN DURING THREE PERIODS OF GROWTH ON THE AVERAGE DAILY GAIN AND FEED CONVERSION

Average Daily Gain (ADG)g

	Period		
	1	2	3
	20 to 29 kg	29 to 36 kg	36 to 45 kg
Treatment			
1. 18 - 18 - 18	253 } 242	235	244
2. 18 - 15.5 - 13	231	238	250
3. 16 - 13.5 - 11	247	235	219
4. 14 - 14 - 14	233	318	238

Feed Conversion Ratio (FCR)

Treatment			
1. 18 - 18 - 18	3.12 } 3.28	4.36	5.11
2. 18 - 15.5 - 13	3.43	4.36	5.16
3. 16 - 13.5 - 11	3.36	4.60	5.57
4. 14 - 14 - 14	3.82	4.15	4.94

The effect of the level of protein over the entire feeding period on average daily gain and feed efficiency are summarized (Table 3).

When comparing the ADG and FCR over the entire feeding period it would again appear that lambs require 16% CP in an all concentrate ration during the initial growing period.

TABLE 3. THE EFFECT OF THE LEVEL OF PROTEIN OVER THE ENTIRE FEEDING PERIOD ON THE ADG AND FCR

	Treatment			
	1	2	3	4
	18-18-18	18-15.5-13	16-13.5-13	14-14-14
Average daily gain (ADG) g	246	234	237	262
Feed conversion ratio (FCR) g	4.06	4.44	4.22	4.35

When the lambs reach a weight of approximately 30 kg, it would appear that a ration consisting of 14% CP would be the optimum level to produce the most economical gain. The slightly superior FCR of those lambs fed 18% CP during the entire feeding period (treatment 1) would not warrant the extra cost of supplementation. The ADG and FCR of lambs on treatment 3 were slightly superior to those on treatment 2, which indicates that a ration consisting of 16% CP can be fed to lambs during the initial growing phase and that approximately 14% CP in the ration from 30 kg to market weight would be the best feeding regime for lambs.

The superior ADG of lambs (treatment 4) receiving 14% CP in the ration would tend to indicate that 11% CP (no protein supplement added to the barley during the final finishing period, treatment 3) would be inadequate.

Digestibility

Digestibility coefficients for dry matter and crude protein as well as nitrogen retention values for four treatments fed at three periods of growth are presented (Table 4).

TABLE 4. NUTRIENT DIGESTIBILITY COEFFICIENTS --

FOUR TREATMENTS AT THREE PERIODS OF GROWTH

Treatment	Average weight of lambs (kg) (period of growth)	Apparent digestibility of dry matter %	Apparent digestibility of crude protein %	Nitrogen retained g/day
18% CP	25 (1)	83.97	82.68	6.04
18% CP	35 (2)	84.24	83.50	6.74
18% CP	40 (3)	83.68	83.30	9.14
11% CP (100% whole barley)	43 (3)	80.91	71.42	3.77

The results of the digestibility studies (Table 4), suggest that the apparent digestibility of dry matter and crude protein does not change with increasing body weight of the lamb. The increase in nitrogen retention as the lambs gained weight is difficult to explain in view of the fact that the amount of feed required per unit gain increased as the lambs approached market weight. The apparent digestibility of dry matter and crude protein of the whole barley when fed alone to lambs (80.91 and 71.42 respectively) compare favourably to literature values.

E. SUMMARY

The results of this study appear to indicate that it is both economical and biologically feasible to raise sheep under total confinement conditions provided their nutritional and management requirements are met. These requirements can be achieved using feeds and techniques available to sheep producers in British Columbia. The biological and economic efficiency of such a production system is dominated by the resources required to maintain the breeding ewe.

Provided the overall nutrition of the young female is adequate, the long term reproductive performance is not impaired by early breeding. Ewe lambs may be bred to lamb at 14 months of age and at 8 month intervals thereafter and hence attain maximum lambing performance. These ewes can utilize low quality roughage during both the pregnancy and lactation periods providing it is adequately supplemented with a concentrate mixture. Rapeseed meal or soybean meal may be used in such a supplement to provide approximately 11% CP in the ration during late pregnancy and early lactation. Feed intake during late pregnancy should be such that ewe lambs (45 kg) are ensured of receiving approximately 68 g DCP and 2.6 Mcal DE per ewe per day. In the lactation period these ewes apparently require about 92 g DCP and 4.0 Mcal DE per ewe. Rapeseed meal when fed at levels of 22 and 25% of the pregnancy and lactation rations respectively, did not cause any detrimental effects in either the ewes or the lambs.

Suckling lambs do not appear to consume appreciable amounts of creep feed until they are 3 to 4 weeks of age or approximately 9 to 11 kg. The ration ingredients and nutrient composition of creep feed do not appear to be as critical as palatability and hence intake with regard

to lamb growth rate.

Dry matter and protein digestibility of the rapeseed meal and soybean meal rations were not affected by the stage of pregnancy of the ewe. Nitrogen retention tended to increase with advancing pregnancy up until the 18th week of gestation, however, no consistent increase was noted after this period.

The results of the experiments with mature ewes would suggest that the nutrient requirements of this class of animal suckling single lambs are quite different from the requirements of those with twins. A level of 227 g DCP and 6.6 Mcal DE daily would appear to be adequate for the former while 272 g DCP and 8.4 Mcal DE daily may be closer to the requirement for ewes with twin lambs. This becomes even more apparent when the ewes are bred to lamb every eight months.

Early weaned lambs are capable of efficient utilization of all concentrate diets. Wheat and barley as the energy source produced similar results in terms of growth rate and feed conversion efficiency. Whole grains and in particular whole barley, supplemented with a protein concentrate to provide a 16% CP ration during the initial fattening period (weaning to 30 kg), resulted in the best animal performance. A 14% CP ration is suggested to finish lambs from 30 kg to market weight.

In terms of digestibility, whole grains were utilized with equal efficiency to that of processed forms even when fed to appetite. Feeding all concentrate diets to lambs did not have any detrimental effect on either dressing percentage or on rumen development. It would appear that processing cereal grains for lambs is unnecessary in terms of both digestibility and animal performance.

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APPENDICES I TO V

The experiments as reported in Appendices I and II were carried out mainly as pilot studies to obtain indications of the levels of protein necessary for lactating ewes. These experiments were also used to test procedures, facilities, and equipment which had been designed for precise determinations of intake and digestibility of rations.

The experiments reported in this study gave rise to a large volume of raw data. For simplicity reasons these data are not included in the appendix but are tabulated and recorded in the Department of Animal Science files.

APPENDIX I A comparison of the performance of mature ewes suckling single or twin lambs and fed two levels of energy at a constant level of protein.

1. Introduction

The levels of energy and protein fed to the ewe during gestation and lactation have been shown by many workers to have a significant influence on lamb birthweights and subsequent growth rates. However, there is not complete agreement as to the levels of protein and energy to feed nor when increases in energy and protein fed are most valuable for maximum lamb growth.

Gardner and Hogue (1963) found that feeding higher energy and protein levels during late gestation and lactation than recommended by NRC (1957), increased the 90 day weights of both single and twin lambs.

The primary objective of the experiment reported here was to determine the overall interrelationship of energy and protein levels fed to ewes suckling single and twin lambs and of creep rations on the growth of lambs.

2. Materials and Methods

The 24 animals used in the experiment formed part of a flock of polled Dorset Horn mature ewes ranging in age from 2 to 5 years. The ewes had been bred to rams of the same breed and up until the beginning of the experiment had received approximately 1.8 kg of grass - legume hay per ewe per day. Twelve of the ewes weighing approximately 55 kg had single lambs and were divided equally among treatments according to age and weight while the other 12 had twin lambs and were also divided equally among treatments according to age and weight. All the ewes were housed and fed in the four treatment groups for the eight weeks of lactation. All ewes received 1.8 kg of alfalfa - brome hay plus one of four concentrate supplements (Table 1).

TABLE 1. COMPOSITION OF CONCENTRATE SUPPLEMENTS

	Treatment			
	Singles		Twins	
Ingredients	1	2	3	4
Rolled barley	85	94.5	86.5	96
Soybean meal	8	--	8	--
Minerals *	6	4.5	4.5	3
Vitamins **	1	1	1	1

* all rations were designed to provide 0.28% calcium, 0.21% phosphorus, 0.5% salt

** all rations provided 559 IU vitamin A and 62 IU vitamin D per kg

The treatments were comprised of two levels of DCP and three levels of energy intake (Table 2).

TABLE 2. TREATMENTS

	1	2	3	4
intake per ewe per day	singles		twins	
alfalfa brome hay (kg)	1.8	1.8	1.8	1.8
concentrate supplement g	318	590	771	1225
DCP g (estimated)	227	227	272	272
DE Mcal (estimated)	5.5	6.6	6.6	8.4
daily feed intake per ewe kg (air dry)	2.13	2.40	2.59	3.04

When the lambs reached approximately 14 days of age they were offered a 1:1 mixture of flaked corn and soybean meal until they reached approximately six weeks of age, at which time they were given a 1:1:1 mixture of corn, soybean meal, and rolled barley.

The composition of the feeds used in both the ewe rations and the lamb creep feed is presented (Table 3).

TABLE 3. COMPOSITION OF FEEDS

Ingredients	DM%	CP%*	GE kcal/g*
alfalfa - brome hay	91.41	15.91	4.292
rolled barley	87.45	11.52	4.227
soybean meal	87.67	54.00	4.695
flaked corn	86.67	8.29	4.254

* DM basis

3. Results and Discussion

Ewe performance as measured by ewe weight changes and lamb weaning weignts is presented (Table 4).

TABLE 4. EWE PERFORMANCE

	Singles		Twins	
Treatment	1	2	3	4
DCP g/day	227	227	272	272
DE Mcal/day	5.5	6.6	6.6	8.4
Number of ewes	6	6	6	6
Ewe weights (kg)				
postpartum weight	56.4	53.6	67.5	67.3
56 day weight	53.7	54.6	62.1	65.2
weight gain or loss	-2.7	+1.0	-5.4	-2.1
Lamb weights (kg)				
birthweight	4.03	4.13	3.78	3.30
56 day weight	20.87	21.70	18.03	17.84
weight gain	16.84	17.57	14.25	14.54
average daily gain	0.301	0.314	0.255	0.260
Lamb Creep Feed Intake				
Average Daily Intake g (air dry)	132	82	104	86
	(2M,2F)	(5M,1F)	(8M,4F)	(4M,8F)

There was no significant difference ($p > 0.05$) between the weight changes of the ewes with single or twin lambs or between levels of protein or energy in the rations. However, when comparing treatments 1 and 2 (ewes with single lambs) the ewes receiving the higher energy level tended to gain weight slightly while those on the lower level lost weight slightly when both groups were fed a similar level of protein intake. When comparing treatments 3 and 4 (ewes suckling twin lambs) the ewes receiving the higher level of energy lost less weight than those on the lower level. These results appear to show that 6.6 Mcal and 227 g DCP per ewe per day may be adequate for mature ewes suckling single lambs, while 8.4 Mcal per ewe per day may be close to the energy requirement for ewes suckling twin lambs. There was a highly significant ($p<0.05$) difference between the ADG of single compared to twin lambs. Both the single and twin lambs appeared to respond to the higher energy level offered to their dams.

The average daily creep feed intake of the lambs were group averages and could not be analyzed statistically. However, the mean values indicated that the lambs of ewes on the lower levels of energy consumed more creep feed than those on the higher level. This is difficult to explain in terms of the ADG of the lambs but may reflect the milk production of the ewes. This would agree with the findings of Wilson et al. (1971) who reported that by increasing the energy content of the ewe's ration, the milk production also increased. The results of this experiment would tend to show that as the energy content of the ewe's ration increased, the average daily intake of creep feed decreased. This would not agree with Gardner and Hogue (1963) who concluded that the amount of creep feed consumed was essentially equal regardless of the energy level of the ewe's ration.

APPENDIX II A comparison of mature ewes suckling single lambs when fed two levels of protein at a constant level of energy intake.

1. Introduction

The effects of feeding two levels of dietary protein at a constant level of energy intake on ewe performance and lamb growth rate were studied. A nitrogen balance trial was also carried out to determine the digestibility of the low protein ration.

2. Materials and Methods

Eighteen mature polled Dorset Horn ewes had been bred to rams of the same breed and when they lambed were divided into two equal groups according to their *postpartum* weight and to the sex of their lambs The ewes were individually fed grass hay at the level of 2.3% of *postpartum* weight of ewe plus 680 g of one of two concentrate supplements (Table 1).

When the lambs reached approximately 14 days of age, they were offered a creep feed ration consisting of 1:1:1 rolled barley, soybean meal, and rolled wheat.

A nitrogen balance trial was carried out using three non-pregnant ewes weighing approximately 45 kg. They were fed 340 g of low protein concentrate mixture and 680 g of the chopped grass hay. This level of feed intake was adopted in order that each ewe would receive approximately 50% of the nutrients offered to the lactating ewes.

TABLE 1. COMPOSITION OF SUPPLEMENTS

	Treatment 1	Treatment 2
Ingredient	%	%
Rolled barley	81	56
Soybean meal	9	34
Minerals *	8	8
Cobalt iodized salt	1	1
Vitamins **	1	1

*mineral mixture

28%	Calcium
13%	Phosphorus
0.0125%	Copper
0.006%	Cobalt
0.05%	Fluorine
0.42%	Manganese
0.75%	Iodine
0.375%	Iron

**vitamin mixture
435,000 IU vitamin A
87,000 IU vitamin D
1,700 IU vitamin E
per kg mix

3. Results and Discussion

Ewe performance as measured by ewe weight change and lamb weaning weight is presented (Table 2). There was no significant ($p > 0.05$) difference in the weight changes of the ewe receiving either the low or high protein ration. The lamb performance also showed a non-significant ($p > 0.05$) difference between the two groups in respect to ADG. However, there was a tendency for the lambs on treatment 2 to gain slightly faster than those on treatment 1. This is probably due in part to those lambs consuming more creep feed sooner than those whose dams were on the lower level of protein (treatment 1).

TABLE 2. EWE PERFORMANCE

	Treatment	
	1 11.1% CP	2 14.8% CP
Number of Ewes	9	9
Ewe weights (kg)		
Postpartum weight	53.2	61.2
56 day weight	53.8	60.4
Weight change	+0.6	-0.8
Lamb weights (kg)		
Birth weight	3.98	4.71
56 day weight	18.80	22.48
Weight gain	14.82	17.77
Average daily gain	0.265	0.317
Creep feed consumption of lambs		
Number of lambs (sex)	9(4M,5F)	8*(6M,3F)
Start of creep feed consumption (days)	34	27
Start of creep consumption (kg)	13.6	14.1
Total feed intake (g)	3966	6761
Average daily intake (g)	180	233

* one lamb could not get into creep -- too big

The digestibility coefficients for the low protein ration and nitrogen balance data are presented (Table 3).

TABLE 3. DIGESTIBILITY AND NITROGEN BALANCE

	Treatment 1 (low protein ration)			
	Ewe Number			
	1	2	3	Mean
Dry Matter Digestibility %	71.09	70.15	72.20	71.15
Crude Protein Digestibility %	68.37	67.87	68.82	68.35
Nitrogen Retention g/ewe/day	2.96	1.29	1.42	1.89

Dry matter intake per ewe per day = 924.6 g
Nitrogen intake per ewe per day =
hay 9.72 g
conc. 8.08 g
17.80 g

This digestibility trial was carried out mainly to test the metabolism cages designed by the author. The values however, do closely represent the apparent digestibility of dry matter and protein of the low protein ration fed to the ewes in this experiment.

APPENDIX III Digestibility of Rapeseed and Soybean Meals

1. Introduction

It would seem appropriate from the results obtained in Experiment I to determine the digestibility of rapeseed and soybean meals in order to explain more precisely why the rapeseed (treatment 2) and the soybean (treatment 3) rations had different digestibility values when the levels of intake were similar. The object therefore, was to feed the other two main ingredients (hay and barley alone) to sheep, determine their digestibility and then determine same for the respective protein supplement by difference.

2. Materails and Methods

Digestibility trials were conducted using three non-pregnant ewes weighing approximately 48.5 kg. Each ewe was fed 1020 g of a grass hay similar to that fed to the pregnant ewes in Experiment I.

Digestibility trials were also conducted using three ram lambs weighing approximately 43 kg. Each ram was fed 1,000 g of whole barley which had a protein content of 12.5% on a dry matter basis.

The balance procedure and the analysis of feeds and feces are located in the general methods section of this report.

3. Results and Discussion

The digestibility coefficients for the two feeds are presented (Table 1).

TABLE 1. DIGESTIBILITY COEFFICIENTS

		Treatment	
		Grass Hay	Barley
Dry Matter Digestibility %			
	sheep 1	60.2	82.78
	2	61.9	80.78
	3	64.0	79.18
	mean	62.0	80.91
Crude Protein Digestibility %			
	sheep 1	27.58	71.72
	2	28.94	70.94
	3	29.85	71.60
	mean	28.79	71.42

From the digestibility values (Table 1) of the grass hay and barley fed alone to sheep, the digestibility of rapeseed meal and soybean meal were calculated as follows:-

Ration 2 (low rapeseed meal) had the following compositions (Table 2).

Ingredient	% of DM	Determined CP %	CP provided	Determined digestibility of protein %	DCP provided
Hay	66.7	5.9	3.93	28.8	1.13
Barley	17.3	11.6	2.10	71.4	1.44
Rapeseed meal	11.7	36.0	4.61	x	(3.52)
Minerals plus molasses	4.3	--	--		
Total	100	--	10.55	5.77	6.09

Therefore the digestibility of the rapeseed meal protein as calculated by difference was $3.52 \div 4.61 = 76.4\%$.

The digestibility of the soybean meal protein was calculated in a similar manner and was found to be 85.6%. These values may be compared with the literature values of 82.3% for rapeseed meal and 90.0% for soybean meal, (NRC, 1969). The results of this study support the finding (Experiment I) that soybean meal appeared to have a higher digestibility than rapeseed meal when compared at a similar level of intake. The results also support the conclusion of Manns and Bowland (1963 b) that rapeseed meal in the diet decreases the digestibility of nitrogen and dry matter when compared to soybean meal.

It is interesting to note the nitrogen retention figures obtained when the ewes were fed grass hay alone. Three determinations gave values of -3.19, -1.75, and -2.91. These figures show that grass hay of the crude protein content fed, can not be used as the sole source of protein for any class of sheep.

APPENDIX IV Milk Production and Composition

1. Materials and Methods

Ten ewe lambs in their 28th day of lactation were used to estimate milk production and quality over a 24 hour period. Their lambs were confined to their individual creep pens at 2 a.m.. At 6 and 10 a.m. and at 2 and 6 p.m., the lambs were weighed to the nearest 5 grams, then allowed to suckle until they were no longer interested and immediately weighed again, giving the total milk produced in each four hour period. At 10 p.m. each ewe was intravenously injected with 0.3 ml oxytocin, having a strength of 20 USP units/ml. One quarter of each ewe's udder was then milked out completely and a representative sample taken for analysis. The samples were stored at 4° C until the following day when they were analyzed for milk constituents by the British Columbia Dairy Branch of the B.C. Department of Agriculture using automated infrared milk analyses techniques.

2. Results and Discussion

Daily ewe milk production and composition as determined by average production in four hour periods in terms of both pregnancy and lactation treatment of the ewes is presented (Table 1).

TABLE 1. MILK PRODUCTION AND COMPOSITION

	Treatment				
	1	2	3	4	5
Number of ewes	1 HR-LR	2 HR-HR	2 LR-HR	1 LR-LR	4 LS-LS
Milk production					
Production 4 hrs. g	170	158	183	190	196
Total production 24 hrs. g	1020	948	1098	1140	1176
Milk Composition					
Fat %	9.40	9.02	10.38	6.69	8.87
Total fat 24 hrs. g	95.88	85.51	113.97	76.27	104.31
Protein %	4.46	5.01	4.37	4.11	4.31
Total protein 24 hrs. g	45.49	47.50	47.98	46.85	50.69
Lactose %	5.36	5.16	5.13	5.25	5.26
Total lactose 24 hrs. g	54.67	48.92	56.33	59.85	61.86

A summary of daily ewe milk production and composition in terms of lactation treatment only is presented (Table 2).

TABLE 2. MILK PRODUCTION AND COMPOSITION

	Treatment		
	1	2	3
Number of ewes	4 HR	2 LR	4 LS
Milk production			
Production 4 hrs. g	171	180	196
Total production 24 hrs. g	1023	1080	1176
Milk Composition			
Fat %	9.70	8.05	8.87
Total fat 24 hrs. g	99.74	86.08	104.31
Protein %	4.69	4.29	4.31
Total protein 24 hrs. g	47.74	46.17	50.69
Lactose %	5.15	5.31	5.26
Total lactose 24 hrs. g	52.63	57.26	61.86

Due to the fact that the treatment groups had only a small number of animals, treatment means are only indications of the quantity and quality of milk produced by ewe lambs. The values are comparable to those obtained by Butterworth et al. (1968). The high level of protein appeared to increase the fat content (%) of the milk. This would agree with the findings of Butterworth et al. (1968).

APPENDIX V

STATISTICAL ANALYSIS TABLES

I 1. Analysis of Variance - Weight gain of ewes

(pregnant ewe lambs fed rapeseed meal Experiment I)

Source	df	ss	ms	obs. F	F .05
Total	26	392.1			
Treatment	2	15.4	7.70	0.374	3.63
Replicate	8	47.4	5.93		
Residual	16	329.2	20.58		

Since the observed F 0.374 is less than the value F .05 = 3.63, it may be concluded that there was no significant difference between the weight gains of the ewes fed either ration 1, 2, or 3 during pregnancy.

I 2. Analysis of Variance - Birthweight of single lambs

(pregnant ewe lambs fed rapeseed meal Experiment I)

Source	df	ss	ms	obs. F	F .05
Total	26	48.3			
Treatment	2	1.4	0.7	0.35	3.63
Replicate	8	14.4	1.8		
Residual	16	32.5	2.0		

Since the observed F 0.35 is less than the value F .05 = 3.63, it may be concluded that there was no significant difference between the birthweights of the single lambs born to ewes fed either ration 1, 2, or 3 during pregnancy.

II 1. Analysis of Variance - Weight change of ewes

(lactating ewe lambs fed rapeseed meal Experiment II)

Source	df	ss	ms	obs F	F .05
Total	26	1147.9			
Treatment	2	37.6	18.8	0.714	3.63
Replicate	8	688.5	86.1		
Residual	16	421.7	26.4		

Since the observed F 0.714 is less than the value F .05 = 3.63, it may be concluded that there was no significant difference between the weight changes of the ewes fed either ration 1, 2, or 3 during the lactation period.

II 2. Analysis of Variance - Average daily gain of lambs by lactation treatment only

(lactating ewe lambs fed rapeseed meal Experiment II)

Source	df	ss	ms	obs. F	F .05
Total	26	0.362			
Treatment	2	0.008	0.004	0.222	3.63
Replicate	8	0.064	0.008		
Residual	16	0.290	0.018		

Since the observed F 0.222 is less than the value F .05 = 3.63, it may be concluded that there was no significant difference between the average daily gain of the lambs when their dams were fed either rations 1, 2, or 3 during lactation

II 3. Analysis of Variance - Average daily intake of creep feed (lactating ewe lambs fed rapeseed meal Experiment II)

Source	df	ss	ms	obs. F	F .05
Total	26	286.1			
Treatment	2	12.2	6.1	0.461	3.63
Replicate	8	62.1	7.8		
Residual	16	211.8	13.2		

Since the observed F 0.461 is less than the value F .05 = 3.63, it may be concluded that there was no significant difference between the average daily creep feed intake of the lambs whose dams were fed either ration 1, 2, or 3.

II 4. Analysis of Variance - Age at start of creep consumption (lactating ewe lambs fed rapeseed meal Experiment II)

Source	df	ss	ms	obs. F	F .05
Total	26	1160			
Treatment	2	80	40.0	1.05	3.63
Replicate	8	470	58.8		
Residual	16	610	38.1		

Since the observed F 1.05 is less than the value F .05 = 3.63, it may be concluded that there was no significant difference between the weight at the start of creep consumption of the lambs whose dams received ration 1, 2, or 3 during lactation.

III 1. Analysis of Variance - Lamb performance

(all concentrate rations for lambs Experiment III)

Source	df	ss	ms	obs. F	F .05	
Total	47	187.5				
Treatment	5	44.7	8.9			
Process	2	40.1	20.1	5.9	3.32	**
Grain	1	2.8	2.8	<1		NS
Process x Grain	2	1.8	9.0	2.64		NS
Residual	42	142.8	3.4			

Since observed F 5.9 is larger than the value F .05 = 3.32, it may be concluded that there was a significant difference between the average daily gain of the lambs fed either whole, rolled, or pelleted grain. However, as can be seen above, there was no significant difference between the average daily gain of the lambs fed wheat or barley and there was no process x grain interaction.

III 2. Analysis of Variance - Protein Digestibility

(all concentrate rations for lambs Experiment III)

Source	df	ss	ms	obs. F	F .05	
Total	35	391.7				
Treatment	11	315.6	28.7	9.1	2.3	*
Process	2	32.9	16.5	5.2	3.4	*
Grain	1	170.3	170.3	53.7	4.3	*
Level	1	59.9	59.9	18.9	4.3	*
L x G	1	11.0	11.0	3.5	4.3	NS
L x P	2	3.3	1.7	<1		NS
G x P	2	22.1	11.1	3.5	3.4	*
G x P x L	2	16.1	8.0	2.5	3.4	NS
Residual	24	76.0	3.2			

Conclusions after completing Duncan's test --

1. Processing influenced digestibility of protein - pelleted rel. to rolled.
2. Grain influenced digestibility of barley $<$ wheat.
3. Level influenced digestibility 600 $>$ 1000 g/day.
4. Grain x Process interaction - due to rolling; improving the DCP % of wheat and not barley.

III 3. Analysis of Variance - Energy Digestibility

(all concentrate rations Experiment III)

Source	df	ss	ms	obs. F	F .05	
Total	36	210.3				
Treatment	11	163.4	14.9	7.92	2.24	**
Process	2	1.1	< 1	< 1	NS	NS
Grain	1	116.5	116.5	62.1	4.24	**
Level	1	10.5	10.5	5.6	4.24	**
L x G	1	0.3	0.3	< 1	NS	NS
L x P	2	10.5	5.3	2.81	3.39	NS
G x P	2	16.9	8.4	4.49	3.39	**
G x P x L	2	7.6	3.8	2.02	3.39	NS
Error	25	46.9	1.9			

Conclusions after completing Duncan's test --

1. Processing had no significant effect on DE %.
2. DE % wheat significantly > barley.
3. Level of intake had a significant effect on DE %.
4. An interaction between grain and process was observed.

Analysis of Variance - Ewe weight change

(mature ewes suckling single or twin lambs - Appendix I)

Source	df	ss	ms	obs. F	F .05
Total	23	1956.5			
Treatment	3	542.5	180.8	2.55	3.29
Replication	5	352.5	70.5		
Error	15	1061.5	70.8		

Since the observed F 2.55 is less than the value F .05 = 3.29, it may be concluded that there was no significant difference between the weight change of the ewes fed either ration 1, 2, 3, or 4.

Analysis of Variance - Average daily gain of lambs

(mature ewes suckling single or twin lambs - Appendix I)

Source	df	ss	ms	obs. F	F .05
Total	35	0.05			
Treatment	3	0.10	0.033	16.5	2.90
Residual	32	0.05	0.022		

Since the observed F 16.5 is greater than the value F .05 = 2.90, it may be concluded that there was a significant difference tetween the average daily gain of single and twin lambs (Duncan's test).