AN ABSTRACT OF THE THESIS OF

MARVIN CLARK PANGBORN for the degree of MASTER OF SCIENCE

in ANIMAL SCIENCE presented on DECEMBER 9, 1977

Title: THE EFFECTS OF VARIOUS LEVELS OF DIETARY PROTEIN ON HIGH PRODUCING DAIRY COWS IN EARLY LACTATION

Abstract Approved: Redacted for Privacy

Dr. H.P. Adams

This project was designed to test the biological effects of three levels of dietary protein (12.7, 16.3 and 19.3% CP on a dry matter basis) on high producing Holstein-Friesian dairy cows. Forty five second lactation or older cows that showed the potential to produce over 31.75 kg (70 lbs) per day were selected. Cows were randomly assigned to treatments on day four postpartum and remained on the trial for 90 days. A complete isocaloric ration was fed, consisting of corn or grass silage, alfalfa hay and a grain concentrate.

Four percent fat-corrected milk production did not differ significantly between groups averaging 29.4, 31.3 and 32.0 kg/cow/day for the 12.7, 16.3 and 19.3% CP rations, respectively. Actual milk production was significantly higher in the 16.3% CP group than the 12.7% CP group. Group averages were 30.94, 35.52 and 34.79 kg/cow/day for the 12.7, 16.3 and 19.3% CP rations, respectively.

Milk fat concentration averaged 3.66, 3.21 and 3.46% for the 12.7,

16.3 and 19.3% CP rations, respectively. The average for 16.3% CP ration cows was significantly different from the averages of the 12.7 and 19.3% CP ration cows. Milk fat concentration for all cows was 3.7% for period one (1-30 days), 3.21% for period two (31-60 days) and 3.46% for period three (61-90 days). Milk fat % was greater ($P < .01$) for period one.

Milk protein was not significantly affected by level of dietary protein. Significant differences were found between period one relative to periods two and three. The period averages were 3.76, 3.36 and 3.46 for period one, two and three, respectively.

Persistancy of lactation was significantly different between periods, averaging 106.5% in the first period, 100.2% in the second period and 98.4% in the third period. Persistancy was not affected by treatment.

Feed intake differed significantly due to treatment averaging 17.7, 18.18 and 18.67 kg/cow/day for the 12.7, 16.3 and 19.3% CP rations, respectively. There were no significant differences between periods.

Bodyweight changes were not significant between the three treatments, although they were ($P < .01$) between periods. During the first period all cows averaged a 24 kg weight loss; however, cows gained 3.8 kg in the second period and 13.5 kg in the third period.

Rumen fluid ammonia increased with each level of protein (4.29, 7.66 and 19.3 mg% for the 12.7, 16.3 and 19.3% CP rations, respectively), but was only significant between the 19.3% CP ration relative to the 16.3 and 12.7% CP rations. Rumen fluid pH did not differ between

treatment means.

Blood samples were analyzed for several factors. Plasma urea nitrogen (PUN) measured at six weeks postpartum, averaged 7.89, 10.27 and 18.25 mg% for the 12.7, 16.3 and 19.3% CP rations, respectively. Plasma albumin showed the same trend, being significantly higher in cows on the 19.3% CP ration. Average values were 3.45 mg% for the 12.7% CP level, 3.47 mg% for the 16.3% CP level and 3.85 mg% for the 19.3% CP ration. Blood ammonia levels, determined in 30 cows at various stages of lactation, were not significantly different.

An economic analysis of the profitability of feeding the various levels was completed using actual milk and milk fat yields and actual feed consumption per cow over the 90 day period. Using August, 1977 commercial milk and ration constituent prices, returns above feed costs per cow for the 90 day periods were $459.58 for the cow fed the 12.7% CP ration, $477.67 for cows fed the ration containing 16.3% CP and $456.88 for cows fed the 19.3% CP ration.

THE EFFECTS OF VARIOUS LEVELS OF DIETARY PROTEIN ON HIGH PRODUCING DAIRY COWS IN EARLY LACTATION

by
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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed December 1977

Commencement June 1978

APPROVED:

Redacted for Privacy

Professor of Animal Science in Charge of Major

Redacted for Privacy

Head of Department of Animal Science

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Dean of Graduate School

Date thesis presented December 9, 1977

Typed by Cheryl M. Schurg for Marvin Clark Pangborn

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to my graduate program advisors. Dr. Donald W. Claypool served as my Thesis advisor and was a tremendous teacher and friend. Dr. H.P. Adams and Dr. Frank Conklin were my major and minor professors, respectively, and were extremely helpful in advising and guiding me throughout the program.

I would also like to thank the other members of my graduate committee, Dr. James E. Oldfield, who has encouraged and inspired me throughout my years at Oregon State University and Dr. Lloyd V. Swanson for his advice and often probing questions.

Special thanks go to Professor Emeritus D. Curtis Mumford who advised me in the preparation of the economic aspects and to fellow graduate student Ellen Jordan who shared the cows and hours of labor at the dairy center.

Most importantly I wish to thank my fiancee, Jane McKergow for her help, encouragement, love and devotion and to my parents, Mr. and Mrs. Marvin E. Pangborn to whom I owe everything.

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INTRODUCTION

The dietary requirements for ruminant animals include protein, energy, minerals, vitamins and water. These requirements are particularly critical in the high producing dairy cow, which must not only support maintenance and pregnancy, but must also meet the stress and demands of lactation. The two constituents needed in the largest quantity for milk production are protein and energy (Church, 1977).

In the past 12 years dairy cow numbers have dropped from about 15.4 million in 1965 to under 11 million at the present time (USDA, 1976). However, production per cow has increased tremendously. Since 1960, the average annual milk production of dairy cows in the United States has increased from 3150 kg (7000 pounds) of milk to between 4500-4950 kg (10-11,000 pounds). Herds with annual average production of 9091 kg (20,000 pounds) of milk per cow are not uncommon.

This increase in per cow performance has caused scientists, extension personnel, the feed trade and farmers to question the recommended levels of dietary protein. Early protein recommendations were based on data obtained from research in which low to average producing cows were used. Many of the trials were of a short duration and in many cases energy could have been just as limiting as protein.

Thomas (1971) cited the work of Broster et al. (1960), Lassiter et al. (1957), Moore (1951), Perkins (1925), Perkins (1957), and Waite

et al. (1968) which agreed that 10% Crude Protein (CP) was adequate for normal production of 10 to 15 kg of milk per day. Current recommendations of the National Research Council (NRC, 1971) calls for CP to constitute 16% of the ration dry matter (DM) when production per cow is greater than 29.7 kg per day and 15% CP when production is between 20.3 and 29.7 kg of milk per day.

The need to re-evaluate dietary protein requirements is further emphasized by the theory that the current feeding of more concentrates has increased milk protein percentages and total protein yields (Gordon, Volcani and Birk, 1971a,b; Holmes and Arnold, 1960). Reid, Moe and Tyrrell (1966) have suggested that protein digestibility is reduced as dry matter intake was increased to satisfy greater production needs; therefore, additional protein might be needed to offset lowered availability. These authors also propose that the use of body protein stores to produce milk has concealed the cows true requirement for protein. These factors, combined with the stress of feedlots and crowding and group rather than individual feeding, have sparked the interest of the dairy industry.

In addition, there is the economic fact that protein supplements, whether natural (True Protein) or non-protein nitrogen (NPN) are costly and often of uncertain availability.

Reports of recent research on dietary protein requirements are conflicting, with some authors reporting benefits from increased protein levels up to 19% CP, while others have recommended lower levels.

This study was designed to examine the effect of three different

protein levels (approximately 13, 16 and 19% CP on a dry matter basis) on the performance of high producing dairy cows during the first 90 days of their lactation. Measurements were made to determine the effects of dietary protein on milk production (corrected to 4% milk fat), milk fat percentage, milk protein percentage and lactation persistency. In an attempt to determine the physiological effects of the various protein levels, bodyweight changes were recorded, feed intake noted, rumen fluid analyzed for rumen ammonia and pH, and blood levels of ammonia, urea nitrogen and albumin measured.

LITERATURE REVIEW

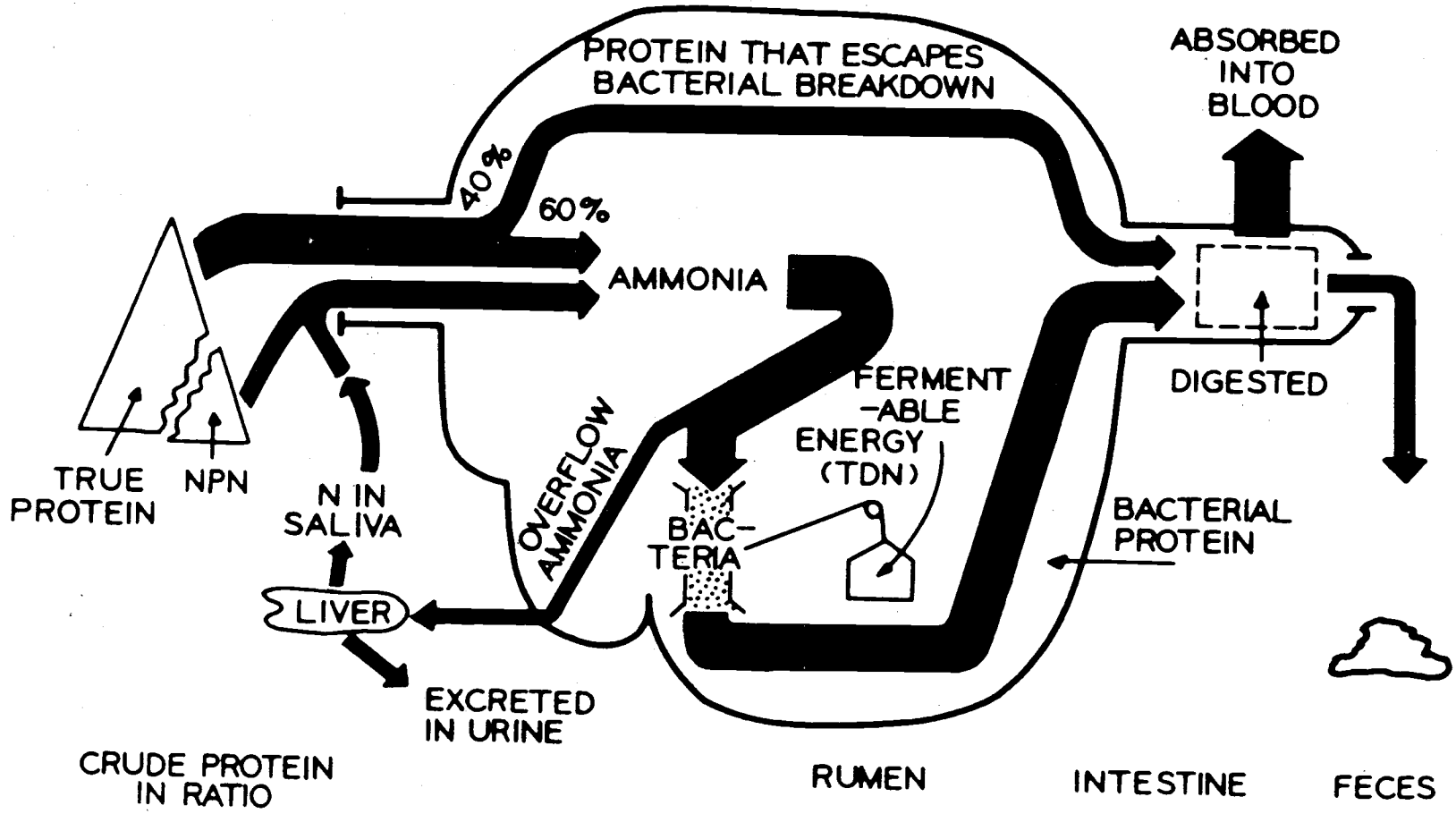
Nitrogen Utilization in the Ruminant

The utilization of nitrogenous materials by ruminants is a topic which has been discussed for years. Pearson and Smith (1943) and McDonald (1948a,b) were among the first to recognize that the rumen microorganisms contain enzymes which break nitrogen-containing compounds (proteins and non-protein nitrogen) into forms which can be used by the microorganisms (bacteria and protozoa) in their growth and development.

Most of the nitrogenous material ingested by ruminants receiving natural feeds consists of proteins. The remainder nitrogenous material consists of non-protein nitrogen (NPN), which varies with the type, maturity and method of harvesting and storing of the feedstuff. Krober and Gibbons (1962) reported that the NPN fraction of the total N in cereal grains decreased from 30 to 40% in the immature stage to 4 to 5% in the dry seed stage. Brady (1960) found that fresh forages contain 10 to 30% of their nitrogen as NPN and dried forages, such as hay or haylage, contain 25 to 50% NPN. Waldo (1968) determined that the NPN content of unwilted silage increased to 60 to 75% of the total nitrogen during storage.

The schematic illustration (Figure 1) prepared by Satter, Whitlow and Beardsley (1976) is helpful for gaining a perspective of nitrogen metabolism in the rumen.

Once the nitrogen source enters the rumen, about 60% comes under


PROTEIN THAT ESCAPES BACTERIAL BREAKDOWN
ABSORBED INTO BLOOD
40%
60%
AMMONIA
DIGESTED
FERMENT -ABLE ENERGY (TDN)
TRUE PROTEIN
NPN
N IN SALIVA
OVERFLOW AMMONIA
BAC-TERIA
BACTERIAL PROTEIN
LIVER
EXCRETED IN URINE
CRUDE PROTEIN IN RATIO
RUMEN
INTESTINE
FECES

the attack of microbial enzymes and is converted to amino acids and ammonia. The remaining 40% escapes breakdown and passes into the abomasum to be acted upon by gastric proteolytic digestive enzymes. In the rumen some of the amino acids resulting from protein degradation are absorbed through the rumen wall, but most are reduced to ammonia (McDonald, 1952), carbon dioxide and short chain fatty acids (Portugal and Sutherlan, 1966). Cook, Brown and Davis (1965) have shown that small amounts of amino acids can be incorporated into bacterial protein.

The relative importance of ammonia compared with amino acids in the nutrition of rumen bacteria was discussed by Bryant and Robison (1962). They found that 82% of the rumen bacteria could be grown on a relatively non-selective medium with ammonia as the sole source of nitrogen; 25% required ammonia and 56% could use either. Al-Rabbit, Baldwin and Weir (1971) determined that 61% of the microbial nitrogen was derived from ammonia and 39% was derived from amino acids and peptide nitrogen.

The synthesis of microbial proteins is accompanied by cell growth and is governed essentially by the organisms utilization of energy and the availability and uptake of nutrients. Microbial growth is determined largely by the rate at which organisms can release and utilize energy in the form of high energy compounds, such as adenosine triphosphate (Hogan, 1975).

The availability and uptake of amino acids and ammonia depends upon their release from dietary and endogenous sources. Satter,

Whitlow and Beardsley (1976) list protein solubility as one of the main factors affecting protein degradation. Feeds such as succulent grasses contain large amounts of soluble proteins that tend to be more readily degraded than feeds such as fishmeal and distillers by-products; which tend to be relatively resistent to rumen microorganisms. The solubility of the feed itself is influenced by feed particle size and density, heat or chemical exposure and strength or integrity of the plant cell wall, which gives protection to its protein constituent.

Another factor cited in the literature as having an effect on protein degradation is the amount of time spent by microorganisms in the rumen (Hogan, 1975). The residence time itself is affected by level of feed intake, physical features of the feed particles and associative effects of other ration ingredients (Satter, Whitlow and Beardsley, 1976). For maximum yields of microbial cells, sufficient time must be permitted for the organisms to develop. However, the cells must be removed before they reach either a lag phase where substrate is used for maintenance purposes without further growth or before the cells are destroyed by autolysis. New Zealand workers, using polyethylene glycol markers (PEG), found the mean resistance time to be about five hours for dairy cows grazing rich pastures (Tulloh, Hughes and Newth, 1965).

In the ruminant, nitrogen metabolism and carbohydrate digestion must be considered together. The balance of nitrogen and carbohydrate influences nitrogen utilization, carbohydrate utilization and feed intake. Nitrogen can affect feed intake in the following ways: firstly, inadequate nitrogen slows fiber digestion which reduces feed intake, and secondly,

excess nitrogen relative to energy can produce high rumen ammonia which will also reduce feed intake (Waldo, 1968).

The effects of lipids on rumen ammonia are variable. The Rowett Research Institute (1962) found that when the diet of ruminents was composed of three percent nitrogen, added oils depressed rumen ammonia and rate of flow of rumen fluids. These findings coincide with work of Chalmers (1960) and Jayasinghe (1961) as cited by Waldo (1968). When dietary nitrogen was greater than three percent, Robertson and Hawke (1964) found that added oils increased rumen ammonia.

There are several other factors which affect the amount of ammonia produced, in addition to level of protein, carbohydrate and lipid. These include the amount of urea consumed, the vegetative stage of the forage consumed and the composition of the microbial population. The various aspects of feeding urea to ruminants have been discussed extensively in the past 25 years. Excellent reviews on feeding urea to dairy cows may be found in Roffler, Schwab and Satter (1976), Aitchison et al. (1976), Roffler and Satter (1975a), Roffler and Satter (1975b), Polan, Miller and McGilliard (1976), Van Horn et al. (1975), Van Horn et al. (1976), Roffler et al. (1976), Polan et al. (1977), Satter (1976), Huber (1975), and Burroughs, Nelson and Mertens (1975). The ingestion of spring grass, particularly the leafy portions when grazed naturally, tend to cause rapid ammonia production in the rumen (Smith, 1969). Ammonia production is also influenced by the composition of the microbial population. Smith (1969) reviews the work of Christenson, Kawashima and Burroughs (1965), Luther, Trenkle and Burroughs (1966), Purser and Moir (1966) and Chalmers

et al. (1964) which showed reduced ammonia concentrations in rumen fluid when protozoa populations were suppressed. Eadie and Hobson (1962) and Giesecke, Lawlor and Walser-Kärst (1966) found an increase in the bacterial population associated with decreased protozoa numbers.

Referrring again to Figure 1, ammonia which is not utilized by microbial cells is often termed "overflow ammonia". Roffler, Schwab and Satter (1976) suggest that microbial protein synthesis is unaffected by rumen ammonia concentrations over five milligrams ammonia nitrogen per 100 milliliters rumen fluid (12-13% CP). However, recent in vitro studies by Edwards, Bartley and Bechtle (1977) found that microbial protein and amino acid production increased steadily as crude protein increased up to 27% of dietary dry matter. The overflow ammonia is absorbed from the rumen, and is generally converted into urea in the liver (McDonald, 1948a,b; Blackburn, 1964). However, work by Aliev and Korsorev (1967) suggests that some conversion of ammonia to urea may take place in the rumen mucosa (Smith, 1969). A close correlation between concentrations of ammonia in the rumen and urea in the blood have been found by Lewis (1957) and Weston and Hogan (1967).

Waldo (1968) reviewing the work of Gärtner (1961) and Bloomfield et al. (1963) described a reduction in ammonia absorption when rumen pH decreased. Combe, Tribe and Morrison (1960) have pointed out that incidence of urea toxicity increases with increased rumen pH.

The production of urea is a direct result of a functioning urea cycle. Some reasearch has shown that animals can develop a tolerance for higher levels of urea. Payne and Morris (1969) found an increase in

urea cycle enzymes (ornithine transcarbamoylase, arginine synthetase and arginase) in sheep fed high protein diets. This fact has considerable practical application in the avoidance of urea toxicity when feeding urea.

If excesses of ammonia exist to such a level that the animal's system cannot convert all the ammonia to urea, toxicities may develop. Toxic effects are very rare in animals fed natural diets, but can be troublesome in urea supplemented rations. Lewis, Hill and Annison (1957) state that when rumen ammonia levels approach 100 mg%, the livers capacity for urea synthesis is exceeded and ammonia accumulates in the blood, causing urea toxicity. At high ruminal ammonia levels, a sizable amount of ammonia can escape from the rumen into the peritoneal cavity and peripheral blood system, bypassing the liver. Smith (1969) mentioned that Juhasz (1965) had reported rumen motility to be inhibited by high rumen ammonia levels.

Once urea is formed, Figure 1 demonstrates that the urea can go one of two ways. First, it can be recycled into the rumen via the saliva. Bailey (1961) estimated that the rate of return of nitrogen through saliva in dairy cows was equivalent to 1.8 grams per kg of dry matter intake. Satter and Roffler (1975a) state that the amount of nitrogen recycled into the reticulorumen expressed as a percentage of dietary intake is not constant when applied to low as compared to high protein rations. Within the range of protein content normally encountered in dairy rations, however, an amount of nitrogen equivalent to 10 to 15% of dietary nitrogen intake appears to be recycled into the reticulorumen in a form

available to microorganisms.

The second major pathway of urea is excretion via the urine. Urea represents about 70% of total urinary nitrogen and appears to be a more variable fraction when water intake is restricted. Livingston, Payne and Friend (1962) and Topps and Elliott (1964) have shown an increase in nitrogen retention with restricted water intake at low levels of protein intake. Thornton and Wilson (1972) reported that the amount of urea excreted in urine is regulated more by plasma urea concentration than by renal processes.

It has been suggested by Houpt and Houpt (1968) that there is some urea gain across the rumen wall from the bloodstream. However, work by Hogan and Connell (unpublished, 1975) and by Nolan, Norton and Long (1973) suggests that these levels are insignificant. Church (1975), after reviewing a great deal of literature, concluded that the passage of urea nitrogen into the rumen is of physiological significance only in animals on low protein diets.

Once the microbial protein and undegraded protein leaves the rumen it passes through the reticulum, omasum and abomasum. The abomasum has a proteolytic effect upon the proteins, breaking them to peptide chains.

The metabolism of nitrogen in the intestines can be considered in two sections: (1) digestion and absorption in the small intestine, and (2) digestion and absorption in the large intestine. Apart from ammonia, which is not generally present in large amounts, the nitrogenous compounds entering the duodenum consist mainly of proteins or products of protein digestion. These compounds can be derived partly from the ration, partly

from microbial protein and partly from endogenous secretions into the abomasum. Smith, McAllen and Hill (1969) reported that nucleic acids comprise 8 to 13% of the total nitrogen of many diets and are absorbed to an extent of about 80% in the small intestine. However, limited evidence was presented which suggests that 40 to 50% of the microbial nucleic acids produced in the rumen are either not absorbed from the gut, or, if absorbed, are excreted in the urine as allontoin, with most of the remainder entering the urea pool (Smith, 1969).

By the time the digesta leaves the ileum of the small intestine, amino acids comprise about two-thirds of the nitrogen in the digesta as compared to about 80% of the nitrogen before entering the duodenum (Hogan, 1975). In other experiments, Hogan (1973) found absorption of essential amino acids in the duodenum to be about 80% of that in the ileum.

In the cecum, proteins are degraded rapidly with a further rapid deamination of amino acids (Hecker, 1971). Protein synthesis by microorganisms also takes place in the large intestine, but is limited by lack of fermentable substrate. Therefore, only insignificant quantities of essential amino acids are absorbed from the large intestine and the microbial protein synthesis that does take place merely increases the output of amino acids in the feces. Faicheney (1969) suggests that volatile fatty acid production in the cecum is only eight percent of that in the rumen.

The feeding value of microbial protein has been a source of interest for years. Church (1975) reported on work by Uselli and Fiorni (1938)

in which rumen protozoa gave better growth in chicks than did rumen bacteria. Johnson et al. (1944) determined that dried protozoa had a True Digestibility of 86.2% and a Biological Value of 68%. McNaught et al. (1954) analyzed rumen microorganisms and found that bacteria True Digestibility equaled 74%, Biological Value equaled 81% and Net Protein Utilization equaled 60%. When these analysis were applied to the rumen protozoa, results were 90, 80 and 73%, respectively.

The poor digestibility of microbial protein and the action of microorganisms in the cecum results in greater relative losses of nitrogen in the feces of ruminants than in monogastric species. Waldo (1968), citing the work of Bondi and Meyer (1948), Salo (1957), and Van Soest (1965) suggests that the truly indigestible nitrogen associated with lignin is another factor that reduces digestibility. Digestibility may also be reduced by inhibitory substances in some plants, such as goitrogens in raw soybeans.

Mukherjee and Kehar (1949) found an increase in fecal N excretion in cattle as dietary N levels increased. The amount of nitrogen excreted in the feces on nitrogen free diets has been estimated by Holter and Reid (1959) as .545 to .576 grams of nitrogen per 100 grams of feed dry matter or as .642 grams of nitrogen per 100 grams of food organic matter. The nitrogenous compounds excreted in the feces consist in part of undigested or unabsorbed food nitrogen and in part of metabolic fecal nitrogen. This metabolic fraction comprises substances originating in the body, such as residues of the bile and other digestive juices, epithelial cells from the digestive tract and bacterial residues (Maynard

and Loosli, 1969).

Protein Level Effect Upon Milk Production and Composition

The modern high producing dairy cow has critical nutritional demands. For cows to fulfill their genetic potential, rations must be provided which meet their needs for maintenance, reproduction, growth and lactation. If the dairyman is to stay in business he must meet these needs in the most efficient and economical method possible.

Protein and energy are the two most important constituents of the dairy cows' diet, with minerals and vitamins being needed in lesser amounts. Protein is necessary for building and repair of tissues. For young cows additional protein is needed to insure that they attain mature size. Extra protein is also needed by the pregnant cow for fetal growth.

But by far the largest stress to the cows system comes from the phenomenon of lactation. Reid et al. (1966) found that at nitrogen equilibrium, the efficiency of utilization of digestible protein for the combined functions of maintenance and milk production was about 60%. They found that one kilogram of 4% fat-corrected milk contains 34.98 grams of protein, therefore a cow requires 58.3 grams of digestible protein (34.98/.60) for each kg of milk produced. They also found that body reserve can be used to produce milk and losses of 360 grams of body protein per day are very possible during early lactation.

Despite a great deal of work on the subject, dietary protein recommendations by various authors has been contradictory. Thomas (1971), citing work of Broster et al. (1960), Lassiter et al. (1957), Moore

(1951), Perkins (1925, 1957) and White et al. (1968), stated that dietary crude protein (CP) levels of 10% appeared adequate for "normal" (10 to 15 kg/day) milk production.

In the last decade milk production has increased tremendously. This has led many researchers to question the old standards. Gardner and Park (1973) state that protein levels need to be re-evaluated because milk production (including protein yield) has increased considerably in the past few years. Also, as dry matter intake increases to meet greater production needs, protein digestibility is reduced. Further, the use of body protein stores to produce milk has concealed the cows true protein requirement. Finally, they feel the management practice of group feeding may cause some changes in protein recommendations, from those proposed when cows are individually fed.

Current National Research Council (NRC, 1971) recommendations for CP% can be interpreted to approximate 16% of ration dry matter[1] when production is 29.7 kg (66 lbs.) or more per day and 15% CP when production is 20.25-29.7 kg (45-66 lbs.) per day. The remainder of this section reviews results of past work.

In 1966, Reid, Moe and Tyrrell used nitrogen balance data to determine that the average rate of utilization of digestible protein for maintenance and lactatin was equal to 60 to 65%. Therefore, milking cows need a minimum digestible protein equivalent to 154% of the quantity of protein found in the milk. Since protein digestibility decreases as TDN intake increases, they suggest a varying scale of protein intake from

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[1] Unless otherwise stated, all CP values are in terms of % of dry matter.

55.6 g/kg of fat-corrected milk for cows producing 4.5 kg of milk per day to 66 g/kg of fat-corrected milk when yields are 100 lbs. (45 kg) per day. Broster (1972) compiled data from 16 sources and determined a mean value for optimum intake at 56.12 ± 1.82 grams of CP per kg of milk produced (Lewis and Annison, 1974).

Two groups of researchers have looked at the interaction of energy and protein. Gordon and Forbes (1970) designed four diets that consisted of 80 or 120% of the established energy and protein requirements. They found no differences in production other than the effects of the higher protein levels on increasing the milk energy output and increasing the NPN content of the milk. Gardner and Park (1973) conducted a series of experiments with diets based on corn silage and alfalfa hay. Energy was set at 115 and 170% of maintenance. They found that milk production increased as protein levels increased from 13.2 to 15.5% CP while a slight improvement in production was seen between energy levels. Milk production results were the same in a second trial with levels at 13.9 and 15.8% CP. These dietary protein levels would be about 210% of the protein found in the milk. No differences were seen in milk composition in either experiment.

In an extensive test in Belgium, Paquay et al. (1973) fed isocaloric rations that varied in CP levels from 8.4 to 22.4%. They found that the utilization of dietary nitrogen for milk secretion was influenced by the level of nitrogen intake, but only when dietary CP was lower than a particular limiting value, which varied according to stage of lactation. The authors suggested a CP level of 15 to 16% when production was greater

than 20 kg/day, 12 to 13% for 15 to 17 kg/day and 11 to 12% when production was less than 10 kg/day. Using a depletion-repletion method and feeding a corn based ration, Botts, Hemken and Bull (1977) placed cows on protein levels of 9, 14, 18 or 22% CP after they had been on a 9% CP ration for 8 to 16 weeks. Milk production was highest at 18% CP. Production at the 9 and 22% CP levels were lower and approximately equal to each other.

Most recent research has been based on diets with corn silage as the main source of roughage. In a two year trial, Thomas (1971) found no significant differences in the production of cows fed a 10.7 or a 17.6% CP ration for the first 90 days of their lactation. However, during the second lactation, production improved by 1300 kg/cow and persistancy was greater on the high protein intake ration. Van Horn and Jacobson (1971), Sparrow et al. (1973), Polan, Miller and McGilliard (1976) and Polan et al. (1977) have all demonstrated increases in milk production as the result of increasing dietary protein within the range of 9.4 to 17.5% CP. Van Horn and Jacobson (1971) noted an increase in Solids-Not-Fat (SNF) composition of milk and nitrogen retention in cows on higher levels of protein intake. Sparrow et al. (1973) found increases in milk fat percentage with increased protein intake. Nitrogen balance tests showed losses of -37.4 grams of nitrogen per day at 13.5% CP and gains of 5.8 and 31.4 grams of nitrogen per day at 15.5 and 17.5% CP, respectively.

Recent work by Roffler and Satter (1976) and Cressman et al. (1977) reported no milk production increases in young cows fed rations varying

from 12.4 to 17.5% CP. However, both groups of researchers found significant differences in latter lactation cows (four years and older). Such results have led Satter and Roffler (1976) to recommend that in early lactation cows should receive levels of 15 to 16% CP (no NPN) and that the level can be dropped to 10 to 11% CP in late lactation. Bull, Ross and Thacker (1974) have made similar recommendations.

Powers and Kesler (1977) fed cows for two lactations on diets containing 12.7 and 17% CP. A third ration consisted of feeding 17% CP until milk yield dropped below 60 pounds (27 kg) per day and then switching to the 12.7% CP feed. The 17% CP group produced 900 kg (2000 pounds) more milk for the first lactation. In the second lactation the 17% CP and mixed rations were nearly equal in production, and both were superior to the 12.7% CP group by 1350 kg (3000 pounds).

Grieve, Macleod and Stone (1974), feeding an alfalfa haylage, shelled corn and soybean meal ration, found that increased protein intake increased milk fat percentage and lactose and decreased milk protein percentage. Treacher et al. (1975) found that cows changed from an alfalfa, beet pulp and grain ration containing 12.75% CP to one containing 16.5% CP increased in milk production, percentage of milk fat, protein and lactose, percentage persistancy and peak yield.

Contradictory to these results, Wallenius (1976) found only slight differences in 305 day lactations of cows fed rations of legume/grass silage and alfalfa hay containing 14 to 16% CP.

Van Horn et al. (1975) fed rations based on 25% sugarcane bagasse, a 25% mixture of various ratios of soybean meal and molasses and either

50% ground corn or 50% citrus pulp. Protein levels ranged from 9.7 to 16.9% CP. The high levels of CP increased solids-corrected milk yields. Methionine Hydroxy Analog (MHA) increased the percentage of milk fat on rations with higher levels of soybean meal. Van Horn et al. (1976) fed rations containing 11.5, 13 and 14.5% CP composed of citrus pulp, corn and soybean meal. Milk yields were only slightly increased, averaging 26.7, 26.6 and 27.5 kg/day for the 11.5, 13 and 14.5% CP rations, respectively. In a second experiment with the same protein levels and a cottonseed hull, citrus pulp and corn diet no differences in milk yield were noted. The authors recommended 13.5% CP for cows producing under 6370 kg of milk per 305 day lactation.

Moe and Tyrrell (1977) examined the effect of rations containing 14, 17 and 20% CP on the utilization of metabolizable energy by lactating cows. The metabolizable energy was the same for the 17 and 20% CP rations, but lower for the 14% CP level (59% versus 55% ME). They also found that the additional CP in the 20% CP diet improved digestibility.

Work by Julien, Conrad and Redman (1977) has attributed the metabolic disease known as "Alert Downer Cow Syndrome" to high levels of dietary protein. They found the incidence of pre- and postpartum metabolic disease to be 7.14% for cows receiving rations containing 8% CP and 69.2% for cows receiving 15% CP. Of the 26 cows on the high protein diet, eight exhibited downer cow symptoms, three aborted, four developed parturient paresis, three suffered displaced abomasums and six cows died. However, in the group receiving an 8% CP ration only two cows developed parturient paresis and none died.

Protein Level Effect on Bodyweight

The high producing dairy cow requires a great deal of energy to maintain high levels of milk production. Immediately postpartum, the cow fed traditional feedstuffs generally cannot take in as much nutrient material as her body demands. To overcome this, most high producing cows will utilize body fats (and proteins, if necessary), which results in body weight losses for the first 30 to 90 days of lactation (Rakes, Smith and Stallcup, 1976). These authors also report that high producers lose more weight during the first 30 days of their fifth or sixth lactation than in earlier lactations. Further positive correlations were found betweend end of lactation bodyweight and fat-corrected milk (FCM) yield and between days dry, bodyweight and various production factors.

Several authors have reported the effect of various levels of protein on bodyweight changes. Gardner and Park (1973) found weight losses on corn silage, alfalfa and grain concentrate to be equal during the first 30 days of lactation for cows receiving 13.2, 14.4 and 15.5% CP. These results are supported by Treacher et al. (1975) who found equal weight changes on a 12.75 and 16.5% CP hay, beet pulp and grain ration. When Sparrow et al. (1973) fed levels of 13.5, 15.5 and 17.5% CP in a 50% corn silage and 50% grain diet, weight losses were -3.5, -4.9 and -8.9 kg, respectively, between the second and twelfth week postpartum.

Protein Level Effect on Feed Intake

Higher levels of dietary protein generally increases feed intake. On corn silage based diets, Van Horn and Jacobson (1971) found that in-

take increased from 17.2 to 18.1 kg of dry matter when cows were switched from a ration containing 11.4% CP to rations containing 13.3 or 15.1% CP. In a number of experiments Polan, Miller and McGilliard (1976) and Polan et al. (1977) found dry matter intake to increase several kg per cow per day when CP% was increased within the range of 9.4 to 16.2% CP.

Roffler et al. (1976) fed rations containing 13.7 and 19% CP to first, second and third lactation cows. Feed intake was greatest in the high protein group, and increased with age. Botts, Hemken and Bull (1977) found dry matter intake to be 13.6 kg per day on a ration containing 9% CP. Intake increased to 19 kg per day when the protein of the ration was increased to 14 and 18% CP. Decline in intake was noted in rations over 22% CP. Cressman et al. (1977) feeding hay, corn silage and a mixture of corn and soybean meal grains found intake to increase when the protein level increased from 12.4 to 17.7% CP.

Grieve, Macleod and Stone (1974) found no correction between dry matter intake and CP content for the first 70 days of lactation on alfalfa haylage, shelled corn and soybean meal rations. However, a strong correlation between ration protein level and feed intake was noted for the second 70 day period of the lactation.

Protein Level Effect on Rumen pH

Rumen pH varies according to the nature of the diet and according to when it is measured after ingestion of food. The addition of feedstuffs with large amounts of starch or soluble carbohydrates will result in lower pH values than those rations containing carbohydrates which are

metabolized more slowly (e.g. cellulose).

Polan, Miller and McGilliard (1976) found rumen pH to consistently average 6.75, even though the crude protein percentage in different rations was between 9.4 and 16.2% CP. They also found a tendancy in low protein rations for pH to increase as urea replaced protein.

Protein Level Effect on Rumen Ammonia

Dietary protein is degraded by rumen microorganisms to several products, of which the primary one is ammonia. Lewis, Hill and Annison (1957) showed that rumen ammonia increases with increased protein intake.

Blowey, Wood and Davis (1973) found that starch facilitates micrbial growth, thereby decreasing ammonia levels in the rumen. This agrees with work by Roffler and Satter (1975) which showed that rumen ammonia concentration is negatively correlated with the TDN content of the feedstuff.

When dietary CP levels approach 12 to 13% of the ration, Satter, Whitlow and Beardsley (1976) suggest that a point is reached where ammonia is not used rapidly by microorganisms and accumulates in the rumen. This theory was challenged by Edwards, Bartley and Bechtle (1977) who measured significant microbial growth up to 27% CP *in vitro* (see page 9).

Polan, Miller and McGilliard (1976), Polan *et al*. (1977) and Fenderson and Bergen (1976) all found rumen ammonia concentrations to increase with the level of dietary protein. Hawkins, Linsey and Strength (1977) demonstrated the effect of protein solubility on rumen ammonia

concentration in isonitrogenous rations. Their findings based on 25% CP diets showed that soybean meal rations caused higher levels of rumen ammonia than did cottonseed meal rations.

Protein Level Effect on Blood or Plasma Urea Nitrogen

Excess or "overflow ammonia" produced in the rumen is generally absorbed across the rumen wall and travels via the portal circulation to the liver. The ammonia is usually converted to urea in the liver and is carried by the renal vein to the kidneys. The urea can then pass through the kidneys to be excreted in the urine or it can enter the bloodstream to become what is commonly called blood urea nitrogen (BUN) or plasma urea nitrogen (PUN).

Lewis (1957) found that different levels of BUN could be positively correlated with different levels of rumen ammonia. Preston, Schnakenberg and Pfander (1965) showed a close relationship between protein intake and BUN levels in growing and finishing lambs. Torrell et al. (1974) found a correlation of .99 between nitrogen intake and BUN in mature sheep. Pfander et al. (1975) was able to increase lamb growth performance after assigning them to various protein level diets based on BUN measurements.

In 1966, Lane and Campbell reported that advancing age and pregnancy would lower BUN levels in Guernsey cows. They also found that cattle grazing pastures reached peak BUN levels in the spring. However, research by Torrell et al. (1974) with sheep reported that age had no significant effect on BUN levels. Mason (1973) reported that estrus

cycles have no effect upon BUN levels.

Polan et al. (1972) and Treacher et al. (1972) discovered that BUN levels increased as CP content of the diet increased from 10.9 to 16.5% CP. With CP levels ranging from 10 to 40% CP, Fenderson and Bergen, measured higher BUN levels as CP% increased. Hawkins, Linsey and Strength (1977) found BUN levels to be the same in isonitrogenous soybean or cottonseed meal ration, despite different methods of processing.

Protein Level Effect on Serum Albumin

Plasma albumin is formed almost exclusively in the liver. It is the most abundant plasma protein and is responsible for about 80% of the total potential osmotic pressure of the plasma proteins (Frondson, 1974). Weeth et al. (1969) measured plasma albumin levels of 3.11 grams per 100 milliliters or 41% of the total plasma protein in Hereferd heifers.

Famichev (1972) reported an increase in blood albumin levels as protein intake increased. Blowey, Wood and Davis (1973) found that decreasing serum albumin is a good indication of decreasing dietary protein intake. Treacher et al. (1975) found that serum albumin levels increased at a faster rate in postpartum cows fed 16.5% CP than in those receiving 12.75% CP diets. Cotrut et al. (1974) reported that serum albumin levels were low in underfed cows. According to Hawkins, Linsey and Strength (1977) serum albumin levels are not affected by method of processing of soybean or cottonseed meals.

Protein Level Effect on Blood Ammonia

Ammonia absorbed across the rumen wall is carried via the portal circulation to the liver. The liver is able to convert the absorbed ammonia to urea until the level of ammonia in the portal blood reaches .8 millimoles; this corresponds to a rumen fluid ammonia level of 55 to 60 millimoles (Lewis, Hill and Annison, 1957) or 84 mg% (Lewis, 1960).

Repp et al. (1955) correlated excess peripheral blood ammonia with excess rumen ammonia levels. Lewis, Hill and Annison (1957) also found that blood ammonia concentrations increased markedly when the rumen pH exceeded 8.

Kulasek, Gorwacki and Borej (1970) demonstrated that when rumen ammonia levels were high, as in the case of high dietary protein, peripheral blood ammonia levels were increased. When feeding diets containing urea in conjunction with high and low levels of concentrates, Bolduon et al. (1973) found that blood ammonia levels were highest on the low concentrate rations.

EXPERIMENTAL DESIGN

Forty five (45) Holstein-Friesian dairy cows were selected from the Oregon State University dairy herd over a six and one-half month period. Cows that had completed at least one lactazion were selected if they showed the potential for peak production of 31.5 kg (70 pounds) or more of milk per day, adjusted to a mature equivalen basis. Using a randomized numbers table, cows were assigned at three days postpartum to one of the three experimental rations. The experiment ran for eight and one-half months, with each cow on the experiment for 90 days.

Cows were fed a total ration containing approximately 12.7, 16.3 or 19.3% crude protein (CP) as a percentage of dry matter for the first 90 days of their lactation. Rations for the first six months of the test were composed of corn silage, alfalfa hay and a grain concentrate. For the last two and one-half months, grass silage replaced the corn silage in the rations. Rations were isocaloric, averaging 75% Total Digestible Nutrients (TDN) for the corn silage ration dry matter and 71% TDN for the grass silage ration dry matter. Tables 1 and 2 show nutrient values of the rations. Monthly samples of the total rations and their components were subjected to a Kjeldahl Nitrogen test and occasional tests were run for Acid Detergent Fiber, Calcium and Phosphorus. Total Digestible Nutrients and some Crude Protein, Calcium and Phosphorus data were obtained from Church *et al.* (1972). The cows were group-fed their rations *ad libitum* as a complete mixed feed once daily at about 8:30 a.m. A record was kept of feed distributed and the accumulated rejected feed was

TABLE 1

Proximate or Calculated* Analysis of
Experimental Rations - Corn Silage Base

Composition in kg of dry matter	Low CP Ration	Int. CP Ration	High CP Ration
		kg of DM/100 kg as fed	
Corn Silage	15.02	15.02	15.02
Alfalfa Hay	8.69	8.69	8.69
Barley, Pacific	24.88	20.48	15.10
Soybean Meal	-----	5.50	10.90
Molasses, Cane	1.62	.73	.73
Salt, Iodized	.15	.15	.15
Mg Oxide	.031	.031	.031
Dicalcium Phosphate	.20	.08	-----
Limestone	.386	.46	.46
Total kg DM/100 kg as fed	50.98	51.14	51.08
ANALYSIS			
Crude Protein, % DM	12.8%	16.5%	19.5%
TDN, % DM	75.2%*	75.0%*	74.7%*
Calcium, % DM	.9%*	.9%*	.9%*
Phosphorus, % DM	.42%*	.4%*	.4%*
ADF, % DM	21.4%	21.9%	22.9%

* Church et al. (1972)

TABLE 2

Proximate or Calculated* Analysis of
Experimental Rations - Grass Silage Base

Composition in kg of dry matter	Low CP Ration	Int. CP Ration	High CP Ration
		kg DM/100 kg as fed	
Grass Silage	13.66	13.66	13.66
Alfalfa Hay	8.69	8.69	8.69
Barley, Pacific	24.88	20.48	15.10
Soybean Meal	-----	5.50	10.90
Molasses, Cane	1.62	.73	.73
Salt, Iodized	.15	.15	.15
Mg Oxide	.031	.031	.031
Dicalcium Phosphate	.20	.08	-----
Limestone	.386	.46	.46
Total kg DM/100 kg as fed	49.62	49.78	49.72
ANALYSIS			
Crude Protein, % DM	12.4%	15.8%	18.9%*
TDN, % DM	71.6%*	71.2%*	71.0%*
Calcium, % DM	.30%	.36%	.36%
Phosphorus, % DM	.37%	.36%	.36%
ADF, % DM	33.90%	32.50%	28.20%
ESTIMATED AVERAGE VALUE FOR ENTIRE FEEDING PERIOD			
Crude Protein, % DM	12.7%	16.3%	19.3%

*Church et al. (1972)

weighed weekly to estimate average daily consumption.

Cattle were separated into treatment groups and housed in a free-stall barn bedded with wood shavings. Aisles were cleaned regularly by a water flush system. All three groups were milked together in the same facility twice daily.

Milk yields were recorded at each milking from DeLaval calibrated receiving jars. Milk samples were collected from two consecutive milkings each week and the composite analysed for per cent milk fat and protein.

Milk fat was analyzed by the Banco Fat Determination Method.[1] Protein was determined by the dye binding technique of Ashworth, Seals and Erb (1960), modified for use of a colorimeter with a one centimeter light path. Average daily actual milk, 4% fat-corrected milk (FCM) and average weekly per cent milk fat and protein were calculated for each cow for each of the consecutive 30 day periods. Persistency was calculated by dividing the current weeks' actual average daily production by that of the previous week. From these values, average persistency for each cow for each of the 30 day periods was determined.

Cows were weighed three days postpartum when they entered the experiment and at monthly intervals thereafter. Bodyweight changes were calculated for each period.

When the cows were between six to eight weeks into their lactation, rumen fluid was obtained four to six hours after feeding by applying

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[1]Banco Laboratory Chemicals--Anderson Laboratories, Inc., Forth Worth, Texas.

vacuum to a stomach tube attached to a 1000 ml Erlenmeyer flask. Approximately 300-800 ml of rumen fluid was obtained. Rumen fluid pH was determined on 30 ml of sample using a Fisher Accumet model 210 pH meter.[2] Two-five ml samples of strained rumen fluid from each cow were analyzed for ammonia using a modified Van Slyke and Cullen method as proposed by Hawk, Oser and Summerson (1954).

Eight to ten ml of blood from the caudal artery was drawn from all cows into heparinized tubes by a tail puncture, at six to eight weeks postpartum. The blood was centrifuged witin two hours and the plasma removed and refrigerated. Plasma urea nitrogen was determined by a colorimetric procedure using the Urea Nitrogen Rapid Stat Kit.[3] Samples were run in duplicate for each cow. Plasma Albumin was measured using the colorimetric procedure for the Spectru-AB 2 Albumin Reagent.[4] Samples from each cow were run in triplicate.

Blood from 30 cows at various stages of lactation and from all three groups, was analyzed for ammonia, using a colorimetric method proposed by Ternberg and Hershey (1960) as modified by Chaney and Marbach (1962). All cows tested for blood ammonia had been on the experiment for at least two months. Eight to ten ml of blood was collected via tail puncture into heparinized tubes for each analysis at 8 a.m.

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[2]Blood samples of 8-20 ml were being drawn weekly from these cows for a separate experiment

[3]Pierce Company, Box 117, Rockford, Illinois 61105--Urea Nitrogen Rapid Stat Kit (1975)

[4]Pierce Company, Box 117, Rockford, Illinois 61105--Spectru-AB2 Albumin Reagent

The tubes were immediately packed in ice and centrifuged within one-half hour. Each sample was analyzed in triplicate.

RESULTS

A total of 12 production and physiological measurements were made during the course of the experiment. In seven of the measurements the treatment, period and interactions were analyzed using a split-plot design. The remaining five measurements (rumen ammonia, blood ammonia, rumen pH, PUN and plasma albumin) were only measured once and were therefore analyzed using a completely randomized design. Analysis of various tables may be found in the Appendix.

There were no significant differences in the average age of the cows; the average age at calving being 4-06, 5-02 and 4-03 years for the 12.7, 16.3 and 19.3% CP rations, respectively.

Table 3 lists treatment means and Table 4 lists period means.

Feed Intake

Cows consumed significantly more ($P < .01$) of their specific rations as the CP level of the diet increased. There was no significant effect of period on feed intake.

Bodyweight Change

Changes in bodyweight were not significantly affected by level of dietary protein, although there was a trend for weight losses to be greater in the higher dietary protein groups. Bodyweight losses over the 90 day periods were -.78, -2.67 and -3.35 kg for each cow in the 12.7, 16.3 or 19.3% CP rations, respectively. The trend towards greater weight losses as dietary protein increase agrees with work by

TABLE 3

Certain Differences due to Treatment and an Indicator of Those Which Vary Significantly*

Measurements	Rations Protein Levels 12.7%	16.3%	19.3%	$S\bar{x}$
Bodyweight Change during Treatment (kg)	-.78	-2.67	-3.35	± 3.01
Protein Intake per Day (kg)	2.24a	3.02b	3.63c	± .027
Feed Intake per Day (kg)	17.70a	18.18b	18.67c	± .166
Milk Yield per Day (kg of 4% FCM)	29.37	31.31	31.97	± 1.25
Milk Yield per Day (kg of actual milk)	30.94a	35.52b	34.79a	
Persistency (%)	101.70	102.20	101.20	± .507
Milk Fat (%)	3.66b	3.21a	3.46b	± .087
Milk Protein (%)	3.55	3.53	3.50	± .110
Rumen NH_3 (mg/100 ml)	4.29a	7.66a	14.24b	± 1.01
Blood NH_3 (µg/100 ml)	466.30	469.30	516.80	±23.3
Rumen pH	6.49	6.53	6.39	± .092
PUN (mg/100 ml)	7.89a	10.27a	18.25b	± .799
Plasma Albumin (g/100 ml)	3.45a	3.47a	3.85b	± .055

*Means with different subscripts differ significantly at the 5% level

TABLE 4

Certain Differences due to Period and
Indicators of Those Which Vary Significantly*

Measurements	Experimental Periods			$S\bar{x}$
	ONE (0-30 days)	TWO (30-60 days)	THREE (60-90 days)	
Bodyweight Change (kg)	-24.10a	3.80b	13.51b	± 3.69
Protein Intake per Day (kg)	2.92	3.00	2.97	± .025
Feed Intake per Day (kg)	18.10	18.60	18.40	± .160
Milk Yield per Day (kg of 4% FCM)	31.06b	31.30b	29.80a	± .336
Milk Yield per Day (kg of actual milk)	33.34a	35.61b	33.02a	
Persistency (%)	106.50c	100.20b	98.40a	± .516
Milk Fat (%)	3.70b	3.22a	3.39a	± .064
Milk Protein (%)	3.76b	3.36a	3.46a	± .082

*Means with different subscripts differ significantly at the 5% level.

Gardner and Park (1973), Treacher et al. (1975) and Sparrow et al. (1973).

A highly significant difference in bodyweight changes was seen between period one and the other two periods. During the first period all cows averaged a weight loss of 24 kg, however cows gained 3.8 kg in the second period and 13.5 kg in the third period.

Milk Production

Milk production (corrected to 4% milk fat) was not significantly affected by treatment, averaging 29.37, 31.31 and 31.97 kg/cow/day for the 12.7, 16.3 and 19.3% CP rations, respectively. The average total 4% fat-corrected milk production per cow for the 90 day period was 2643, 2818 and 2880 kg/cow for the 12.7, 16.3 and 19.3% CP rations, respectively. When lactations were projected to 305 days (McDanie, Miller and Corley, 1965) and corrected for age and month of calving (Norman et al., 1974), production equaled 7790, 8199 and 8474 kg/cow/305 day lactation for the 12.7, 16.3 and 19.3% CP rations, respectively.

Fat-corrected milk yield for the three periods averaged across all cows equaled 31.6, 31.3 and 29.8 kg/cow/day. These results were not significant between the first and second period, but were significant between these two periods and the third period.

Actual milk production averaged 30.94, 35.52 and 34.79 kg/cow/day for the 12.7, 16.3 and 19.3% CP rations, respectively. The 16.3% CP ration cows produced significantly more milk than did those on the 12.7% CP ration. Period means for actual milk production were 33.34,

35.61 and 33.02 kg/cow/day for period one, two and three, respectively. Period two means were significantly higher.

Persistency

The ability of cows to maintain milk production from week to week was measured by dividing the current weeks' actual milk production by that of the previous week. The persistencies were averaged over the 30 day periods.

There were no significant differences in persistency between groups due to treatment. Averages per treatment group were 101.7, 102.2 and 101.2% for the 12.7, 16.3 and 19.3% CP rations, respectively. These findings conflict with those of Thomas (1971), who found that persistency increased with increased dietary protein.

Persistency was significantly influenced by period; the average for all cows for period one was 106.5%, for period two, 100.2% and during the third period, 98.4%.

Milk Fat Percentage

Milk fat content was higher ($P < .01$) in the cows on the 12.7% CP ration, averaging 3.66% as compared to 3.21% for the 16.3% group and 3.46% for the 19.3% CP group. The probable explanation for the differences between groups is that cows were selected for the experiment on the basis of milk production, therefore there could have been genetic differences affecting milk fat percentage. Sparrow et al. (1973), Grieve, McLeod and Stone (1974) and Treacher et al. (1975) found milk

fat percentage to increase with dietary protein level.

Milk fat percentage averaged over all cows was significantly higher ($P < .01$) during the first period at 3.7%. It reached its lowest level during the second period at 3.21% and was 3.46% during the third period.

Milk Protein Percentage

The percentage of protein in the milk was not significantly affected by the level of dietary protein consumed, averaging 3.55, 3.53 and 3.50% for the 12.7, 16.3 and 19.3% CP rations, respectively. The literature is contradictory on this aspect as Treacher et al. (1975) found increased milk protein percentage as dietary CP increased from 12.75 to 16.5%. However, Grieve, Macleod and Stone (1974) observed a milk protein percentage depression as dietary protein increased from 14-18% CP.

There was a highly significant effect of period on milk protein percentage, between period one and the other two periods. The protein content of the milk was highest during the first period at 3.76%, was 3.36% in the second period and 3.46% during the third period.

Rumen Ammonia

Rumen fluid was removed via a stomach tube from each cow at six to eight weeks postpartum. Analysis for rumen ammonia showed the 19.3% CP diets to produce significantly higher ($P < .01$) levels of rumen ammonia. Ammonia levels were 4.29, 7.66 and 14.24 mg% for the 12.7, 16.3

and 19.3% CP rations, respectively. These findings agree with work by Polan, Miller and McGilliard (1976), Fenderson and Bergen (1976), and Polan et al. (1977).

Rumen pH

The effects of various levels of dietary protein on rumen pH were not significant. The average pH of rumen fluid for the groups was 6.49, 6.53 and 6.39 for the 12.7, 16.3 and 19.3% CP rations, respectively. This agrees with the work of Polan, Miller and McGilliard (1976), who found pH to remain constant as dietary protein levels increased from 9.4 to 16.2% CP.

Blood Ammonia

Blood ammonia levels were determined in 30 cows who were at various stages of lactation. Blood ammonia levels were 466, 469 and 517 micrograms/100 milliters for the 12.7, 16.3 and 19.3% CP rations, respectively. However, blood ammonia levels were not significantly different. These findings contradict the work of Repp et al. (1955) and Kulasek, Gorwacki and Borej (1970), who found significantly higher blood ammonia levels with higher levels of rumen ammonia.

Plasma Urea Nitrogen

Levels of urea nitrogen in the plasma were higher ($P < .01$) in the 19.3% CP ration cows than in those cows on the lower CP rations. PUN levels equaled 7.89, 10.27 and 18.25 mg% at the 12.7, 16.3 and 19.3%

CP levels, respectively. This trend agrees with work of Lewis (1957), Preston, Schnakenberg and Pfander (1965), Torrell et al. (1974), Pfander (1975), Treacher et al. (1975), Polan et al. (1972) and Fenderson and Bergen (1976).

Plasma Albumin

There was no significant difference in plasma albumin levels between the cows fed 12.7 or 16.3% CP rations (3.45 vs. 3.47 mg%). However, plasma albumin increased ($P < .05$) to 3.85 mg% in the cows fed rations containing 19.3% CP. The trend towards increasing plasma albumin levels as dietary CP increased agrees with work by Famichev (1972), but varies from the report of Treacher et al. (1975), who found that serum albumin levels were higher at 16.5% CP than at 12.75% CP.

DISCUSSION

From the results of this experiment it may be concluded that the performance of dairy cows in early lactation was not significantly improved by feeding rations which contain more than 13% crude protein, on a dry matter basis. Although not statistically significant, trends were found towards higher fat-corrected milk production as dietary protein intake increased. Actual milk production was significantly higher according to Tukey's test at the 16.3% CP level than at the 12.7% CP level.

Several factors may explain the trend towards increased milk production as dietary protein levels increased. Firstly, feed intake was significantly higher as dietary protein increased. Soybean oil meal, used in this experiment to vary the protein content of the rations, increased ration palatability. This in turn increased the daily energy intake possible resulting in increased milk yield. Secondly, although not significantly different weight losses were greater as protein in the ration increased, this may support the theory that increased protein helps to convert body fat to energy.

Milk fat percentage was seen to vary with level of dietary protein; however, this may be explained by the fact that cows were selected for this experiment on the basis of milk production, so it is quite possible that genetic differences caused the observed differences.

Physiological measurements showed that as dietary protein was increased, higher levels of rumen ammonia, plasma urea nitrogen and blood ammonia were found. These differences were greater between 16.3 and 19.3% CP rations, than between the 12.7 and 16.3% CP rations. This would

TABLE 5

Economic Analysis for Three Groups of Cows
Fed 12.7, 16.3 and 19.3% Crude Protein Rations

	Percentage CP		
	12.7	16.3	19.3
90 day milk prod. (kg)	2785	3197	3131
Milk Fat %	3.7	3.2	3.5
Price/kg of milk	22.3663¢	21.1309¢	21.8721¢
Total returns	$622.90	$675.56	$684.82

Feed Costs (as fed/tonne)	12.7		16.3		19.3	
	kg	cost	kg	cost	kg	cost
Barley @ $105	279.5	$29.35	230.1	$24.16	169.8	$17.83
Soybean Meal @ $237	0	0	61.8	14.65	122.7	29.08
Silage @ $23	593.8	13.66	593.8	13.66	593.8	13.66
Alfalfa Hay @ $94	97.4	1.16	97.4	9.16	97.4	9.16
Mol., Cane @ $75	21.6	1.62	9.7	.73	9.7	.73
Salt, Iod. @ $82	1.5	.12	1.5	.12	1.5	.12
Mg Oxide @ $314	.31	.10	.31	.10	.31	.10
Dical. Phos. @ $259	2.0	.52	.80	.21	0	0
Limestone @ $40	3.86	.15	4.60	.18	4.60	.18
Cost per tonne of ration		$54.68		$62.97		$70.86
Feed consumption/cow/day (kg)		36.6		38.5		39.4
Feed consumption/cow/90 days (kg)		3294		3465		3564
Feed costs/cow for 90 days		$180.12		$218.19		$252.55
RETURNS ABOVE FEED COSTS		$422.78		$457.37		$432.27

tend to indicate that the rumen microorganisms can utilize the products of the degradation of increased protein to a certain point, but then the "law of diminishing returns" takes affect and losses of rumen ammonia through absorption in the bloodstream and conversion to PUN takes place. Significantly higher plasma albumin levels at the 19.3% CP level would indicate that some of the excess ammonia absorbed from the rumen is converted to this product in the liver.

An economic analysis taking into account both actual milk and milk fat production, as well as the cost of each ration, showed a decided advantage for the 16.3% CP ration. It is also interesting to note that the 12.7% CP ration was more feasible economically than the 19.3% CP ration.

Differences for all cows due to the effect of the three 30 day periods were generally what is expected of cows in early lactation. Weight losses were high in the first 30 days, followed by modest gains in the second and third periods. Milk fat % and milk protein % showed a negative relationship to milk yield. Actual milk yield peaked in the second period, although there were no significant differences in 4% fat-corrected milk due to period. Persistency was highest in the first period and gradually declined through period two and three.

Figure 2 graphically illustrates the relationship between milk production and dietary protein intake.

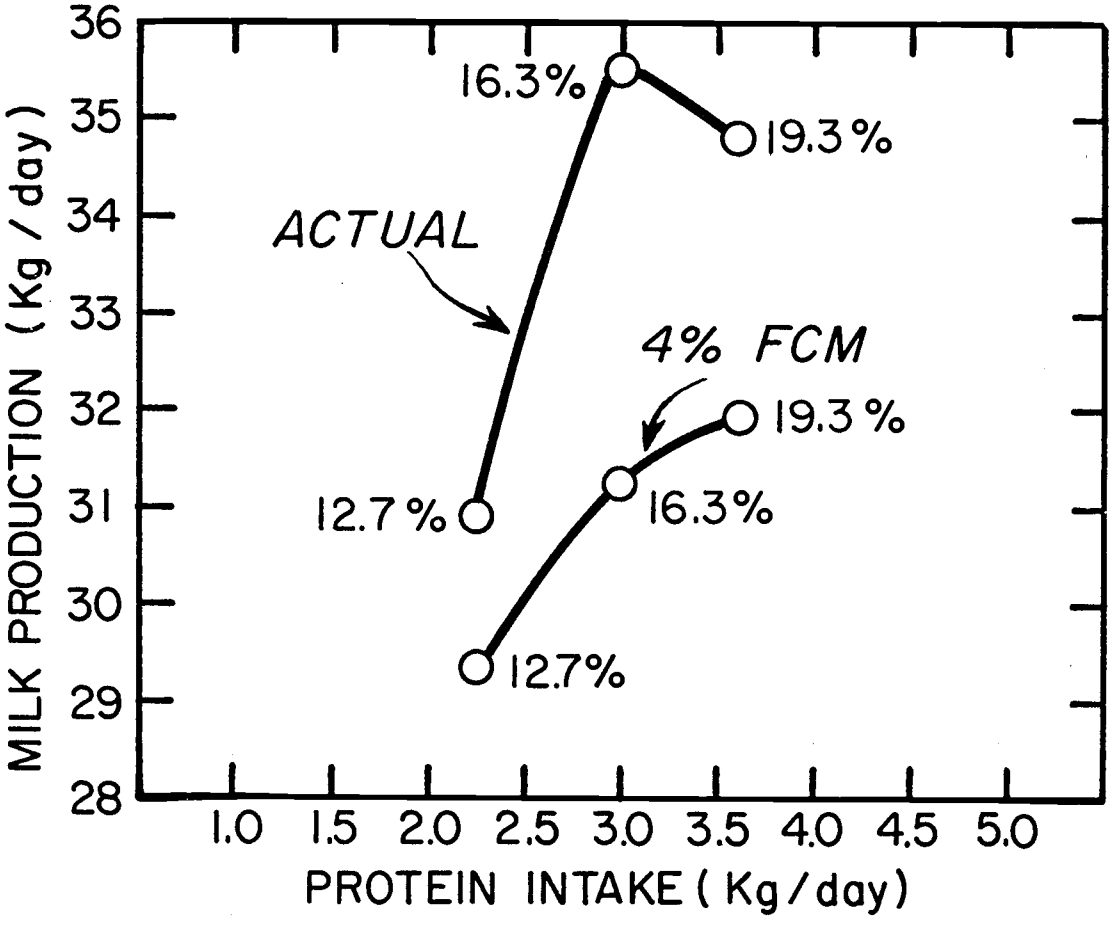

Figure 2. Graphic Illustration of Protein Intake Effect Upon Milk Production

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APPENDICES

TABLE 1. ANALYSIS OF VARIANCE TABLE FOR FEED INTAKE

	DF	MS	F	
Treatment	2	72.59	11.98	**
Period	2	13.20	2.35	NS
Tre. x Per.	4	.6193		
Cow, Tre. x Cow	42	6.058	.1102	NS
Per. x Cow, Tre. x Per. x Cow	84	5.618		
Total	134			

Treatment Means	Frequency	Means
12.7% CP	45	17.7a
16.3% CP	45	18.18b
19.3% CP	45	18.67c

**P < .01

$S\bar{x}$ = .16643

$HSD_{.05}$ = .4759898

TABLE 2. ANALYSIS OF VARIANCE TABLE FOR PROTEIN INTAKE

	DF	MS	F	
Treatment	2	105.10	678.1	**
Period	2	.34953	2.495	NS
Tre. x Per.	4	.02770	.1978	NS
Cow, Tre. x Cow	42	.15499		
Per. x Cow, Tre. x Per. x Cow	84	.14008		
Total	134			

Treatment Means	Frequency	Means
12.7% CP	45	2.24a
16.3% CP	45	3.02b
19.3% CP	45	3.63c

**P < .01

$S\bar{x}$ = .0266205

$HSD_{.05}$ = .0761346

TABLE 3. ANALYSIS OF VARIANCE TABLE FOR BODYWEIGHT CHANGE

	DF	MS	F	
Treatment	2	388.4	.1967	NS
Period	2	8336.9	27.98	**
Tre. x Per.	4	161.3	.0541	NS
Cow, Tre. x Cow	42	1974.7		
Per. x Cow, Tre. x Per. x Cow	84	2979.8		
Total	134			

Period Means	Frequency	Means
Period 1	45	-24.1a
Period 2	45	3.8b
Period 3	45	13.5b

**P < .01

$S\bar{x}$ = 3.6911246

$HSD_{.05}$ = 10.41012

TABLE 4. ANALYSIS OF VARIANCE TABLE FOR MILK YIELD (4% PCM)

	DF	MS	F	
Treatment	2	407.35	1.18	NS
Period	2	216.84	8.78	**
Tre. x Per.	4	16.954	.684	NS
Cow, Tre. x Per.	42	343.61		
Per. x Cow, Tre. x Per. x Cow	84	27.704		
Total	134			

Period Means	Frequency	Means
Period 1	45	31.6b
Period 2	45	31.3b
Period 3	45	29.8a

**P < .01

$S\bar{x}$ = .3360858

$HSD_{.05}$ = .9477518

Treatment Means	Frequency	Means
12.7% CP	45	29.37
16.3% CP	45	31.31
19.3% CP	45	31.97

$S\bar{x}$ = 1.2534361

$HSD_{.05}$ = 3.5848272

TABLE 5. ANALYSIS OF VARIANCE TABLE FOR MILK YIELD (ACTUAL)

	DF	MS	F	
Treatment	2	1314.95	2.97	*
Period	2	426.23	34.6	**
Tre. x Per.	4	34.561	1.91	NS
Cow, Tre. x Cow	42	442.95		
Per. x Cow, Tre. x Per. x Cow	84	18.08		
Total	134			

Treatment Means	Frequency	Means
12.7% CP	45	30.94a
16.3% CP	45	35.52b
19.3% CP	45	34.79a

*P < .1

$S\bar{x}$ = 1.423246

$HSD_{.05}$ = 4.0704835

Period Means	Frequency	Means
Period 1	45	33.34a
Period 2	45	35.61b
Period 3	45	33.02a

**P .01

$S\bar{x}$ = .028755

$HSD_{.05}$ = .810883

TABLE 6. ANALYSIS OF VARIANCE TABLE FOR MILK PROTEIN %

	DF	MS	F	
Treatment	2	.02996	.1027	NS
Period	2	.89385	5.493	**
Tre. x Per.	4	.22738	1.397	NS
Cow, Tre. x Cow	21	.29167		
Per. x Cow, Tre. x Per. x Cow	42	.16271		
Total	71			

Period	Frequency	Means
Period 1	24	3.76b
Period 2	24	3.36a
Period 3	24	3.46a

**P < .01

$S\bar{x}$ = .0823

$HSD_{.05}$ = .235378

TABLE 7. ANALYSIS OF VARIANCE TABLE FOR MILK FAT %

	DF	MS	F
Treatment	2	2.2999	6.734 **
Period	2	2.6643	14.495 **
Tre. x Per.	4	.15080	.82040 NS
Cow, Tre. x Cow	42	.34156	
Per. x Cow, Tre. x Per. x Cow	84	.18382	
Total	134		

Treatment	Frequency	Means
12.7% CP	45	3.66b
16.3% CP	45	3.21a
19.3% CP	45	3.40a

**P < .05

$S\bar{x}$ = .08712

$HSD_{.05}$ = .24917

Period	Frequency	Means
Period 1	45	3.70c
Period 2	45	3.22a
Period 3	45	3.40b

**P < .05

$S\bar{x}$ = .0639116

$HSD_{.05}$ = .180231

TABLE 8. ANALYSIS OF VARIANCE TABLE FOR PERSISTANCY

	DF	MS	F
Treatment	2	14.496	1.25 NS
Period	2	803.92	67.2 **
Tre. x Per.	4	44.063	3.68 **
Cow, Tre. x Cow	42	11.583	
Per. x Cow, Tre. x Per. x Cow	84	11.959	
Total	134		

Period	Frequency	Means
Period 1	45	106.5c
Period 2	45	100.2b
Period 3	45	98.4a

$S\bar{x}$ = .5155212

$HSD_{.05}$ = 1.4537697

Treatment x Period	Frequency	Means
Tre. 1, Per. 1	15	104.2b
Tre. 1, Per. 2	15	101.2a
Tre. 1, Per. 3	15	99.6a
Tre. 2, Per. 1	15	108.3b
Tre. 2, Per. 2	15	99.9a
Tre. 2, Per. 3	15	98.7a
Tre. 3, Per. 1	15	106.9c
Tre. 3, Per. 2	15	99.6b
Tre. 3, Per. 3	15	96.9a

$S\bar{x}$ = .5155212

$HSD_{.05}$ = 1.9125836

**P < .01

TABLE 9. ANALYSIS OF VARIANCE TABLE FOR RUMEN AMMONIA

	DF	MS	F
Treatment	2	383.92	25.19 **
Error	42	15.24	
Total	44		

Treatment Means	Frequency	Means
12.7% CP	15	4.29a
16.3% CP	15	7.66a
19.3% CP	15	14.24b

**P < .01

$S\bar{x} = \pm 1.0079682$

HSD = 3.4674106

TABLE 10. ANALYSIS OF VARIANCE TABLE FOR BLOOD AMMONIA

	DF	MS	F
Treatment	2	8025.85	1.483
Error	27	5410.66	
Total	29		

Treatment Means	Frequency	Means
12.6% CP	10	466.3
16.3% CP	10	469.3
19.3% CP	10	516.8

$P < .05$

$S\bar{x} = \pm 23.260825$

HSD = 81.761799

TABLE 11. ANALYSIS OF VARIANCE TABLE FOR RUMEN pH

	DF	MS	F
Treatment	2	.063	.6864
Error	30	.092	
Total	32		

Treatment Means	Frequency	Means
12.7% CP	11	6.49
16.3% CP	11	6.53
19.3% CP	11	6.39

$P < .05$

$S\bar{x} = \pm .0914527$

HSD = .3191699

TABLE 12. ANALYSIS OF VARIANCE TABLE FOR PLASMA UREA NITROGEN

	DF	MS	F
Treatment	2	442.30	46.23 **
Error	42	9.57	
Total	44		

Treatment Means	Frequency	Means
12.7% CP	15	7.89a
16.3% CP	15	10.27a
19.3% CP	15	18.25b

**P < .01

$S\bar{x} = \pm .798749$

HSD = 2.7476965

TABLE 13. ANALYSIS OF VARIANCE TABLE FOR PLASMA ALBUMIN

	DF	MS	F
Treatment	2	.07594	1.69
Error	42	.04488	
Total	44		

Treatment Means	Frequency	Means
12.7% CP	15	3.45a
16.3% CP	15	3.47a
19.3% CP	15	3.85b

$P < .05$

$S\bar{x} = \pm .0546991$

HSD = .1881649

BIOGRAPHICAL SKETCH

The author of this thesis was born on December 25, 1953 in Tillamook, Oregon. His early years were spent on a small dairy farm and golf course owned by his parents Mr. and Mrs. Marvin E. Pangborn. He attended Tillamook High School and graduated in 1972. After the death of his father in 1970, he operated a small farm for several years, on which dairy heifers and a multi-suckled crossbred beef herd were the primary enterprises.

After completing a year as a state FFA officer, he entered Oregon State University in the spring of 1973. His initial major was Agricultural Education, but during the 1974 academic year he undertook a double major program with Animal Science. His junior year (1975) was completed at Lincoln College, Canterbury, New Zealand as a member of the first OSU-Lincoln exchange program. He graduated from the Animal Science Department (Production Option) in December of 1976 and in January of 1977 began a graduate program which has lead to a Masters of Science Degree in Dairy Production, with a minor in Agricultural and Resource Economics. Concurrent with his graduate program, he has completed the requirements for a Bachelor of Science degree in Agricultural Education.

During summers he has gained additional practical experience through working on several Tillamook County dairy farms.

He will marry Jane McKergow of New Zealand in December of 1977 and they will return to N.Z. in February of 1978. Plans are to return to the U.S. within several years.

Career objectives are to become involved in the dairy industry or a related agri-business so as to eventually be in a management position.