Economic Evaluation of the Use of Ammoniated Feeds in Beef Cow Rations

by

Gary Melville

A thesis
presented to the University of Manitoba
in fulfillment of the
thesis requirement for the degree of
Masters of Science
in
Department of Agricultural Economics and Farm Management

Winnipeg, Manitoba

October 1988

ISBN 0-315-48001-7

ECONOMIC EVALUATION OF THE USE OF AMMONIATED FEEDS IN BEEF COW RATIONS

BY

GARY MELVILLE

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

MASTER OF SCIENCE

I hereby declare that I am the sole author of this thesis.

I authorize the University of Manitoba to lend this thesis to other institutions or individuals for the purpose of scholarly research.

Gary Melville

I further authorize the University of Manitoba to reproduce this thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research.

Gary Melville

The University of Manitoba requires the signatures of all persons using or photocopying this thesis. Please sign below, and give address and date.

ABSTRACT

The process of ammoniation uses anhydrous ammonia or its hydroxide to treat fibrous crop residues and low quality forages. The resultant product has greater available energy, higher protein content and is more palatable or fungus resistant. Potential demand exists for the process and its product but adoption in existing feeding systems requires evaluation of its competitiveness as a feedstuff relative to commonly used feeds .

This study attempts such an evaluation through formulation of least cost rations from a set of feed ingredients that include ammoniated alfalfa hay and barley straw. Rations are formulated for three conditions of pregnant beef cows and under different price and environmental conditions. The results of analysis indicate that feed price , nutritional content and diet energy requirements are the important considerations in such feeding. Cost savings of up to 11 cents per head per day and maximum treatment costs of $42.00 per tonne were obtained in some animals for the usage of treated straw. While ammoniated hay was not included in any solutions the results for treated straw establish that there is economic value to pursuing such treatment and usage of its product as feed.

ACKNOWLEDGEMENTS

I would like to express my thanks to the members of my advisory committee, D.Kraft, K.Wittenberg and R.Josephson for their role in this process.

I would also like to thank the committee at the Commonwealth Scholarship and Fellowship Plan for funding me over this period.

Special thanks to my friends. They know who they are. Couldn't have done it without you.

Finally I must thank the members of my family for their support and understanding during my stay here. I am especially grateful to my daughter Afeisha and to Nover her mother. Thanks for your patience and kindness.

CONTENTS

ABSTRACT iv

ACKNOWLEDGEMENTS v

Chapter page

I. 1

Introduction 1
Overview of Chemical Processing 4
Methodology of Ammoniation 6
Problem Statement 9
Objectives and Scope of Study 10

II. THEORETICAL FOUNDATIONS AND REVIEW OF LITERATURE 12

Introduction 12
Theory and Concepts 12
Feed Substitution Studies 15
Other Issues in Ration Formulation 18
The Net Energy System and Environmental Considerations. . . 19
Feed Evaluation Studies 22
Ammoniation Studies 25
Summary 29

III. LEAST COST MODEL, POSTOPTIMAL ANALYSIS, AND DATA 30

Choice of Technique 30
Linear Programming 32
Properties and Assumptions 34
Model Specification 35
Energy Considerations In the Analysis 37
Environmental Aspects in The Model 39
Parametric Programming 40
Specific Model Assumptions 42
DATA 43

IV. RESULTS AND DISCUSSION 51

Introduction 51
Results For 450 kilogram Beef Cows. 51
Under Thermoneutral Environmental Conditions. 51
Average Winter Conditions 56
500 kilogram Beef Cow. 60
Thermoneutral environment 60
Average Winter Conditions. 64

Results for 550 Kilogram Beef Cow 67
Thermoneutral Conditions 67
Average Winter Conditions 71
Results of Energy Content Variation of Ammoniated Feeds . . 73

V. CONCLUSIONS AND RECOMMENDATIONS. 74

Summary 74
Weaknesses and Recommendations for Further Research 76

BIBLIOGRAPHY 78

Appendix page

A. DATA 83

B. RESULTS OF ENERGY VARIATION OF AMMONIATED FEEDS 87

LIST OF FIGURES

Figure page

2.1. Relations in Regulation of Feed Intake in Ruminants 16

2.2. Relationship of Domestic Animal With its Environment 22

2.3. Framework for By-Product Utilization Research. 28

4.1. Comparisons of Usage of Ammoniated Feeds Over Cost Ranges for a 450 kg Heifer in Thermoneutral Environment 55

4.2. Comparisons of Ammoniated Feed Usage Over Cost Ranges For a 450 kg Heifer in Average Winter Conditions. 59

4.3. Comparisons of of Ammoniated Feed Usage Over Cost Ranges for a 500 kg Cow in a Thermoneutral Environment 63

4.4. Comparisons of Ammoniated Feed Usage at Cost Ranges for a 500 kg Cow in Average Winter Conditions. 66

4.5. Comparisons of Ammoniated Feed Usage With Cost Variations for a 550 kg Beef Cow in Thermoneutral Environment 69

4.6. Comparison of Ammoniated Feed Usage With Cost Variations For 550 kg Beef Cows in Average Winter Conditions. 70

LIST OF TABLES

Table | page

1.1. Estimated Quantities of Major Crop Residues in Western Canada('000s of tonnes) 3

3.1. Feed Ingredients and Prices Used in Analysis. 44

3.1. Feed Ingredients and Prices Used in Analysis(contiued) 44

3.2. Nutrient Content of Feedstuffs(Dry Matter Basis) 46

3.2. Nutrient Content of Feedstuffs(continued) 46

3.3. Nutrient Requirements and Intake Levels(Dry Matter Basis) for Animals in The Analysis 49

3.4. Increase in Daily Energy and Intake Levels due to Environment. 50

4.1. Results of Least Cost Analysis and Cost Variation For 450 kg heifer Under A Thermoneutral Environment. 52

4.2. Results of Least Cost Analysis and Cost Variation For 450 kg heifer under Average Winter Conditions 57

4.3. Results of Least Cost Analysis and Cost Variation For 500 kg Cow Under A Thermoneutral Environment. 61

4.4. Results of Least Cost Analysis and Cost Variations For 500 kg cow Under Average Winter Conditions. 65

4.5. Results of Least Cost Analysis and Cost Variations For 550 kg Cows in A Thermoneutral Environment. 68

4.6. Results of Least Cost Analysis and Cost Variation For 550 kg Cow Under Average Winter Conditions. 72

Chapter I

1.1 INTRODUCTION

Since the turn of the century, researchers have attempted to improve the feeding value of straw and other low quality plant material(Sundstol et al. 1979). The basis for this interest can be summarized in the following points;

1. Relatively higher cost of grain feedstuffs.
2. Increasing ruminant production in regions where grain is required for human consumption.
3. Disposal of crop residues from cereal grain and sugar production where enviromental problems restrict burning.
4. Higher effective demand for animal protein in countries with limited grain supplies but ample quantities of fibre.
5. Competition for land between pastoral grazing and crop production and possible intensification of the above factors with rising world and national populations.

Given some potential demand for crop residues and low quality forages in ruminant livestock feeding, there exists a serious underutilization of these materials(Kossila 1984). Tremendous quantities of crop residues are produced annually in developed and developing countries. Studies by the Food and Agriculture Organization(Jackson 1978) give annual rates of as much as 7 tonnes of crop residues per livestock unit in North and

Central American nations. Slightly lower rates are found in other regions. Due to high cereal production, Western Canada has a great potential for use of crop residues (table 1.1).

A major reason for the underutilization of crop residues and low quality forages is their inability to meet the nutrient requirements of ruminant livestock(Huber 1981). Physical and chemical treatments of these materials can improve this aspect. Numerous studies involving these treatments have been conducted and a 1983 National Research Council (NRC) study suggested that the greatest increase in residue utilisation was likely to come from chemical treatments and improved practices. Given the potential demand for straw usage and the possibilities of chemical processing, there is incentive for investigation of the roles of such materials in livestock feeding.

TABLE 1.1

Estimated Quantities of Major Crop Residues in Western Canada('000s of tonnes)

Kind	Man.	Sask.	Alberta	B.C	Total
		Amount of Residue			
Wheat	3,015.53	15,084.92	5,502.17	123.38	23,726.00
Oats	1,613.91	1,982.23	2,287.96	85.19	5,969.29
Barley	1,082.29	2,562.84	3,773.04	117.57	7,535.74
Rye	100.70	269.44	166.02	2.91	538.97
Mix.Grain	196.86	143.34	381.93	6.17	728.30
Flax	479.91	466.30	237.69	--	1,183.90
Rapeseed	333.85	1,404.35	1,097.71	--	2,835.91
Total	6,823.05	21,913.42	13,446.52	335.12	42,518.11
Cattle (in '000s of head)	1,196	2,852	4,133	618	8,799

(Source:Coxworth and Kullman, 1978)

1.2 OVERVIEW OF CHEMICAL PROCESSING

The basis for processing of straw and low quality forages, lies in their anatomical and chemical characteristics. These materials have low levels of available energy and because of the importance of energy in animal diets, crop residues and low quality forages are limited in their potential as a feed ingredient. Compared to a good quality forage, there is a larger cell wall to cell content ratio in straws. The result is a greater concentration of structural carbohydrates and lignin. Consequently, needed nutritional elements are less readily available to the consuming animal. In order for ruminants to obtain their dietary needs, some breakdown of these structural materials is necessary. Alkalis and other chemicals achieve such a breakdown and hence their potential.

Owen et al.(1984) discussed the characteristics of the ideal chemical for upgrading roughages for feeding. Improvement in digestibility and/or intake after processing, relatively lower treatment costs and wide availability of the treatment chemical are the major ones listed. These factors point to a reagent that is produced using an inexpensive energy source. In addition, the chemical residues found in the treated material should be non toxic to the animal. No residues should be left in meat or milk of fed animals and their wastes must be non polluting to soil and water. The handling of such a chemical should not be hazardous to man and it is an asset if the chemical itself is a nutrient required by the animal. Owen et al.(1984) reviewed a number of chemicals including acids, alkalis, salts and sulphur compounds and found alkalis to be the most promising reagents in chemical improvements of straw. Sodium hydroxide and ammonia, in particular, were found to have suitable properties for roughage upgrading. While acknowledging the need for further research and the lack of feeding trials for some reagents, the authors concluded that no obvious alternatives to these chemicals existed at present.

Both sodium hydroxide and ammonia have been extensively researched and developed for improving the nutrient availability of crop residues and low quality forages. Though some researchers indicate lower energy values for ammoniated materials, ammoniation achieves the same basic benefits of sodium hydroxide treatment and provides a few unique ones. Animals fed sodium hydroxide treated roughage void sodium in feces and urine and this presents a potential salinity problem. No such mineral residue is obtained with ammoniation. Commercial energy requirements for the ammoniation process are lower than for sodium hydroxide treatment and depending on technology used most methods of ammoniation are simple and relatively inexpensive. Treatment by the popular stack method however, is tremendously time consuming.

Ammonia and sodium hydroxide effect the hydrolysis of linkages in cell wall materials. This provides more ready access to the digestive agents (microbes and enzymes) of the rumen so that increased nutrient uptake can occur. The amount of hemicellulose (complex carbohydrates) in the roughage is reduced and a resultant increase in dry matter and organic matter digestibility takes place. In this manner increased energy is available to the consuming animal. One of the major advantages of ammonia usage is an increase in amino acid uptake. This results from microbial synthesis of these protein building blocks from the additional nitrogen provided by ammonia. This effect is similar to feeding a non protein nitrogen source to the animal. The extent of the nitrogen utilization depends upon factors such as total nitrogen content, speed of nitrogen release, available carbohydrates in the rumen and degradation of dietary protein. By affording protection from fungal infestation, ammonia exerts a preservative effect on high moisture content forages. In crop residues and low quality forages, increased intake is observed when ammoniated materials are fed. These factors make the ammoniation procedure more attractive to some researchers and is the paramount reason for its selection as the process to be examined in this study.

1.2.1 Methodology of Ammoniation

Techniques used for treating straw and other materials with ammonia vary with the form of chemical used, production systems and weather conditions. The results of treatment can also vary. Sundstol and Coxworth(1984) ascribed this variation to the quantity of ammonia used, temperature, time of treatment, forage moisture content and type and quality of the treated material. The basic treatment involves the introduction of anhydrous ammonia or ammonium hydroxide (ammonia solution) into covered stacks or sealed heated containers.

The stack method as the former treatment is called, involves sealing the straw in a gas tight enclosure. The material to be ammoniated is neatly stacked in a rectangular or other shape and covered with plastic sheet. The cover is folded and sealed to prevent entry of air or exit of the ammonia and is further weighted down to prevent wind removal. Anhydrous ammonia is injected into the stack via a pipe and the stack remains covered and sealed for a number of weeks depending on climatic conditions. Alternately, aqueous ammonia can be used as the reagent. After opening the stack, the treated material is aerated for some time before being used as feed.

The oven method of ammoniation involves the circulation of anhydrous ammonia in a heated chamber. The material has to be dry before processing. Therefore it has to be dry before baling and storage (Staniforth, 1982). The storage aspect also requires extra space on the farm. High capital costs, mechanical problems and lower levels of output may also be associated problems. There are also advantages of the oven method as some authors regard it as being more consistent than the stack treatment and having more potential for industrial scale use. Sundstol et al.(1984) note that significant automation of this ammoniation method is possible.

Recent years has seen the development of a freeze explosion process of ammoniation(Sundstol and Coxworth 1984). In this process liquified anhydrous ammonia is mixed with straw in a high pressure reactor. Pressure causes temperature to fall in the reactor and ammonia within the cell structures expands and breaks up the cell wall. This process may also have industrial potential but is still in the experimental stages.

Like most processes there are some drawbacks to the ammoniation technology. High percentages of ammonia loss to the surrounding air occurs in application(in stacks). This presents a possibility for farm building pollution so that some care must be taken in its usage. The smell of ammonia is also unpleasant to some individuals and can result in illness. More importantly in some situations it produces a toxic reaction in animals. Utilization of ammonia depends upon growth of microbes and is limited by availability of readily fermentable carbohydrates(Shirley 1986). Since it is produced from fossil fuels, there may also be the problem of rising costs in the future. However with its distinct properties, the ammoniation process does merit some examination since as indicated in our brief review it has tremendous potential. The advantages of ammonia in relation to other chemicals strongly suggest that it be used in any analysis of the potential of chemical processing of straw.

1.3 PROBLEM STATEMENT

Animal feeding can be classified into three broad categories(Crotty 1980). There is the large feed mill type, where formulation of the concentrate portion of a spectrum of rations is undertaken for selected producers. A different type of operation is where the larger scale farms blend their own formulations. This category is often representative of state farms and private feedlots. The last farm organisation includes small scale commercial and subsistence farmers. They are also responsible for all aspects of their livestock feed preparation although on a different scale to the above category. Relatively high transport costs of straw and low quality forages make the ammoniation procedure more suited for on farm usage(Potts, 1982) as it has to be close to the source of material.

Given the potential for the ammoniation technique in livestock feeding, its performance relative to other feeding alternatives must be measured. The demand for any feedstuff in terms of an animal or class of animal, is based on the requirements of that livestock for energy, protein and other nutrients(Funk 1977). Before inclusion of a feedstuff in a commercial feeding system, it would be of importance to have certain knowledge of its economic performance in that system. The ability to compete with other available feedstuffs at given prices, the economic conditions under which it is competitive and its substitution possibilities in a given economic environment need to be understood for its usage. Such an examination of ammoniated feedstuffs is needed to evaluate the economic potential of the ammoniation procedure.

1.4 OBJECTIVES AND SCOPE OF STUDY

The objectives of the study are;

1. To examine the ability of ammoniated feedstuffs to meet the diet requirements for selected ruminant livestock in relation to other feedstuffs.
2. To determine the economic conditions under which substitution of of ammoniated feedstuffs in ruminant diets is likely to occur.
3. To gain some indication of the manner in which other possible improvements in such feedstuffs can impact on the substitution process.

Achievement of the above objectives is attempted through formulation of least cost rations for selected ruminant livestock and selected diet requirements.[1] Ration formulation is accomplished by use of linear programming techniques. Post optimal analysis of optimal solutions is involved in the methods used to achieve the objectives.

The available methods of ammoniation are potentially beneficial to a variety of ruminant livestock, in a number of countries and regions and for a range of plant materials. In addition, complementary physical treatments and effects of different treatment techniques along with environmental factors and price relationships can affect adoption of the process. For practical reasons, it is not possible to fully consider all these scenarios in a study of this size. Thus, the present study is limited to available feedstuffs and economic conditions existing in the province of Manitoba for price periods of differing roughage - concentrate price relationships. The analysis is performed for beef cattle and

---

[1] Rationale for selections is given in chapter 3.

it is limited to two feedstuffs ammoniated by the conventional stack method.

Chapter II

THEORETICAL FOUNDATIONS AND REVIEW OF LITERATURE

2.1 INTRODUCTION

The present study focuses on an economic evaluation of ammoniated straw and low quality forages as livestock feedstuffs. The evaluation is conducted by formulation of least cost rations. In an attempt to understand the theoretical precepts of this approach, the present chapter involves defining the conceptual framework for ration formulation. The nutritional and economic aspects of the problem are further discussed in a review of studies of feedstuff substitution and evaluation. In this manner, the theoretical foundations of this analysis and the directions taken by other researchers of similar problems can be established. Finally, an examination of economic studies on the ammoniation process is carried out with a view to determine relative and potential contributions of this research.

2.2 THEORY AND CONCEPTS

Methods of production, choice of products and quantity produced are assumed to be the key decisions involved in agricultural production processes(Beattie and Taylor, 1985). The study of production economics is based on these choices and also encompasses the changes in decisions with the advent of new technical or economic information. Given the profit maximization(implicit cost minimization) assumption of neoclassical economics, a rational producer selects the input bundle which optimises this objective(Miller et al, 1986). In livestock feeding, the least cost or profit maximizing set of feed ingredients(given technical relationships) are used to produce a given output. Given the high proportion of feed costs in the activity, the development of new feed ingredients through research represents a need for reevaluation of previous allocation decisions(Farris and Simpson, 1982).

Economic analysis of biological processes in crop and livestock production is based on the production response or production function. This represents the physical relationship between output activity and inputs used. In livestock production, the feeding relationship can be denoted as;

$$y = [\ f1(w1,b1), f2(w2,b2), \ldots, fm(wm,bm)] \qquad (2.1)$$

where;

y = output of livestock product(weight gain, milk production) and or maintenance,

wi = animal weight,

bi = amount of the ith nutrient consumed,

fi = a function relating performance to weight and nutrient intake.

This basic relationship can also include factors such as sex, dry matter intake and environmental variables and interaction between nutrient concentration and intake(Brokken, 1976). There is some concern as to the functional form taken by the response function. The assumptions about functional form determine the analytical tools that may be used in analysis of problems. If the livestock response function was determined to have a quadratic form, then this would be considered in the programming or econometric analysis. In cases where the assumption of linearity is made, von Leibig's law of the minimum comes into effect(LaFrance and Watts, 1986). This relation basically states that the nutrient in shortest supply constrains the rate of growth or other production. In this instance the above relation becomes;

y = minimum [f1(b1,w1), f2(b2,w2),......,fm(wm,bm)] (2.2)

2.2.1 Feed Substitution Studies

Dillon(1977) has shown that a number of relationships can be derived from the response function. Isoquant maps, rates of technical substitution, factor - factor relationships and elasticities are some of the economic ones identified. For purposes of this study, the important aspects are the feed input substitution relationships. Brokken et al.(1976) and Heady et al (1980) have conducted studies on concentrate - forage substitution. Similar analysis on silage - concentrate relationships and corn silage - forage relationshipshas been performed. The following is a brief review of their findings.

Brokken et al.(1976) outlined the traditional analytical approach used by economists in assessing animal performance. This approach utilized the production response to develop the isoquant and other economic relationships described above. Technical substitution relations for major feed types could be arrived at by movement along the relevant isoquant for differing price ratios(Dillon 1977). Brokken et al.(1976) found this approach to be unsatisfactory as it did not consider factors as rate of gain, specific weights and the animal's intake. Based on the work of livestock scientists, the above authors set up a system that incorporated such aspects. Nutrient concentration of the diet is related to animal performance by setting up daily voluntary intake as a function of ration energy concentration and animal weight. Values for feed intake were based on feeding trial results. Daily feed energy required for maintenance and growth is considered to be a function of rate of gain and animal weight. This analysis provided a more realistic appreciation of aspects of livestock feeding and the results provided some intriguing questions to economists involved in such work. Estimated relationships from feeding trials is required for such analysis. Where adequate data is not available, the framework outlined cannot be properly used. In the present study, this data limitation dictates against use of this approach.

Traditional analysis as previously mentioned, postulated a decreasing marginal rate of substitution between concentrate and forage feedstuffs. This meant that as grain prices increased relative to forage prices,more of the latter and less concentrates are included in the optimal ration. This would be represented by a convex isoquant. Brokken et al.(1976) and later Heady et al.(1980) disputed this. The former postulated that the physiological demand for energy in ruminants is met by regulating feed intake. In relatively low energy feeds, gut fill limits attainment of demand. This is seen in figure 2.1 where at low levels of energy concentration, intake is limited by rumen capacity. At a particular level

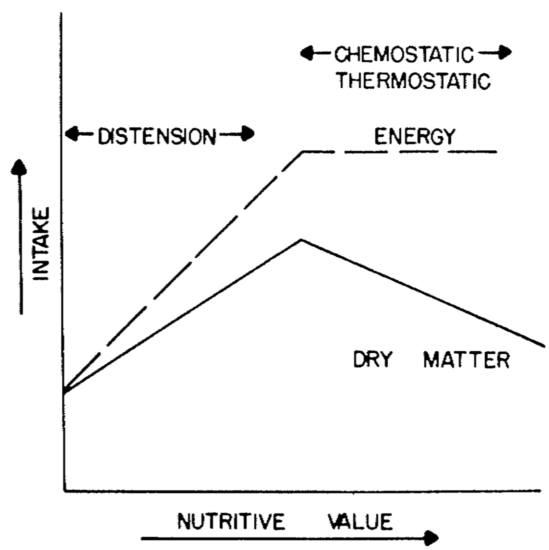


Figure 2.1: Relations in Regulation of Feed Intake in Ruminants Source; Montgomery and Baumgardt(1965) as shown in Brokken et al.(1976)

of energy concentration, rumen fill ceases to be a limiting factor and further increases in energy concentration result in reduced dry matter intake. Thus voluntary dry matter intake increases to a maximum and then falls as energy concentration increases. To the left of this peak, gut capacity regulates intake and to the right (figure 2.1) physiological mechanisms are responsible for intake regulation.

Both sets of studies obtained results that differed from the traditional results. Though both admit their results were inconclusive, the conventional convex isoquant was not obtained in analysis. Instead they found evidence of a non convex portion of the isoquant for concentrate - forage substitution. Heady et al. (1980) obtained concave and linear shapes depending on conditions specified for the concentrate forage isoquant. The low energy ration does fall into the convex region and the assumptions of the traditional analysis would be valid for such rations. Heady et al.(1980) also obtained a limiting ratio of 2:1 for forage to concentrate in beef rations at high forage low grain prices. The reverse price scenario gave values of 10:1 and is the upper limit for this relationship. The salient points to be gained from these studies involved the nutritional factors that should be considered in ration formulation. The isoquants obtained, raises questions about the functional form of the livestock response function. The intake aspect is one that has to be especially reckoned with as in addition to the gut fill problem, the animal itself ultimately controls if and what it consumes(Heady et al.1980). This presents an even greater problem.

2.2.2 Other Issues in Ration Formulation

Sonntag and Hironaka(1974) added to the framework necessary for use of the ration formulation process,they include;

1. The absolute and relative prices of alternate feedstuffs.
2. Prices received for the sale of animals and related products.
3. Interest rates.
4. Carcass quality under different feeding regimes.
5. Nutrient requirements and growth characteristics of the animal
6. The length of feeding period involved. The growth characteristics of the animal and performance on alternative diets that differ in ingredients but meet nutrient specifications.

The present study is non dynamic and involves explicit cost minimization. Consequently, all of the above factors may not be relevant to the analysis. However, an indication of the kinds of considerations involved in the analysis of optimal feeding strategy can be be obtained from these factors. Prices are necessary in any such analysis and interest rates are important where optimisation over time is involved. The complexities of the nutritional relationships and their primary importance in actual production require that proper attention be given to them in the conceptualisation of the feeding problem.

2.3 THE NET ENERGY SYSTEM AND ENVIRONMENTAL CONSIDERATIONS.

The two most important nutrients in ruminant feeding are protein and energy. Given the variation in conditions under which production occurs there has been concern about the specifications of these nutrients in economic models. Brokken(1971) has set up a system whereby the specification of energy is more realistic with respect to physical environment and physiological processes. Using the net energy system proposed by Lofgreen and Garrett(1968), Brokken's formulations are thought to provide more accurate representation of the energy relations in feeding. The net energy system represents the energy actually used by the animal after losses in digestion and metabolic reactions are subtracted out from the available(gross) food energy(GE). These losses vary with feedstuffs and occur in the form of energy in unutilized feed in the excrement {fecal energy(FE) }, urinary energy (UE), combustible gases from substrate fermentation(GPD) and heat losses from fermentation and nutrient metabolism. These heat losses make up the heat increment(HI).

The energy remaining after losses is net energy for maintenance and net energy for production(NEm and NEp). NEm is expended as heat and NEp is that available after maintenance needs are met. Other measurements of energy include digestible energy(DE) and metabolizable energy(ME). The former is gross energy less fecal energy. ME represents DE less urinary energy and combustible gases from fermentation. The portion of net energy which is not recoverable in gain or other animal product is termed total heat production(HP). This can be denoted as;

$$HP = HI(ME - NEm - NEp) + NEm + HB$$

where HB is energy diverted from production to heat to keep the body warm in chill stress or alternatively to keep the body cool in heat stress. The energy in HB may come from body reserves if feeding level is not high enough.

The net energy system is composed of three equations that can be written as;

$$\alpha \Sigma a_1 jXj = AW^{75} \qquad (2.3)$$

$$1-\alpha \Sigma a_2 jXj = (Bg+Cg^2)W^{75} \qquad (2.4)$$

$$\Sigma a_3 jXj = ME \qquad (2.5)$$

where

α = the portion of feed for maintenance

a_1j, a_2j and a_3j are respectively the NEm, NEp and ME values for the jth feed ingredient

Xj = the quantity of feed j consumed

W^{75} = the metabolic weight of the animal when W is body weight in kilograms and g is daily gain in grams

A,B,C = parameters as specified by Loftgreen and Garrett(1968).

The right hand side values denote daily energy intake in Mcal per day. The ME values can vary depending on temperature conditions. Brokken(1971) used parametric programming to vary ME while keeping NEm and NEp constant. In this manner, variation of heat increment occurs and rations for different heat increments are obtained. An indication of levels of change in performance for change in rations under environmental stress could then be observed. Brokken further stressed that the increased ration cost due to the heat adjustment could be offset by the increase in animal performance.

A 1981 NRC study provides equations for changes in energy requirements and dry matter intake as a result of thermal environment. A more precise analysis can then be conducted instead of parametric variation on equation (3.5).

The relationship of animals to their thermal environment can be dealt with in the context of the thermoneutral zone(NRC1981). In this zone heat production is at a normal level, body temperature is at a basal level and there is a sensation of maximum comfort(Mount, 1974). This is shown in figure 2.2 where, within a range of ambient temperatures in the thermoneutral zone, there are optimal conditions for performance and health. At lower temperatures, a cool zone exists and at higher temperatures a warm zone is present in the thermoneutral zone. In the respective subzones, postural adjustments and changes in NEm consumption serve to maintain homeothermy. At the lower end of of each subzone or at the lower critical and upper critical temperatures, changes in metabolic heat production occur. This requires further changes in energy intake to facilitate attainment of the animal's performance needs.

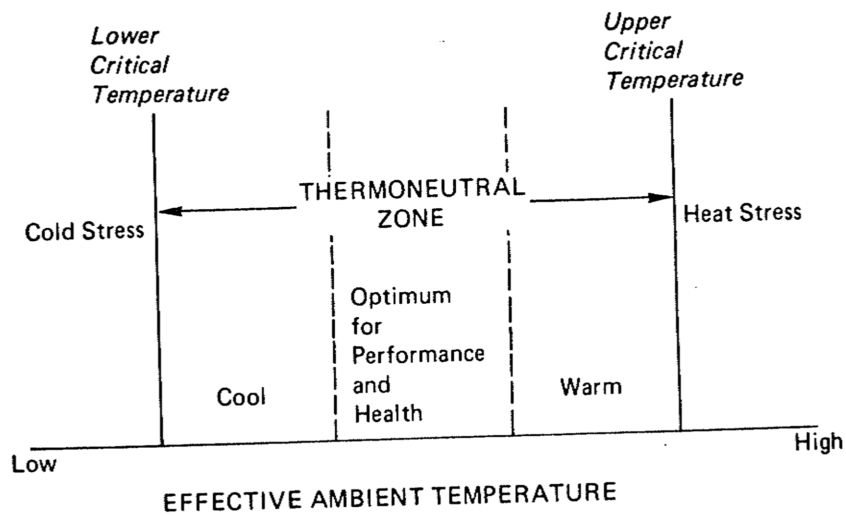


Figure 2.2: Relationship of Domestic Animal With its Environment
Source;NRC 1981.

2.4 FEED EVALUATION STUDIES

Development of a new feedstuff or improvement on an existing feed presents a need for evaluation of its prospects and potential. Nelson et al.(1957) produced a brief review of methodologies available for economic evaluation of such products. This effort was primarily directed at optimal resource use in hay and pasture production. The estimates of resource use were based on the value of fodder. Three distinct methodologies are described and an example of using a production function to set up a programming model is presented. Feed evaluation studies using linear programming models are also reviewed in this section.

The first method involves the determination of total value product by residual imputation. The costs of all inputs with the exception of that being currently valued are subtracted from the gross income. The residual is then the value of that input. The working assumption is that market price of each resource is equal to its marginal value product. If each input obtains its correct factor reward then no residual will occur. Thus the remainder equals the input's cost. The accuracy of the above assumption and problems in valuation of farm labor were given as disadvantages of this technique.

Multiple regression analysis was another method selected. Factor elasticies are calculated in this method and marginal value products thus determined. The assumption of perfect aggregation is made here and the method is criticised on this basis. Linear programming is the other method described and by incorporation of Euler's theorem it is assumed that factor rewards will be obtained.

In terms of evaluation of new feedstuffs using linear programming, some studies of importance can be found. Funk(1977) used least cost formulations to perform demand analysis on faba beans in Manitoba. Utilizing other available feed ingredients and prices for three different periods he attempted to compute demand curves for faba beans in chicken, swine, and cattle rations. Growth inhibitors present in faba beans were used as upper limits on their consumption. The value of the research conducted was considered as the increase in consumer surplus obtained by decrease in these inhibitors. Lancaster's theory of non market goods was used to calculate demand in terms of nutrient characteristics of faba beans. Parametric programming was used on the optimal solution to observe sensitivity to changes, particularly price ranges at which faba beans could be marketed. Consumer surplus estimates of $200,000 were generated in the low price period 1973 and $20,000,000 in the high price period 1976. Zero estimate was obtained for the median price period. Differences between the above and this present study exist as the latter is not a market analysis and is intended to be a part of the process of ammoniation research.

Klein, Salmon, and Gardner(1981) conducted an evaluation analysis on the use of rapemeal in chickens. Employing data from livestock trials on broilers, the authors formulated a linear programming model for least cost rations involving rapemeal as an ingredient. The same model was used by Klein, Salmon and Larmond (1979) for evaluation of the role of rapemeal in turkey diets. The objective in both studies was to determine the economic competitiveness of rapemeal with other feedstuffs and especially with soybean meal

A feeding program to maximize returns per lot of broilers was calculated. The programme was set up subject to nutrient, ingredient, intake and production capacity constraints. The analysis also included consideration of quantity and quality of output(meat). Rapemeal was found to be competitive in low price periods relative to soybean meal. nutrient density of the ration was also important as high protein diets were optimal in the majority of cases. Optimal level of rapemeal was found to vary with market conditions. They also determined that with reasonable (as judged by Klein et al.) price ratios, rapemeal could be included as a portion of most other high protein feeds. In conclusion Klein et al.(1981) noted that such studies demonstrate that cooperative research between biological scientists and economists can produce more valuable output than seperable use of resources.

Davies et al.(1973) have set up a framework for evaluation of feedstuffs by parametric programming. These authors proposed three different types of evaluation including price, nutrient and diet constraint variations. This methodology was employed by Paulding, Pesti and Miller(1986) for evaluation of the use of full fat soybean meal in broilers. Full fat soybean meal was hypothesised as being able to replace solvent extracted soybean meal that is commonly used in poultry feeding. Davies and Burdick(1972) found this substitution to be uneconomic at existing prices over the period October 1971 to May 1972. The study of Paulding et al.(1986) attempted to exploit potential price variability obtained by parametric ranging. Parametric programming and marginal cost mapping were used in the analysis. Marginal cost mapping involves the application to the linear programming framework. The results obtained gave a full range of prices at which the above substitution was economical.

2.5 AMMONIATION STUDIES

Given the existing state of ammoniation research, it is no surprise that there is limited research on the economics of the process. The studies of Giaver(1984), Jackson(1978) and Potts(1982) are the major ones in existence and are good indicators of the needs to be satistfied in this respect.

Jackson(1978) and Giaever(1984) have focussed on the potential usage of ammoniation in different world regions. Both studies have also narrowed their focus to straw usage. Giaever discusses feed relationships and mentions the importance of feed quality in determining feed use. Land rents, agricultural wages, straw prices, chemical prices, livestock product prices and prices of alternative feedstuffs are presented as economic forces in ammoniation usage. In terms of straw usage in different regions, Giaever suggests that ratios of land area to population size , the state of agricultural technology and factor(land, labor and capital) scarcities as being important variables in determining potential demand for the process. Based on these economic conditions and assumptions, Gieaver postulates that straw usage will have different merits in different areas. As a result he classifies world regions into four categories. These are;

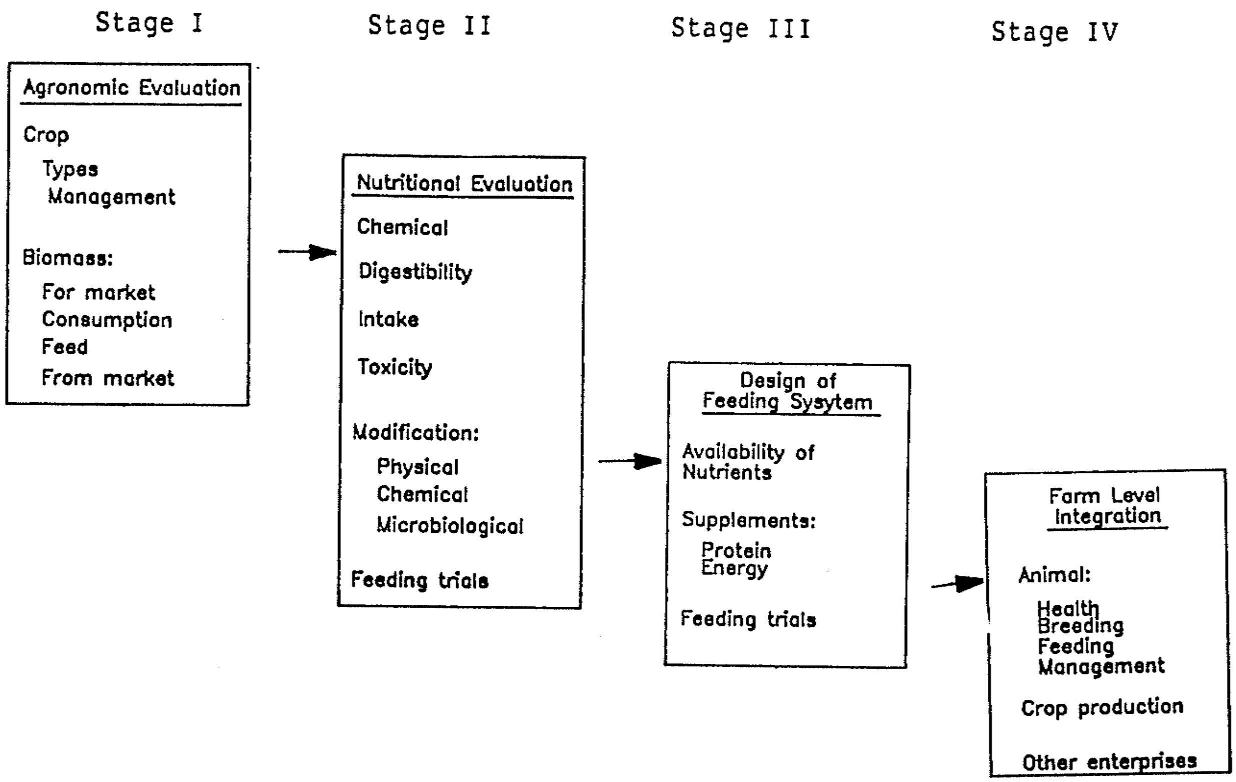
1. Less developed with high population density.
2. Less developed with low population density.
3. Industrialized with ample food supply.
4. Industrialized with little agricultural land per capita and high priority self sufficiency in food.

The first category is regarded as the region most likely to use such materials as they form a high proportion of available feed. This contention was first put forward by Jackson who cited cases in India where such usage was found to be profitable. The second world region were regarded as having less incentive for concentrated production and greater pasture availability.This is due to greater availability of land per capita and less upward pressure on food production per unit of land. More natural grazing of animals occurs and straw treatment may not be as profitable and may be more seasonal in nature. Nations belonging to the third region(including Canada and the US) were thought to have less requirement except for satsifaction of seasonal and minimum fibre constraints in diets. Indeed, Jackson argues that Norway is the only industrialized nation which uses treated straw extensively. Norway falls into the fourth category of nations and it is thought that potential feasibility exists in similar nations. The potential for world use is thus greatest in region one followed by the second, fourth and third respectively. It must be noted that explicit consideration of individual countries within this classification is limited.

In addition to these studies, some workers have done costing studies of the ammoniation. Kernan, Coxworth,Nicholson and Knipfel(1981) calculated costs for three different rations and found an ammoniated straw ration that was supplemented with oats to be cheaper than an untreated straw(similarly supplemented) or a hay ration. They found savings ranging from 13.1 cents to 6.8 cents on a daily per head basis for treated versus untreated straw and 24.9 to 18.6 cents for ammoniated straw versus hay. In addition to exclusion of a primary concentrate ration the above analysis did not consider changes in conditions and was limited in terms of ingredient range.

Potts(1982), also did a costing study on ammoniation but extended his approach to the four stage scheme outlined in Figure 2.3 The first two stages involve identification of suitable materials and determination of their costs and nutritional potential. Stage three determines how the potential is exhibited in actual performance situations. Stage four involves the analysis of the on farm or farm system performance of the by-product in question. Potts indicated that most of the research into ammoniation has been up to stage three of his scheme and suggested that more work is needed in the area of stage four.

Figure 2.3: Framework for By-Product Utilization Research. Source; Potts,1981



2.6 SUMMARY

The studies and concepts outlined in this chapter serve to set up the framework in for this study. Least cost ration formulation has its foundations in optimal resource use in feeding. The relationships involved were reviewed and a method of evaluating a new feedstuff by incorporation into this framework proposed.

Chapter III

LEAST COST MODEL, POSTOPTIMAL ANALYSIS, AND DATA

In the previous chapter, an introduction to the analytical tools employed in feed evaluation was obtained. The present study attempts to evaluate the economic competitiveness of ammoniated straw and hay. It further aims to determine conditions under which this competitiveness occurs. Based on these desired objectives,and the properties of available analytical methods, a choice of analytical technique is made. The assumptions used in the analysis, rations selected and price and feed ingredients used are also presented. These are provided along with an exact specification of the analytical model(s).

3.1 CHOICE OF TECHNIQUE

Models used for economic analysis in agriculture can be classified in three different ways(Anderson, 1972) These classifications are based on the existence or lack of time dependent elements, probabilistic entity and optimization of a goal function. In ration optimization the two basic analytical approaches involve use of econometric analysis on a marginal analysis model or mathematical programming. In terms of the latter, prevailing techniques include linear programming, dynamic programming and quadratic programming.

The marginal analysis appproach has been popularised in the work of Heady and Dillon(Day and Sparling, 1977). It involves the application of equimarginal principles to a cost or profit function of the feed ingredients to be used. Some form of econometric analysis is used to estimate this and the optimal use of the ingredients obtained. This approach has particular merits as was observed in the substitution studies. It has been criticised on the basis that optimal rations thus derived are a function of the feedstuffs used with no consideration of nutrient responses (Miller et al.,1986).This type of analysis involves use of a limited number of feedstuffs and is not well suited to situations such as this study where many alternative ingredients are used. More importantly, econometric estimation requires extensive feed trial data as regression analysis uses actual observations.

In terms of mathematical programming, the three types described above are used extensively in ration formulation. This present analysis does not cover continuous feeding over many production periods.[2] The use of dynamic programming is thus excluded. The quadratic programming technique has been used to formulate least cost rations by a number of authors(Dent, 1968, Townsely,1968 and Miller et el., 1986). This is based on the assumption that the response function has a quadratic shape. In addition to some complexities of the technique, the problem of flexibility in accomodation of large numbers of ingredients and the questions as to the exact functional form of the response function are some of the problems with this approach. Estimation of a quadratic response surface from feeding data is also necessary. Such a requirement cannot be met in this case and quadratic programming is not applicable. The use of linear programming in this analysis is as a result of the factors discussed above and the need for flexibility in postoptimal

[2] Rationale explained in specifications of the model.

analysis. In the review of studies, the use of this method in feed evaluation studies was observed. Adoption of this technique in subsequent analysis necessitates some consideration of its properties and limitations.

3.1.1 Linear Programming

The linear programming method has been used in the ration formulation problem for over five decades(Day and Sparling,1977). It can be used in situations where the same decision is being repeatedly made using the same information and has prescriptive, predictive and descriptive roles in agriculture(McCarl and Nuthall 1982). The general linear programming problem is composed of three parts(Lee, Moore and Taylor 1985). These can be outlined as follows;

1. The actual levels or quantity of products or resources in each problem are called the decision variables.These can be denoted as

$X_1, X_2, \ldots, Xj, \ldots, Xn$

where;

Xj = quantity of activity j(product or resource),

and $j = 1 \ldots n$.

2. The contribution of each decision variable towards attainment of the objective of the optimisation can be denoted by cj. The sum of these contributions makes up the objective function. This can be represented by;

$$\text{Max(Min) } Z = c_1X_1 + c_2X_2 + \ldots + cjXj + \ldots + cnXn \quad (3.1)$$

3. Finally, the restrictions within which optimization occurs have to be defined. These usually represent minimum requirements or maximum allowable resource use. For example, the amount of resource i used by each activity(Xj) can be represented by aij. The limits on resource use by each activity can be denoted by bi and the relationship expressed as;

$$
\begin{array}{l}
a_{11}X_1 + a_{12}X_2 + \ldots + a_1jXj + \ldots + a_1nXn \quad (\geq, =, \leq) \; b_1 \\
a_{21}X_1 + a_{22}X_2 + \ldots + a_2jXj + \ldots + a_1nXn \quad (\geq, =, \leq) \; b_2 \\
\quad \vdots \qquad\qquad \vdots \qquad\qquad \vdots \qquad\qquad \vdots \qquad\qquad \vdots \qquad\qquad \vdots \\
ai_1X_1 + ai_2X_2 + \ldots + aijXj + \ldots + ainXn \quad (\geq, =, \leq) \; bm \\
\qquad\qquad X_1, X_2, \ldots\ldots, Xj, \ldots\ldots, Xn \qquad \geq \; 0
\end{array}
\qquad (3.2)
$$

In ration formulation the vector of n resources is represented by feed ingredients such as roughages and concentrates. The vector of constraints is represented by maximum or minimum nutrient requirements for a given weight and performance. Linear programming deals with the determination of feasible plans which are optimal with respect to a linear objective function. This provides an ultimate plan which maximizes(minimizes) the linear function over all possible feasible plans.

3.1.2 Properties and Assumptions

In addition to the linearity assumption, the general linear programming framework involves implicit properties and assumptions. The major ones with respect to this analysis can be listed as;

1. Analysis is static and specific for a particular point in time.
2. The method assumes perfect knowledge of the model parameters in terms of prices, nutrient requirements and constraints as well as nutrient content of feedstuffs.
3. Constant composition of feed ingredients in terms of nutrient elements and additivity in these nutrients.

In Funk's(1977) study, these properties limit the conclusions which may be drawn from the analysis. The static analysis assumes constant prices and price relationships. Analysis for different time periods would give a better indication of a variety of price relationships and provide more generalized results. Perfect knowledge assumes participants in the feeding process are certain of price, nutritional factors, feed composition utilization. In practise this may not be the case given their variability and the costs be involved in gathering information. The optimising objective in this study is minimization, being the major objective of the enterprise.

Nutrient composition of feedstuffs varies with time, place, date of harvesting and other factors. This variability does incorporate an element of uncertainty into the analysis. However, in studies which involve large numbers of feedstuffs, the likelihood of obtaining perfect and universal composition data is not very great. The specific model attempts to address some aspects of the uncertainty problem.

3.2 MODEL SPECIFICATION

Solution of the following problems provide the quantity of ammoniated feedstuff contained in each ration used for different pricing periods and under varying restrictions. The basic formulation is;

Minimise $C_{fk} = \Sigma P_{jf} X_{jfk}$ $(k = 1,2,\ldots,r)$ $(j= 1,2,\ldots,n)$

Subject to;

$$\Sigma\Sigma a_{ij} X_{jfk} \quad (\geq,=,\leq) \quad b_{ik}$$

$$X_{jfk} \quad \geq \quad 0$$

$$X_{jfk} \quad \leq \quad u_{jk}$$

where;

C_{fk} = Daily cost of formulating ration for one animal of the kth class of livestock, in the fth price period.

P_{jf} = Price of one kilogram of the jth feed ingredient in the fth time period.

X_{jfk} = Quantity of jth feed ingredient contained in the daily ration of each animal of the kth class of livestock in the fth time period.

a_{ij} = Content of the jth feedstuff with respect to the ith nutrient. Expressed another way, it is grams of the ith nutrient per 100 grams (dry matter basis) of the jth feedstuff in decimal form.

b_{ik} = Level of nutrient i required in the daily feed ration per animal of the kth class of livestock.

u_{jk} = Upper bound limiting the quantity of feedstuff j in ration for animal of the kth class.

A total of 26 feedstuffs were included in each ration. The ammoniated feedstuffs used were ammoniated alfalfa hay and ammoniated barley straw. These were chosen based on experiments conducted at the University of Manitoba's Animal Science department. Rations formulated were maintenance rations for pregnant beef cows. Tembo(1987) noted that various studies had exhibited potential for usage of ammoniated feeds in this type of feeding.

3.2.1 Energy Considerations In the Analysis

Using the net energy system the model is solved for the animal's maintenance and production requirements(NEm and NEp). In this study the latter component represents energy required for gain. Rations are formulated for three animals in different conditions. To incorporate the net energy system in the model requires certain changes to the constraint equations with respect to maintenance and gain requirements. Brokken's (1971) three equation system contains a parameter α which represents the portion of feed consumed that is used for maintenance. The first two equations as previously mentioned are

$$\alpha \Sigma a_1 jXj = NEm \qquad (3.3)$$

$$1- \alpha \Sigma a_2 jXj = NEp \qquad (3.4)$$

dividing by α, this becomes

$$\Sigma a_1 jXj = NEm/\alpha \qquad (3.5)$$

and

$$\Sigma a_2 jXj = NEp/1-\alpha \qquad (3.6)$$

Since α is unknown, a range of values can be set for this parameter by determining its upper and lower limits. It is obvious that $0 < \alpha < 1$. Also, $a_1 j > a_2 j$ since the Mcal value of a unit of feedstuff is greater for maintenance purposes than it is for production. The portion of ration feed energy used for maintenance is at a minimum if all $aij = a_1*$, where a_1* is the largest NEm coefficient of all available ingredients. Similarly $1-\alpha$ is at a minimum if all $a_2 j =$

a_2* where a_2* is the largest NEg coefficient. Values could be specified for α within a range set by ;

$$NEm/ a_1{*}bm < \alpha < 1 - NEp/a_2{*}bm \quad (3.7)$$

where bm is the upper limit of dry matter intake. The values for the range and interval specified for each situation are shown in table 2 in appendix A. Given values for α it is now possible to include this variable in the model specification and ensure the attainment of both NEM and NEg requirements in each solution. A set of t_{ig} values can be defined corresponding to each value of α specified. Here t_{1g} represents NEm/α and t_{2g} represents $NEp/1-\alpha$.

The energy constraints in the model can now be defined as;

$$\Sigma a_1jXj - \Sigma t1gTg = 0 \quad (3.8)$$

$$\Sigma a_2jXj - \Sigma t2gTg = 0 \quad (3.9)$$

where Tg is a weighting factor and $\Sigma Tg = 1$, $Tg \geq 0$.

3.2.2 Environmental Aspects in The Model

Maintenance feeding of beef cows is a usual winter practise in temperate environs. Given the lower temperatures experienced in this season and the severity of such temperatures in Manitoba, analysis should also include situations for feeding ammoniated feedstuffs in cold conditions. This can be achieved by respecification of nutrient requirements for animals in the cool zone(see figure 2.2). To this end, calculation of increased maintenance requirement and dry matter intake is done(NRC 1981). Thus analysis is performed for two different thermal environments for each animal included. These scenarios can be described as;

1. Thermoneutral environmental conditions where the animal has optimal temperature conditions for production activities. Nutrient requirements (including NEm and NEp) are those recommended for beef animals of the relevant weight, sex and production category.

2. Average winter conditions of -15°C ambient temperature, where the animal is in the cool zone and requires energy levels above those in (1). According to NRC (1981), dry matter intake increases 5 - 10 percent in the temperature range -5°C and -15°C. The upper limit of this range is used since more specific data could not be obtained. The obvious weakness in such an approach is that this value has not been tested.

   The NRC(1984) maintenance energy requirement in thermoneutral conditions is denoted by aW^{75} where a = 0.077 and W = liveweight(kg). For the pregnant beef cows used here, 2.15 Mcal of this requirement is for conceptus and the remainder is based on the above formula. In lower environmental temperatures, the parameter a increases by .0007 for every °C drop in temperature below 20°C.. Requirements specified are calculated in this manner.

3.2.3 Parametric Programming

The nutrient composition of feedstuffs can vary and this affects the potential of the feedstuff in providing the animal's nutrient requirement. Nutrient content can determine the usage potential of a feedstuff. The effects of variations in nutrient composition and price are important considerations in the evaluation of this potential and assist the researcher in determining future improvements and conditions for the usage of the product.

Parametric programming on the optimal ration solution allows one to perform variations and observe their effects. By permitting the analyst to check for changes in the model parameters without having to resolve the problem, it provides indicators of changes in economic value of feedstuffs. The effect of variation of nutrient composition and costs of the ammoniation process can be studied for the model in use and these operations can be denoted as;

(a) Parametric changes in feed prices result in the objective function $Z = \Sigma$ Cjfk Xjfk being changed to

$$Z = (\ Cjfk + \gamma jQ1)\ \ Xjfk \qquad (3.10)$$

where;

γj = rates at which coefficient Q1 is being changed

and

Q1 = increase or decrease of the coefficient of contribution for activity j.

(b) Parametric nutrient ranging which involves change in the system constraint as;

$$\Sigma\Sigma\ aij\ Xjfk\ (\geq,=,\leq)\ \ bik \qquad (3.11a)$$

becomes

$$\Sigma\Sigma\ (aij + \beta Q2)\ Xjfk\ (\geq,=,\leq)\ \ bik \qquad (3.11b)$$

with Q2 playing the same role as Q1 and β having the same function as γ in (1).

With respect to variation in nutrient content, some care must be exercised in terms of nutrient(s) chosen for study. Varying each nutrient individually is time consuming as well as unnecessary since the limiting factor in the use of straw and low quality roughages is their available energy content.

3.2.4 Specific Model Assumptions

1. Animal performance is assumed to be identical on diets with identical nutrient composition but different constituent feed ingredients.
2. Nutrient requirements are based on normal levels of intake for good to excellent forages such as hay(this assumption is included in the NRC feed content analyses used in this study). Feeding of lower quality ingredients is facilitated by supplementation with higher valued feeds to meet nutrient constraints.
3. Given normal levels of intake, the optimal ration in the solution provides optimum conditions for the level of performance indicated. If intake varies from assumed levels, ration remains in nutrient balance and performance[3] will reflect nutrient intake.
4. Given the changes in ration requirements for winter conditions it is assumed to have minimal effect on rumen microbial functions and the dry matter intakes specified are not limited by bulk(similar rationale was adopted in the environmental specifications in NRC 1981.)

[3] Given the fact that performance is dependent upon factors such as type of animal, nutrient history, age of animal and feedstuffs used.

3.3 DATA

The objective function specified above is the vector of feed prices for the periods first quarter 1985 and fourth quarter 1985. Given the assumption of higher forage use in periods of high grain prices, the first period represents relatively high to intermediate pricing periods for grain. The period covered by the second series represents falling grain prices and rising forage prices. Feed prices are calculated as CIF(Cost, Insurance and Freight) Winnipeg as done in Funk(1977). Data for each pricing period are mainly average weekly prices from various publications over a thirteen week span . A listing of the feed ingredients and their prices is provided in Table 3.1 As indicated in the table some feed prices are Minneapolis prices adjusted for exchange rate differential and transport costs to Winnipeg.

Choices of feedstuffs were based on Manitoba Department of Agriculture(1978) and Canada Grains Council(1978) recommendations for beef. The nutrient content of the feedstuffs used are presented in table 3.2 and values for feed composition were obtained from National Research Council publication of feed composition tables for common feedstuffs utilised in beef production. Nutrient requirements were also based on the NRC recommendations and maximum limits were were set for urea and percentage straw content of the ration. These limits were based on concerns of toxicity and gut fill respectively. The urea limit is 1 percent of ration dry matter(NRC, 1984) and the straw limit, 75 percent of dry matter intake.[4]

[4] Suggested by Dr. Wittenberg.

TABLE 3.1

Feed Ingredients and Prices Used in Analysis.

FEEDSTUFFS	PRICES [6]	
	First Quarter1985	Fourth Quarter1985
	--- cents per kilogram ---	
Soymeal (49%) [1]	30.875	30.180
Soymeal (44%) [1]	28.837	28.930
Alfalfa meal(17% dehyd.) [1]	17.600	11.290
Alfalfa hay [2]	7.914	8.020
Ammoniated alfalfa hay [5]	9.956	10.235
Barley [2]	12.490	10.520
Barley straw [2]	2.198	3.018
Ammoniated barley straw [5]	4.239	5.230
Corn [2]	16.530	12.186
Beet pulp [4]	14.750	14.750
Silage corn [2]	6.300	6.450
Linseed meal [1]	28.510	15.500
Limestone [1]	3.970	4.120
Molasses [1]	14.450	12.100
Dicalcium phosphate [1]	4.810	6.120
Rock phosphate [1]	4.870	4.920
Oats [2]	13.670	10.010
Rapemeal [3]	20.930	15.920
Rye [2]	10.650	11.760
Timothy hay [2]	4.580	4.563
Middlings [2]	9.500	10.770
Screenings [2]	11.600	10.900

TABLE 3.1

Feed Ingredients and Prices Used in Analysis(contiued)

Wheat[2]	15.680	12.530
Brome- alfalfa hay[2]	6.600	5.940
Urea [1]	26.006	26.830
Oat straw [2]	2.130	1.460

SOURCES

[1] (Feedstuffs, 1981 and 1985) These are Minnesota prices on a Decatur basis and corrected for exchange rate changes (1.38 in 1985 (4), 1.32 in 1985(1), and 1.31 in 1981) and added transportation charges to obtain CIF Winnipeg prices.

[2] (Manitoba Cooperator, 1981 and 1985) These are 13 week average asking prices.

[3] (Statistics Canada, Cereals and Oilseeds Review,catalogue number, 22-007, 1981 and 1985).

[4] Obtained from Manitoba Sugar Company.

[5] See table A.1 in AppendixA.

[6] Adjusted to dry matter basis. For example price of beet pulp shown = Po / % dry matter content. Po represents original price.

TABLE 3.2

Nutrient Content of Feedstuffs(Dry Matter Basis)

FEEDSTUFF	NUTRIENTS				
	NEm	Crude Protein	Calcium	Phosphorous	NEg
	-Mcal/kg-	-%-	-%-	-%-	-Mcal/kg-
Soymeal(49%)	2.150	55.100	0.290	0.700	1.480
Soymeal(44%)	2.060	49.900	0.330	0.710	1.400
Alfalfa meal(17%dehyd)	1.340	18.900	1.520	0.250	0.770
Alfalfa hay[1]	1.283	14.300	1.370	0.150	0.711
Ammoniated alfalfa[1]	1.520	24.500	1.560	0.160	0.926
Barley	2.060	13.500	0.050	0.380	1.400
Barley straw[1]	1.145	6.900	0.240	0.230	0.585
Ammoniated straw[1]	1.425	16.300	0.410	0.290	0.841
Corn	2.240	10.100	0.020	0.350	1.550
Beetpulp	1.760	9.700	0.690	0.100	1.140
Silage corn	1.380	8.400	0.340	0.190	0.800
Linseed meal	2.000	37.900	0.450	0.960	1.350
Rock phosphate	--	--	32.000	18.000	--
Dicalcium phosphate	--	--	22.000	19.300	--
Limestone	--	--	34.000	0.020	--
Molasses	1.700	5.800	1.000	0.110	1.080
Oats grain	1.850	13.300	0.070	0.380	1.220
Oat straw	0.790	4.400	0.240	0.060	0.250
Rapemeal	1.820	38.700	0.720	1.140	1.190
Rye	2.060	13.800	0.070	0.370	1.400
Timothy hay	1.180	8.100	0.430	0.200	0.610

TABLE 3.2

Nutrient Content of Feedstuffs(continued)

Middlings	1.600	18.400	0.130	0.990	1.000
Screenings	1.940	13.100	0.340	0.330	1.300
Wheat	2.210	17.200	0.040	0.430	1.520
Brome-Alfalfa Hay	1.254	13.400	0.840	0.250	0.550
Urea	--	287.000	--	--	--

(Source:NRC,1984)

[1] Data obtained from Tembo(1987).

The three conditions of animals used are a 550 kg pregnant beef cow gaining 0.4 kg per day, a 500 kg pregnant beef cow gaining 0.4 kg per day and a 450 kg pregnant heifer gaining 0.6 kg per day. Choice of animals for this type of feeding is validated by use of similar weight and sex animals in feeding trials by the Eastern Grassland society where ammoniated barley straw was fed. The costs of ammoniation are shown in table A.1 of appendix A and were calculated based on per unit costs of the ammonia and plastic used in processing alfalfa hay and barley straw in the experiments and the prices of these items in the time periods covered in this analysis. These prices compare favourably with the results of similar costing of ammoniated wheat straw(Potts, 1982) and the Eastern Grasslands experiments. Prices were also adjusted for valuation on a dry matter basis. Nutrient constraints represented were net energy of maintenance, net energy of production,calcium, phosphorous,crude protein and dry matter intake. These values are recommended by the National Research Council for animals of that weight and sex on maintenance rations and are listed in table 3.4 below. The increased requirements due to different environments are shown in table 3.3.

TABLE 3.3

Nutrient Requirements and Intake Levels(Dry Matter Basis) for Animals in The Analysis

	NEm	NEg	Calcium	Phosphorous	Protein	Intake
	-Mcal-	-Mcal-	-kg-	-kg-	-kg-	-kg-
A. 550 kg cow gaining 0.4 kilograms per day						
Constraint	GE[1]	GE	GE	GE	GE	LE[2]
Daily Quantity	10.900	--	0.026	0.021	0.790	10.200
B. 500 kilogram cow gaining 0.4 kilograms per day						
Constraint	GE	GE	GE	GE	GE	LE
Daily Quantity	10.290	---	0.025	0.020	0.746	9.500
C. 450 kilogram heifer gaining 0.6 kilograms per day						
Constraint	GE	GE	GE	GE	GE	LE
Daily Quantity	9.670	0.980	0.026	0.019	0.765	9.200

(Source; NRC 1984)

[1] GE refers to greater than or equal to

[2] LE refers to less than or equal to

TABLE 3.4

Increase in Daily Energy and Intake Levels due to Environment.

	Environment	Change over Thermoneutral Levels	New Level
550 kilogram cow gaining 0.400 kilogram per day			
NEm(Mcal)[1]	Winter	positive	13.677
Intake(kg)[2]	Winter	positive	11.220
500 kilogram cow gaining 0.400 kilogram per day			
NEm(Mcal)	Winter	positive	12.882
Intake(kg)	Winter	positive	10.450
450 kilogram heifer gaining 0.600 kilogram per day			
NEm(Mcal)	Winter	positive	12.067
Intake(kg)	Winter	positive	10.120

(Source; NRC, 1981)

[1] NEm = .1015 W^{75} + 2.15 (for conceptus).
[2] Intake = 10% over thermoneutral levels.

Chapter IV

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The results of analysis on the model specified in the previous chapter are presented and discussed in this chapter. These results are organised into three different sections with each section representing one of the beef cows for which analysis has been conducted. Price and variation for each optimal solution is also presented. Factors important in the utilization of ammoniated feeds under different scenarios, can be identified from details of individual rations and usage levels under different scenarios. A fourth section dealing with the results of energy content variation of the ammoniated feedstuffs is outlined and a summary and discussion of the implications of these results are provided in the next and final chapter.

4.2 RESULTS FOR 450 KILOGRAM BEEF COWS.

4.2.1 Under Thermoneutral Environmental Conditions.

With respect to the first objective , ammoniated barley straw is included in the least cost solution for the two price periods under a thermoneutral environment. At existing treatment costs in both periods for 1985, ammoniated straw is utilised at 57% of ration dry matter (table 4.1). Ammoniated alfalfa is not part of the optimal solution for any of the two periods. Total ration costs are lowest in the period

TABLE 4.1

Results of Least Cost Analysis and Cost Variation For 450 kg heifer Under A Thermoneutral Environment.

Ammoniation Cost	Period	Ration Constituents	Total Ration Costs
-cents/kg-	Yr.(Qtr.)	- kg -	-cents/hd./day
		α = .840	
		3.943 Barley straw	
		4.186 Timothy hay	
		0.830 Rye	
4.200	1985(1)	0.242 Ammoniated straw	38.192
		α = .843	
		5.026 Ammoniated straw	
2.041	1985(1)	3.769 Barley straw	29.592
		α = .846	
0.000	1985(1)	8.024 Ammoniated straw	17.637
		α = .841	
		4.345 Timothy hay	
		3.943 Barley straw	
		0.906 Barley	
3.910	1985(4)	0.006 Urea	41.416
		α = .841	
		5.257 Ammoniated straw	
		2.528 Barley straw	
2.212	1985(4)	1.415 Oat straw	37.189
		α = .840	
		6.673 Ammoniated straw	
0.000	1985(4)	2.527 Oat straw	23.828

α = Proportion of feed energy used for maintenance purposes.

first quarter 1985 and highest in the fourth quarter of that year. The difference in levels of straw utilisation for the two periods can be ascribed to differences in price levels of roughages and concentrates and the nature of the ration required by the animal. Over the fourth quarter 1985 period the bulk of ration ingredients are roughage feeds and these are relatively high priced. Price variation relationships and ration constituents over the resultant range of feedstuff provide evidence for this rationale.

Effects of price variation (cost of ammoniation) are shown in figure 4.1 and the content of individual rations at upper and lower cost limits of usage are shown in table 4.1 Price variation results are presented in terms of costs of ammoniation. Variation between costs of 0 cents and costs at which the ammoniated feed exits the optimal ration are considered. In practical solution of the model, an upper limit of 4.2 cents was used. In most cases treated straw exited the solution before this cost value. The starting value of 0 cents is used in an attempt to discern changes in ration constituents and feed costs as the economic value of straw changes. The curves for variation in both quarters in 1985 are highest and show no price responsiveness over the range of treatment costs of 0 cents to 0.56 cents per kilogram. The upper limit of ammoniation costs is a good indicator of price competitiveness of ammoniated straw in all two periods for this specific animal condition and environment. The price competitiveness of treated straw in the 1985 periods is seen in the range of total daily feed costs. At first quarter 1985 prices, the range of daily feed costs between existing ammoniation costs and upper limit of usage is 8.00 cents and in fourth quarter 1985 it is

4.22 cents. Range of daily costs also provide the cost savings associated with usage of ammoniated product.
Determination of the rationale behind the differences in competitiveness can be important in interpretation of the other scenarios considered.

In first quarter 1985, treated straw is the sole ration ingredient at treatment costs between 0 and 0.56 cents per kilogram. These are high values based on cost ranges speculated by Coxworth(1981). Ammoniated straw is included at 57.14 percent between 0.56 and 3.17 cents and in this range, untreated barley straw is the other ration constituent. Above 3.17 cents percentage use falls to 34.8 and the major replacement is timothy hay. At 4.08 cents per kilogram costs, only 2.4 percent of the straw is included rye enters the optimal combination. A similar trend is seen at fourth quarter 1985 prices. Though concentrate prices are lower and roughage prices relatively higher, the same basic usage pattern obtains. The upper cost limit for usage is 3.9 cents per kilogram and at higher costs, the optimal combination is a mix of barley, untreated straw, timothy hay and a little urea.

The general pattern from these results suggests that at low treatment costs ammoniated straw can meet the nutrient requirements of these beef cows. Another good quality roughage such as silage or a combination of low quality roughage(barley straw) and good hay with supplementation can also achieve this result. Price conditions then determine the choice between feed ingredients. The price rationale in this case can be either of the two following situations or a combination of both. It must be noted that energy is the limiting nutrient in this ration. When ammoniated straw is the sole ration ingredient or is included at high levels,

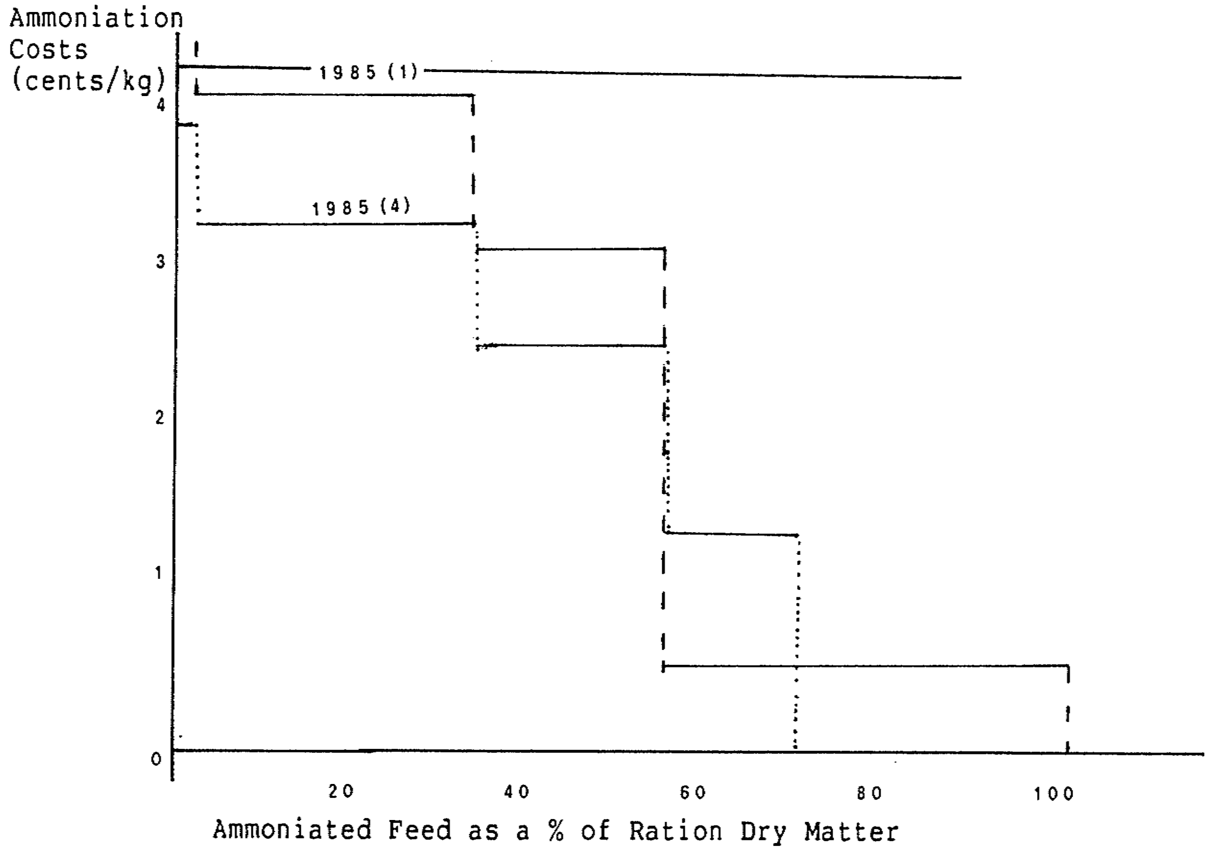


Figure 4.1: Comparisons of Usage of Ammoniated Feeds Over Cost Ranges for a 450 kg Heifer in Thermoneutral Environment

an excess of the other nutrients results. In 1985 with high silage prices and low concentrate prices, the untreated straw combination is more competitive. Given the intake levels and resultant energy density of these rations, concentrates are only included at high levels when their prices are low. In this case concentrates are only included at supplemental levels. Consideration of the results of other scenarios can add to or deviate from this explanation of the nature of the above feedstuff competition.

4.2.2 Average Winter Conditions

The added energy requirement under this thermal regime(tables 3.3 and 3.4) resulted in similar combinations to the previous scenario(see table 4.2). The least cost solutions over both periods in 1985 produced the same ingredient mix. At existing costs in both quarters, 82 percent ammoniated straw was included in the ration. Ammoniated alfalfa was not part of any of the rations. Despite the change in intake and energy levels, the same factors are responsible for ammoniated feed usage.

The results of parametric price variation are shown in figure 4.2 Greater economic value of ammoniated straw in the price conditions for first and fourth quarter 1985 is apparent from the position of these curves. In first quarter 1985, treated straw is included as the sole ingredient over cost range 0 to 0.56 cents per kilogram. Usage level falls to 82 percent of dry matter between 0.56 and 2.59 cents per kilogram and further decreases to 45.90 percent over the range 2.59 to 4.08 cents. At the latter cost, ammoniated straw is not part of the optimal combination. The trend is the same at fourth quarter prices. Usage lev-

TABLE 4.2

Results of Least Cost Analysis and Cost Variation For 450 kg heifer under Average Winter Conditions

Ammoniation Costs	Period	Ration Constituents	Total Ration Costs
-cents/kg-	Yr.(Qtr.)	- kg -	- cents/hd./day
4.081	1985(1)	α = .867 4.337 Barley straw 3.352 Timothy hay 2.431 Rye	50.775
2.041	1985(1)	α = .868 8.331 Ammoniated straw 1.788 Barley straw	39.245
0.000	1985(1)	α = .869 9.754 Ammoniated straw	21.439
3.210	1985(4)	α = .867 4.337 Barley straw 2.431 Barley 3.352 Timothy hay	53.948
2.212	1985(4)	α = .868 8.331 Ammoniated straw 1.788 Barley straw	48.967
0.000	1985(4)	α = .868 9.333 Ammoniated straw 0.787 Oat straw	29.316

α = Proportion of total feed energy used for maintenance purposes.

els are 92 percent between 0 and 1.22 cents per kilogram costs and fall to 83.32 percent over 1.22 cents to 2.3 cents. Between 2.3 cents and and 3.21 cents level of usage is 45.9 percent and treated straw is not included at 3.21 cents.

The basic constituents of the ration at upper cost limits for all periods are the same as under the thermoneutral environment. Urea supplementation does not occur at upper cost limits due to the increased dry matter constrait. This allows protein requirements from the other ingredients selected in the least cost combination. Concentrate levels are greater and this is the primary reason or this effect. The concentrates included in both rations have similar energy values and price is the determining factor in their selection in the optimal basis.

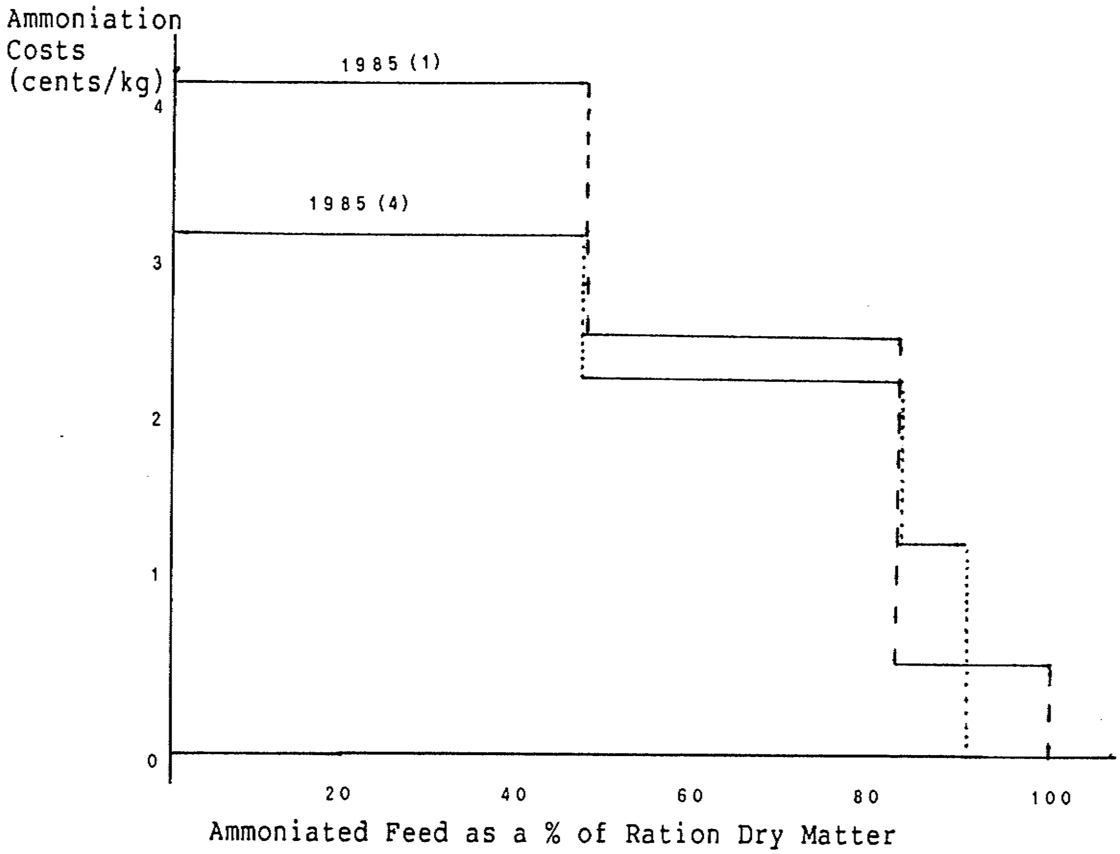


Figure 4.2: Comparisons of Ammoniated Feed Usage Over Cost Ranges For a 450 kg Heifer in Average Winter Conditions.

4.3 500 KILOGRAM BEEF COW.

4.3.1 Thermoneutral environment

At existing treatment costs in first quarter 1985, ammoniated straw constitutes 57.14 percent of ration dry matter. In fourth quarter 1985, ammoniated straw makes up 78 percent of ration dry matter. Table 4.3 shows that total feed costs are lower than for 450 kilogram heifers under similar environment. The lower energy of gain requirement for this animal condition may be the reason behind these differences since the quantity of feed per unit of energy is greater for gain than maintenance. Total ration costs are greatest in fourth quarter 1985 and lowest in the first quarter of that year. Ammoniated alfalfa is not included at any of the two prices. Ration ingredients are similar to those in the 450 kilogram heifers. A combination of ammoniated straw, hay and untreated barley straw is optimal in first quarter 1985. In the fourth quarter of the latter year, oat straw and ammoniated straw make the least cost ration.

Usage patterns obtained through parametric price variation also contain similarities to the 450 kilogram case. For first quarter 1985, use of treated straw extends over the greatest cost range for all periods. Figure 4.3 shows that between 0 and .54 cents per kilogram costs, ammoniated straw is the sole ration ingredient. From 0.54 cents to 3.13 cents per kilogram, usage level is 32 percent of dry matter and further falls to 13.38 percent between 3.13 and 3.14 cents per kilogram. At 3.7 cents, ammoniated straw is no longer a part of the least cost ingredient combination. As treatment costs increase, ammoniated straw is replaced by timothy hay and at its upper cost limit, urea supplementation occurs.

TABLE 4.3

Results of Least Cost Analysis and Cost Variation For 500 kg Cow Under A Thermoneutral Environment.

Ammoniation Costs	Period	Ration Constituents		Total Ration Costs
-cents /kg-	-Yr.(Qtr.)	- kg -		- cents/hd./day-
		3.799	Barley straw	
		0.006	Dicalcium phosphate	
		5.033	Timothy hay	
3.712	1985(1)	0.026	Urea	32.124
		4.506	Ammoniated straw	
		3.379	Barley straw	
2.041	1985(1)	2.375	Timothy hay	26.528
0.000	1985(1)	7.220	Ammoniated straw	15.872
		0.028	Urea	
		0.018	Rock phosphate	
		2.035	Barley straw	
		2.036	Oat straw	
3.220	1985(4)	5.382	Timothy hay	34.497
		5.096	Ammoniated straw	
		0.016	Rock phosphate	
2.212	1985(4)	3.840	Oat straw	32.327
		5.096	Ammoniated straw	
		0.016	Rock phosphate	
0.000	1985(4)	3.840	Oat straw	21.060

At fourth quarter 1985 prices, the general usage pattern is the same(figure 4.3). The upper cost limit is lower and oat straw and barley straw constitute the untreated straw portion of the ration.

The range of total feed costs between existing treatment costs and the upper limit of ammoniated straw utilisation further distinguishes the value of feeds in the three periods. The range of total daily feed costs in first quarter 1985 is 5.59 cents. In the fourth quarter it is 2.17 cents. Range of feeding costs are lower than for heifers under the same environment. The upper limits of straw usage are also lower. The untreated straw combination are slightly more competitive here.

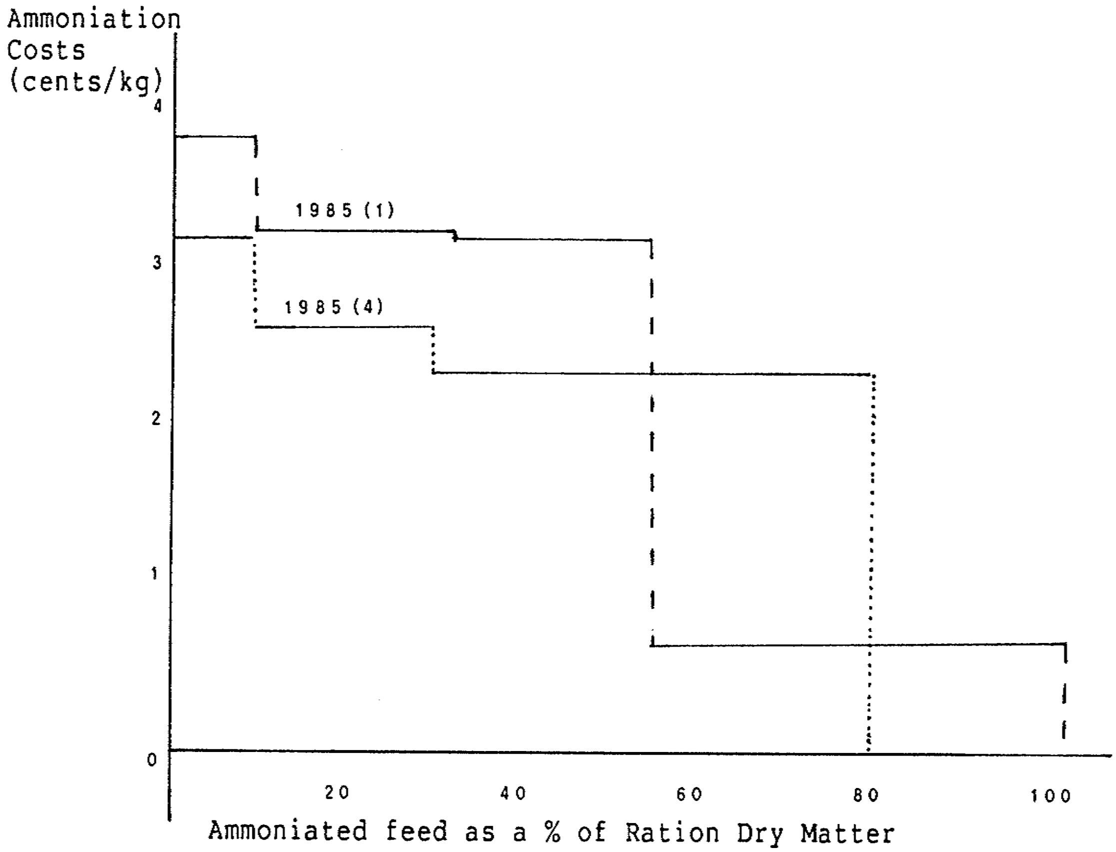


Figure 4.3: Comparisons of of Ammoniated Feed Usage Over Cost Ranges for a 500 kg Cow in a Thermoneutral Environment

4.3.2 Average Winter Conditions.

An increased energy requirement and intake constraint in this scenario does not produce a different picture of ammoniated straw usage. Price variation curves in figure 4.4 show a competitive usage of treated straw at 1985 prices. At existing treatment costs in first quarter 1985 treated straw constitutes 57% of ration dry matter. This percentage extends up to treatment costs of 3.13 cents per kilogram which is 1.08 cents higher than at existing prices. The upper cost limit of usage is 4.02 cents per kilogram which is higher than under thermoneutral conditions.

At existing prices in the fourth quarter 1985, ammoniated straw also forms 57 percent of ration dry matter (see figure 4.4)and is included in the ration at lower levels up to 3.21 cents per kilogram costs. Between 0 cents and 1.22 cents per kilogram costs, treated straw forms 69.7 percent of ration dry matter and at 57 percent in the cost range 1.22 to 2.62 cents. From 2.62 cents to 3.2 cents, ammoniated straw is 27.6 percent of ration dry matter. This pattern is the same for both periods in 1985. Differences in upper cost limits are a result of lower concentrate prices in the fourth quarter. This reduces the cost of supplementation and thus ammoniated straw is competitive over a lower cost range. Though roughage prices are lowest in the first quarter, ammoniated feed provides cheaper energy than other lower valued or higher priced options.

TABLE 4.4

Results of Least Cost Analysis and Cost Variations For 500 kg cow Under Average Winter Conditions.

Ammoniation Costs	Period	Ration Constituents		Total Ration Costs
-cents/kg.-	- Yr.(Qtr.)-	- kg. -		- cents/hd./kg.-
		4.479	Barley straw	
		5.167	Timothy hay	
4.072	1985(1)	0.804	Rye	42.075
		5.641	Ammoniated straw	
2.041	1985(1)	4.230	Barley straw	33.209
0.000	1985(1)	9.040	Ammoniated straw	19.870
		0.804	Barley	
		4.478	Barley straw	
3.201	1985(4)	5.167	Timothy Hay	45.539
		5.971	Ammoniated straw	
		2.351	Barley straw	
2.212	1985(4)	2.127	Oat straw	41.429
		7.285	Ammoniated straw	
0.000	1985(4)	3.164	Oat straw	26.608

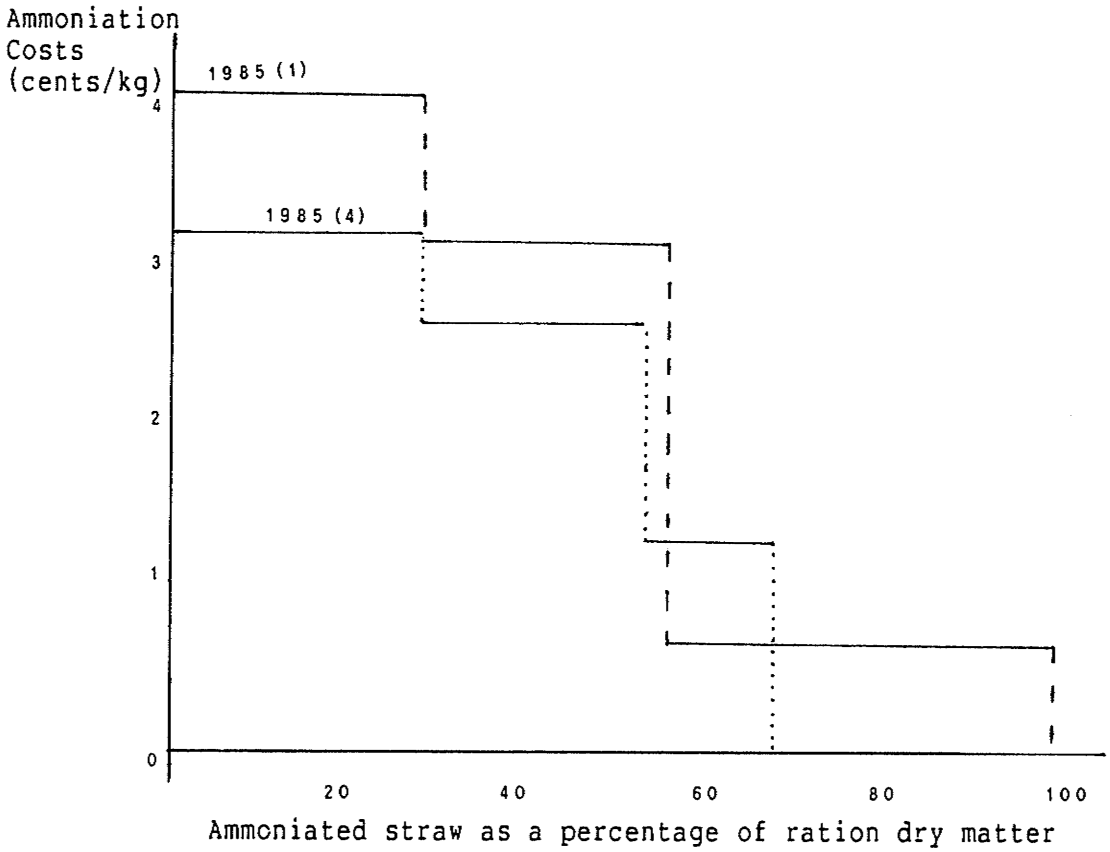


Figure 4.4: Comparisons of Ammoniated Feed Usage at Cost Ranges for a 500 kg Cow in Average Winter Conditions.

4.4 RESULTS FOR 550 KILOGRAM BEEF COW

4.4.1 Thermoneutral Conditions

Least cost solutions for 550 kilogram cows under thermoneutral conditions have straw usage patterns that are similar to those for the 500 kg cow. Ingredient combinations and trends(see table 4.5) for price variation are all similar (figure 4.5) and ingredient combinations only difer due to higher energyy requirements. Given the similarities in maturity, weight and requirements, this can be expected. Low total feed costs are in particular due to lower upper cost levels for ammoniated straw. Compared to 450 kg heifers, the lower energy density of these rations allows for greater usage of bulky, lower valued materials.

Usage patterns for both periods in 1985 show good utilization of ammoniated straw. Figure 4.5 shows that for the first quarter, treated straw is the only ration ingredient for treatment costs of 0 cents to 0.53 cents. Between 0.53 and 2.13 cents per kilogram, the ammoniated straw is included at 57 percent of dry matter and its utilization is 27.07 percent over the range of 3.13 to 3.14 cents. From the latter value to 3.71 cents utilization falls to 13.3 percent. Though absolute levels differ, the fourth quarter of 1985 shows the same pattern. Usage levels of 57 percent, 23.3 and 12.93 percent were obtained over the cost ranges of 0 to 2.33, 2.33 to 2.61 and 2.61 to 3.22 cents per kilogram respectively.

TABLE 4.5

Results of Least Cost Analysis and Cost Variations For 550 kg Cows in A Thermoneutral Environment.

Ammoniation Costs	Period	Ration Constituents	Total Ration Costs
-cents/kg-	-Yr.(Qtr.)	- kg -	-cents/hd./day-
3.716	1985(1)	4.024 Barley straw 0.028 Urea 0.006 Dicalcium phosphate. 5.332 Timothy hay	34.023
2.041	1985(1)	3.579 Barley straw 4.773 Ammoniated straw	28.100
0.000	1985(1)	7.650 Ammoniated straw	16.183
3.225	1985(4)	1.729 Barley straw 0.021 Rock phosphate 2.648 Oat straw 5.786 Timothy hay 0.030 Urea	36.375
2.212	1985(4)	5.398 Ammoniated straw 4.060 Oat straw 0.016 Rock phosphate	34.239
0.000	1985(4)	5.398 Ammoniated straw 4.060 Oat straw 0.016 Rock phosphate	22.290

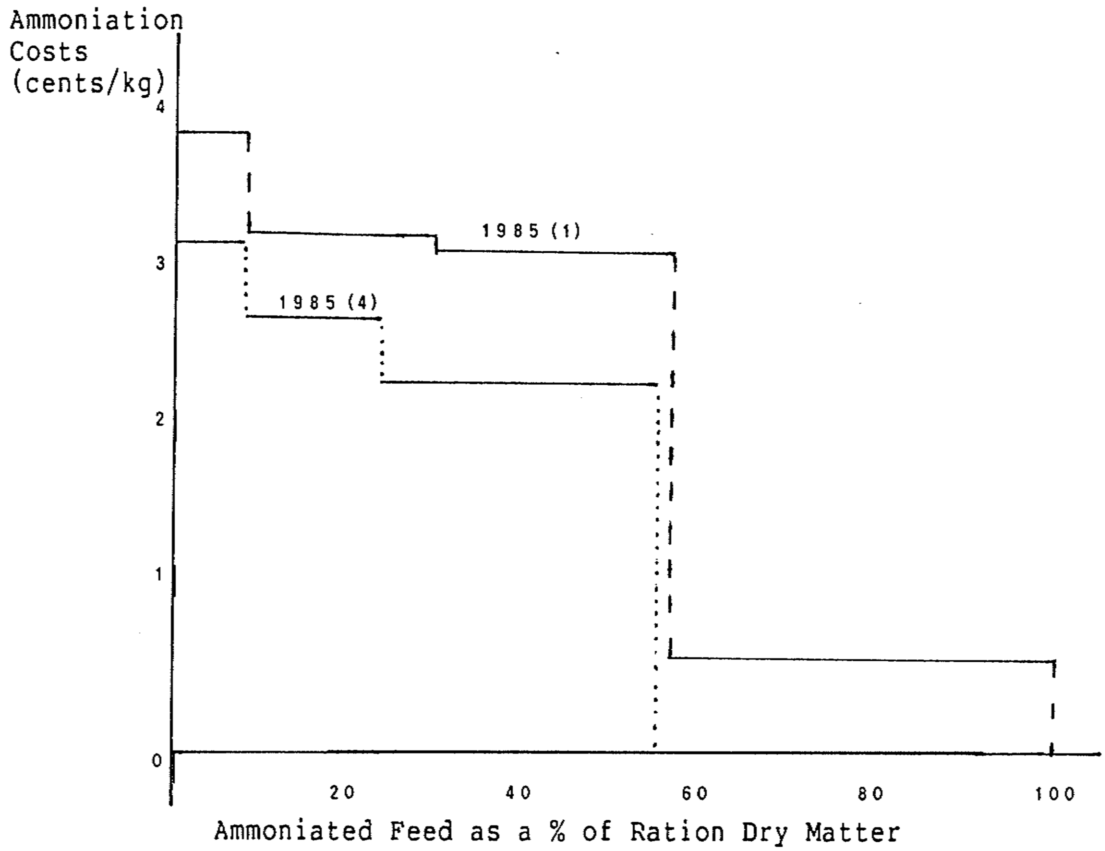


Figure 4.5: Comparisons of Ammoniated Feed Usage With Cost Variations for a 550 kg Beef Cow in Thermoneutral Environment

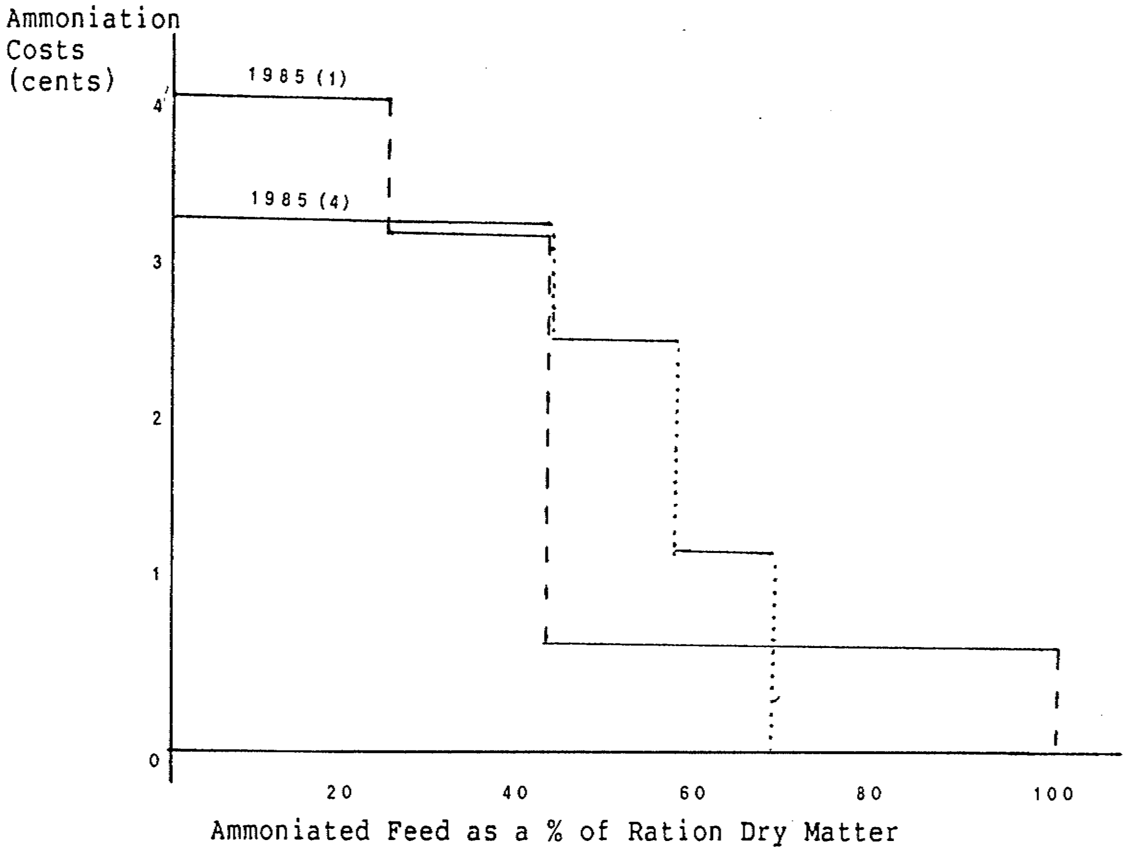


Figure 4.6: Comparison of Ammoniated Feed Usage With Cost Variations For 550 kg Beef Cows in Average Winter Conditions.

4.4.2 Average Winter Conditions

The similarities to other scenarios can also be seen in the results of this section. Usage patterns and feed combinations do not differ greatly when requirements are adjusted for the above environmental condition. The upper cost of treated straw usage in first quarter 1985 is higher than in thermoneutral conditions. In the fourth quarter, a similar rise is not obtained due to the overall lower cost of supplementation. Figure 4.6 shows that in the first quarter 100 percent usage of treated straw obtains over the range 0 to 0.53 cents.Levels of 42.85 percent at cost range 0.53 to 3.13 cents and 22.03 percent between 3.13 and 4.07 cents form the remainder of the usage pattern. Trends in the fourth quarter are no different. A level of 67.55 percent over cost range 0 to 1.23 cents and 57 percent between 1.23 and 2.62 cents per kilogram costs. A level of 22.03 percent is obtained over costs 2.62 to 3.20. Ammoniated alfalfa is not part of the solution.

TABLE 4.6

Results of Least Cost Analysis and Cost Variation For 550 kg Cow Under Average Winter Conditions.

Ammoniation Costs	Period	Ration Constituents	Total Ration Costs
-cents/kg-	-Yr.(Qtr.)-	- kg -	-cents/hd./day
4.072	1985(1)	4.808 Barley straw 5.723 Timothy hay	44.111
2.041	1985(1)	2.472 Ammoniated straw 4.808 Barley straw 3.939 Timothy hay	34.507
0.000	1985(1)	9.598 Ammoniated straw	21.096
3.201	1985(4)	4.808 Barley straw 0.688 Rye 5.723 Timothy hay	47.850
2.212	1985(4)	2.090 Barley straw 2.718 Oat straw 6.411 Ammoniated straw	43.805
0.000	1985(4)	7.580 Ammoniated straw 3.640 Oat straw	28.191

4.5 RESULTS OF ENERGY CONTENT VARIATION OF AMMONIATED FEEDS

One objective of this study was to investigate the potential effect of further increases in the nutrient content of these feedstuffs. Achievement of this objective hinges on parametric variation of the energy content of ammoniated hay and straw . These results are presented in Appendix B and are briefly outlined and discussed here. Analysis was done for thermonetral conditions only and in the majority of cases, variation resulted in increased economic value of the feed. This increase is observed in a lower cost of feeding or a lower shadow price. The latter can be regarded as the opportunity cost of using the resource(Chiang 1984). It should be noted that the increases used here are relatively high and are unlikely to occur for crop residues. The major goal is to investigate if such increases would impact on the utilisation of ammoniated feeds.

In both quarters in 1985, variation caused the quantity of feed in each ration to be lowered. This decrease ranged from 5.343 cents for 450 kilogram heifers in the first quarter to 1.37 cents for 550 kilogram cows in the fourth quarter. This is expected given the fact that energy is the limiting nutrient in feeding treated straw to these animals. An associated benefit of this is the reduction in nutrient excesses in the ration. For alfalfa hay, increased energy content produced no changes in the least cost mix for any ration. Shadow prices were reduced in each case but remained prohibtively high.

Chapter V

CONCLUSIONS AND RECOMMENDATIONS.

5.1 SUMMARY

The economic usage of ammoniated feeds in beef cow rations under the conditions specified in this study depends upon factors identified in the results. An interplay of price relationships, energy requirements, and feed ingredient relationships were the major ones identified. The indications are that such feeding is most suitable in conditions of relatively higher grain prices, higher price of roughages that are close in nutrient composition to the treated material(silage, good quality hay) and for rations with lower intake limits. While many generalizations cannot be made from these specific results, the trends identified help to provide some insights.

Treated straw was more competitive in all situations than ammoniated hay. Given the cost differential between the two and their similarity in energy content this is hardly surprising. Ammoniated straw was a competitive feedstuff in the three beef cow rations and was most economic for 450 kilogram heifers. Energy requirements for the latter are the most complex of the three beef animals examined. The price relationships used to explain these results and the intake requirements of these animals makes treated straw directly competitive with other good quality roughages or combinations containing high percentage of the latter and supplemented with concentrate or urea. When prices of the latter are high, good usage of treated straw results.

As maintenance energy requirements in the rations increase, energy for gain falls and intake limits are raised, the nature of the optimal solution changes. The inclusion of lower valued roughage is cheaper since bulk balances out nutrient(energy) density. This trend is observed at upper limits of treatment costs but is best seen in rations for 500 and 550 kilogram cows. In the latter case, protein deficiencies from lower valued roughage combinations is negated by inclusion of urea.

The economics of feeding straw in cold conditions is basically the same as under average stress free environment. Trend patterns at various costs are the same for each environment for a particular condition of animal. The increase in energy requirement is compensated for by an increase in intake limits. Variations in energy content showed potential for future treatments. Results of this analysis showed that any such increase would reduce feed costs if the treated roughage was already part of the optimal solution. Where this is not the case, lower shadow prices signify a reduction in the amount by which ration cost increases if this ingredient were included. Economic value increases either way and further work is needed in this area.

Based on the analysis conducted, there is potential for usage of ammoniated feeds in wintering rations. In some situations examined here the most economic option at existing costs was a usage level of ammoniated straw that was greater than 50 percent. The major problem in high usages is the excess nutrients thus obtained. Cost savings of 9 to 11 cents per day in 450 kilogram beef cows, translate into savings of $13.50 to 16.50 per animal fed over a 5 month period. The results of this study bode well for future usage as well as research into the ammoniation process in a number of areas.

5.2 WEAKNESSES AND RECOMMENDATIONS FOR FURTHER RESEARCH

Given the limitations of nutrient composition data and the use of only two feedstuffs, there is the need for future work of a similar nature using other materials. The non inclusion of ammoniated alfalfa hay in solutions is probably due to its high costs relative to straw and their similarity in energy content. In addition, nutrient composition of treated straw is relatively high compared to values of other straws and low quality roughages observed in NRC data. The examination of the economics of treating lower valued material other than those of this study may proove interesting. Such results may be more aplicable to situations where residues are of a poorer quality and the need for chemical treatment greater. The energy content of treated hay and straw are based on trials conducted with sheep. Despite similarities in the nutrient value of feeds for these two animals they are not exactly the same. Other possibilities can include analysis for different agronomic varieties and materials in different regional and seasonal conditions.

The validity of linear programming models are the major determinant in the applicability of their results. Utilisation of a more systems oriented approach that includes actual trials using model prescriptions would be a major option in producing very practical solutions. Time constraints and other limitations are foreseeable in such an undertaking but exercising of such options allows for more extensive evaluation of a wider range of materials and scenarios. More exhaustive agronomic and farm level input would be another benefit of such an approach.

The lack of flexibility in the model in terms of animal parameters should also be noted in future studies. Data from feeding trials, in particular, information on intake and performance can alleviate this limitation. Information on the economy of gain or other performance measures will be obtained as well as information on ration comparisons. Such an approach allows for use of other methods of analysis besides linear programming and allows for inclusion of more exact nutritional and economic specifications. A simpler alternative can involve use of the same model formulated in this study and performing a wider variety of parametric and other variation on a single ration. Better evaluation of energy, intake and energy - protein relationships would result.

The high economic value of ammoniated straw in 450 kg rations have implications for use of the process in other rations besides maintenance feeding. Analysis for feeding in rations with low to intermediate energy density and low to intermediate energy of gain requirements is one consideration. Results of analysis also bears implications for other countries where such usage is potentially more exhaustive in terms of types of animals and feeding conditions.

In conclusion, the results of this study are interesting for they at least determine that feeding of ammoniated feeds is economic under some conditions. While not fully exhaustive they have to be considered in the context of the assumptions and methods utilized.

BIBLIOGRAPHY

Anderson, J.R., "An Overview of Modelling in Agricultural Management", Review of Marketing and Agricultural Economics, vol.40,no.3,1972,112-122.

Animals, Feed, Food and People, Ed. R.L.Baldwin, AAAS selected symposia series, Westview Press Inc., Colorado,1980.

Apland,J. "The Dynamics of Beef Cattle Production; Model Formulation, Application and an example", North Central Journal of Agricultural Eonomics, vol.7,no.2,1981, 21-22

Beattie,B.R. and C.R.Taylor , The Economics of Production, John Wiley and Sons, New York, 1985.

Brokken,R.F., T.H.Hammonds, D.A.Dinius and J.Valpey, "Framework for Economic Analysis of Grain versus Harvested Roughage for Feedlot Cattle." American Journal of Agricultural Economics , vol. 58,1976,245-258.

Brokken, R.F, "Programming Models for Use of the Loftgreen - Garrett Net Energy System in Formulating rations For Beef Cattle", Journal of Animal Science , vol.32,1971, 685-691.

__________________, "Formulating Beef Rations for Improved Perormancce Under Stress", American Journal of Agricultural Economics, vol.53,1971, 79-91.

Brown, W.G. and G.A.Arscott, "Animal Production Functions and Optimal Ration Specifications." Journal of Farm Economics, 42; 69,1960.

Canada Grains Council, Canadian Grains for Beef Cattle, Winnipeg,1978.

Chiang, A.C., Fundamantal Methods of Mathematical Economics, McGraw-Hill Publishing Company,1984.

Coxworth, E. and P.Kullman, "Improving the Feeding Value of Straw and Other Forages by the Use of Ammonia", Saskatchewan Research Council, 78-14., vol. 2, Section 6, 1978.

Coxworth,E., J.Kernan, J.Knipfel, and H.Nicholson, "Ammoniation of Straw and Chaffto Improve Their Nutritive Value as Feeds for Ruminant Animals, Saskatchewan Research Council Technical Report no.114, SRC Publication no. C-814-8-B-81,1981.

Crabtree,J.R., "Interactive Formulation System For Cattle Diets", Agricultural Systems, vol.8,1982,291-308.

Crotty, R. Cattle Economics and Development, Commonwealth Agricultural Bureau, Farnham Royal, England 1980.

Davies,Y. , W.K.Trotter and D. Burdick, "Evaluating New or Improved Poultry Feedstuffs by Parametric Linear Programming Techniques", Poultry Science, vol.52: 102 - 107,1973.

Davies, Y. and D.Burdick. "Economic Evaluation of Full Fat Soybeans in Broiler Rations", Feed Situation, 1972,16- 19.

Day,R.H. and E.Sparling. "Optimisation Models in Agricultural and Resource Ecocnomics" in A Survey of Agricultural Economics Literature. Edited by L.R.Martin, University of Minnesota Press, 1977, 93 - 127.

Dent,J.B., "Optimal Rations for Livestock With Special Reference to Bacon Pigs", Journal of Agricultural Economics, vol.16,1964,68-87.

Dillon,J.L., The Analysis of Response in Crop and Livestock Production, Pergammon Press, 1977.

Farris, D.E. and J.R Simpson, The Worlds Beef Buisiness. First Edition, Iowa State Press, Ames, Iowa, 1982.

Feedstuffs The Weekly Newspaper for Agribuisiness(Minneapolis,Miller Publishing Co., various issues,1985 and 1981).

Funk, R.A., "A market Analysis For Fababeans." Unpublished Msc thesis, Department of Agricultural Economics and Farm Management, University of Manitoba, 1977.

Giaever, H., "The Economics of Using Straw as Feed" in Straw and Other Fibrous By - Products as Feed, ed. F.Sundstol and E.Owen, Elsevier Press,1984.

Gillies, M.T., Animal Feeds From Waste Materials, Noges Data Corporation, N.J,USA, 1978.

Glenn, J.J, "A Mathematical Programming Approach for Beef feedlot Optimization." Management Science, vol.26,no.5,1980.

Heady, O., F.Epplin and S.Bhide, "Empirical Investigations of Beef Gain, Roughage - Concentrate Substitution", American Journal of Agricultural Economics, vol.62,1980, 468-477.

Huber, J.T., Upgrading Residues and By - Products for Animals, CRC Press, Boca Raton, Florida, 1981.

Jackson, M.G., "Treating Straw for Animal Feeding. An Assesment of its Technical and Economic Feasibility ", FAO Animal Production and Health Paper no.10, Rome, 1978.

Kennedy, J.O.S., "A Model for Determining Optimal Marketing and Feeding Policies for Beef Cattle", Journal of Agricultural Economics, vol.23,1972,147-159.

Klein, K.K, R.E.Salmon and M.E.Larmond, "A Linear Programming Model for Determining the Optimal Level Low of Glucosinate Rapeseed Meal in Turkey Diets", Canadian Journal of Agricultural Economics' vol.27,1979, 61-69.

Klein, K.K., R.E.Salmon and E.E.Gardiner, "Economic Analysis of the Use of Canola Meal in Diets for Broiler Chickens", Canadian Journal of Agricultural Economics, vol.29,1981,327-338.

Kossila, V.L., "Location and Potential Feed Use", in Straw and Other Fibrous By-Products as Feed, ed. F.Sundstol and E.Owen, Elsevier Press, 1984.

La France, J.T. and M.J.Watts, "The Value of Protein in Feed Barley for Beef, Dairy and Swine Feeding", Western Journal of Agricultural Economics, vol.11,no.1,1986, 16-81.

Lee, S.M., L.J.Moore and B.W.Taylor, Management Science, 2nd. ed., W.M.CBrown publishers, Dubuque, Iowa, 1985.

Livestock Response Functions, Ed. by E.O.Heady and S.Bhide, Iowa State University Press, Ames Iowa,1983.

Loftgreen,G.P. and W.N.Garrett, "A System for Expressing Net Energy Requirements and Feed Values for Growing and Finishing Beef Cattle", Journal of Animal science, vol.26,1968 , 793-806.

McCarl,B.A. and P.Nuthall, "Linear Programming for Repeated Use in the Analysis of Agricultural Systems", Agricultural Systems, vol.8,1982 , 17-39.

McDonough,J.A., "Feed Formulation for Least Cost of Gain", American Journal of Agricultural Economics, vol.53 1971 ,106-108.

Manitoba Co.operator, Winnipeg, 1981 and 1985.

Manitoba Department of Agriculture, Beef Manual, Winnipeg, 1978.

Manitoba Department of Agriculture, "Beef Facts", Winnipeg, April 1983 and September 1984.

Miller, B.R., R.A.Arres and G.M.Pesti, "Formulation of Broiler Finishing Rations by Quadratic Programming", Southern Journal of Agricultural Economics, July 1986, .pp 141-150.

Mount,L.E., 'Concepts of Thermal Neutrality" in J.L.Monteith and L.E.Mount Eds., Heat Loss From Animals and Man, Butterworth,London,1974.

Nelson,M., E.N.Castle and W.G.Brown, "The Use of the Production Function and Linear Programming in the Valuation of Intermedite Products", Land Economics, vol.33,1957 ,257-261.

National Research Council, Effects of Environment on Nutrient Requirements of Domestic Animals, Subcommittee on on Enviromental Stress, Committee on Animal Nutrition, Board on agriculture and Renewable Resources, Committee on Natural Resources, National Research Council, National Academy Press, Washington DC, 1981.

______________, Underutilized Resources as Animal Feedstuffs, Subcommittee on Underutilized Resources as Animal feedstufs, Committee on Animal Nutrition, Board on Agriculture, National research Council, National Academy Press, Washington DC, 1983.

____________, Nutrient Requirements of Beef Cattle, Subcommittee on Beef Cattle Nutrition, Board on Agriculture, National Research Council, 6th rev. ed., National Academy Press, Washington DC, 1984.

____________, Predicting Feed Intake of food-Producing Animals, Subcommittee on Feed Intake, Committee on Animal Nutrition, Board on Agriculture, National Research Council, National Academy Press, Washington DC,1987.

Owen,E., T.Klopfenstein and N.Aurio, "Treatment with Other Chemicals",in Straw and Other Fibrous By-Products, edited by E.Owen and F.Sundstol, Elsevier Press,1984.

Paulding,S.Y., G.M.Pesti and B.R.Miller, "Economics of Substitution and the Use of Full Fat Soybeans in Broiler Diets", Poultry Science; 65,262-269.

Potts,G.R., Appliation of Research Results on By-Product Utilization for Animal Production, IDRC - 206e,Ottawa, Canada, 1982.

Shirley,R., Nitrogen and Energy Nutrition of Ruminants, Academy Press inc., Harcourtand B.J publishers, 1986.

Sonntag,B.H. and R.Hironaka, "A Computer Model for Ration Formulation and Selection of a Feeding Program for Cattle", Canadian Farm Economics, vol. 9,1974,46.

Staniforth,A.R., Straw For Fuel, Feed and Fertiliser, Farming Press Limited, Ipswich,England, 1982.

Statistics Canada, Cereals and Oilseeds Review, Catalogue Number 22 - 007, Ottawa, 1981 and 1985.

Sundstol,F., E.Coxworth and D.N.Mowat, "Improving the Nutritive Value of Straw and Other Low Quality Roughages by Treatment with Ammonia", World Animal Review, vol.26,1979,13-21.

Sundstol,F. and E.Coxworth, "Ammoniation Treatments" in Straw and Other Fibrous By-Products as Feed, ed. F.Sundstol and E.Owen , Elsevier Press,1984.

Tembo,W.K., "The Nutritional Value of Ammonia Treated Roughages as Feed for Ruminants", Published Msc Thesis,Department of Animal Science,University of Manitoba,1987.

Theander, O. and P.Aman, "Anatomical and Chemical Characteristics", Straw and Other Fibrous By-Products as Feed, ed. F.Sundstol and E.Owen , Elsevier Press,1984

Townsley,R., "Derivation of Optimal Livestock Rations Using Quadratic Programming", Journal of Agricultural Economics, vol.19,1968,47-54.

Appendix A

DATA

TABLE A.1

Cost of Ammoniating Straw and Hay Used in Analysis

($ per tonne)

Inputs		Unit Cost	
	Quantity	First Quarter 1985	Fourth Quarter 1985
		- $ -	
Anhydrous ammonia(3%)	30 kilograms	14.40	14.40
Plastic sheet	$45m^2$	4.00	6.68
Total Cost		18.40	20.08

Source
Adapted from Potts(1982). Other reusable materials used in the stack treatment such as poles, injection pipe and sandbags are given negligible costs per tonne of ammoniated material produced.

Note
These values were adjusted for dry matter content before inclusion in analysis

TABLE A.2

Values of α (Proportion of Feed Used for Maintenance) In Analysis (total feed = 1)

	Range of Values	Interval
A.	450 kilogram heifer	
Thermoneutral Conditions	0.4692 to 0.9312	0.0462
Average Winter Conditions	0.5323 to 0.9375	0.035

NOTE These values are calculated from equation 3.7 in the text.

TABLE A.3

Summary of Voluntary Feed Intake of Beef Cattle Under Different Environments

Thermal Environment	Intakes Relative to Values in Nutrient Requirements of Beef Cattle(NRC 1984)
25° to 35°C	Intakes depressed 3 to 10 percent
15° to 25°C	Preferred values as tabulated in Nutrient Requirements of Beef Cattle (NRC 1984).
5° to 15°C	Intakes stimulated 2 to 5 percent
-5° to 5°C	Intakes stimulated 3 to 8 percent
-15° to -5°C	Intakes stimulated 5 to 10 percent
< -15°C	Intakes stimulated 8 to 25 percent. During extreme cold (< -25 C) or during blizzards and storms may be temporarily depressed. Intake of high roughage feeds may be limited by bulk.

Source; NRC 1981.

Appendix B

RESULTS OF ENERGY VARIATION OF AMMONIATED FEEDS

TABLE B.1

Results of Energy Variation in Ammoniated Straw for a 450 kg cow

Daily Feed Costs	Ration Constituents	Price Period	Shadow Price
- cents/hd/day-	- kg -	- Year(Qtr.)	
Original Solution			
	α = .843		
	3.769 Barley straw		
29.592	5.026 Ammoniated straw	1985(1)	--
Result of 0.30 Mcal increase			
	3.350 Barley straw		
26.298	4.467 Ammoniated straw	1985(1)	--
Original Solution			
	5.257 Ammoniated straw		
	2.528 Barley straw		
37.189	1.415 Oat straw	1985(4)	--
Result of .30 Mcal increase			
	5.023 Ammoniated straw		
	0.012 Rock phosphate		
31.846	3.7766 Oat straw	1985(1)	--

TABLE B2

Results of Variation of Alfalfa Hay for 450 kg Cows

Daily Feed Costs	Ration Constituents	Price Period	Shadow Price
Original solution			
29.592	3.769 Barley straw 5.026 Ammoniated straw	1985(1)	5.461
Result of 0.30 Mcal increase			
No change	No change	1985(1)	4.671
Original Solution			
37.189	2.528 Barley straw 1.415 Oat straw 5.257 Ammoniated straw	1985(4)	4.590
Result of 0.30 Mcal increase			
No change	No change	1985(4)	3.951

TABLE B3

Results of variation of ammoniated straw for 500 kg cows

Daily Feed Costs	Ration Constituents	Price Period	Shadow Price
Original Solution			
	3.379 Barley straw		
26.527	4.506 Ammoniated straw	1985(1)	--
Result of 0.30 Mcal increase			
	2.991 Barley straw		
	0.008 Dicalcium phosphate		
23.484	3.979 Ammoniated straw	1985(1)	--
Original Solution			
	5.095 Ammoniated straw		
	0.016 Rock phosphate		
32.327	3.834 Oat straw	1985(4)	--
Result of 0.30 Mcal change			
	4.432 Ammoniated straw		
	0.028 Rock phosphate		
28.209	3.346 Oat straw	1985(4)	--

TABLE B4

Results of Variation of Ammoniated hay for 500 kg cows

Daily Feed Costs	Ration Constituents	Price Period	Shadow Price
Original Solution			
	3.379 Barley straw		
26.528	4.506 Ammoniated straw	1985(1)	5.472
Results of 0.30 Mcal increase			
No change	No change	1985(1)	4.698
Original Solution			
	5.095 Ammoniated straw		
	0.016 Rock phosphate		
32.327	3.834 Oat straw	1985(4)	4.740
Results of 0.30 Mcal increase			
No change	No change	1985(4)	3.812