THE NUTRITIVE CHARACTERISTICS OF MAIZE SILAGE AND MAIZE SILAGE/GRASS RATIONS FOR CATTLE

A thesis
presented in partial fulfilment of the requirements
for the degree
of
MASTER OF AGRICULTURAL SCIENCE
in
ANIMAL SCIENCE
at
MASSEY UNIVERSITY

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1973

ABSTRACT

An experiment was conducted to investigate some of the nutritional properties of maize silage, when fed to rising two year old monozygous twin Jersey and Jersey cross cattle, housed indoors.

In a preliminary experiment, silages made from maize harvested with two types of harvester were evaluated in terms of digestibility, rate of passage, and the extent of kernel loss in the faeces. Fine chop (conventional) silage (mean particle size 1.24 cm) and coarse chop silage (2.20 cm) were each fed to six animals at restricted levels of intake. The mean retention times of the fine (44.6 hours) and coarse (49.0 hours) chop silages were significantly different ($P<0.01$) but differences between DM digestibilities (62.7 and 65.1% respectively) were not significant. Undigested faecal kernel loss from both silages was negligible. Intakes of the fine chop silage were slightly higher than those of the coarse chop, but this may have been due to its higher dry matter content.

In the main experiment maize silage and grass (ryegrass/clover (MP), and Tama (Ta) in separate trials), in the ratios of 100:0 (t_1), 80:20 (t_2), 45:55 (t_3) and 0:100 (t_4), were fed ad lib to four groups of four cattle. The experimental layout was a balanced incomplete block design, and the main parameters measured were digestibility and voluntary intake. Digestibilities rose as the proportion of grass in the rations increased. Approximate OM digestibilities for t_2, t_3 and t_4 were 68.0, 73.0 and 82.0% respectively, however silage (t_1) digestibilities were low, and declined from 65.4 to 57.2% over the duration of the experiment (8 weeks). In most instances, comparisons between t_3 (or t_4) and t_1 were highly significant ($P<0.01$). Voluntary intakes of cattle fed the mixed rations were significantly greater than those of animals fed silage ($P<0.05$) or grass alone, and responses to the t_3 ration were greatest when the Tama was used. When Tama was offered the DM intakes (g/kg $BW^{.75}$) for t_1, t_2, t_3 and t_4 were 95.9, 107.0, 122.3 and 88.9, respectively, and when MP was fed corresponding values were 84.3, 102.1, 108.8 and 101.6. Digestible DM intakes (g/kg $BW^{.75}$) of the cattle fed silage (51.7) were 27% below those of the cattle fed grass alone (66.5 for both grasses). Intakes of t_2 (64.8 (MP), 68.4 (Ta)) were similar to those of t_4, whereas t_3 resulted in much higher intakes, particularly when Tama was fed (70.8 (MP), 80.7 (Ta)). All comparisons between t_1 and the mixed rations were highly significant ($P<0.01$) and the t_1 - t_4 comparisons were significant at $P<0.025$.

The results were discussed, and it was concluded that small amounts of fresh pasture can overcome the protein deficiencies of maize silage, and lead to intakes of digestible DM which are similar to those of cattle fed grass alone. Higher levels of grass supplementation resulted in very high intakes.

ACKNOWLEDGEMENTS

It is with pleasure that I thank my supervisor, Dr G.F. Wilson (Dairy Husbandry Dept, Massey University) for the advice and guidance he has given during the production of this thesis. He has willingly contributed much of his time in providing this assistance. Also, I extend my thanks to Professor R.J. Townsley (Agricultural Economics and Farm Management Dept) for his assistance in the statistical analyses.

I wish to thank all those who have helped in other ways, and in particular:

Messrs J.A. Raven, N.A. McLean and G. Jukes, who assisted in the chemical analyses.
Mr J.S. Wheeler (Dairy Husbandry Dept), who supervised the harvesting of the maize.
Mr A.W.F. Davey (Dairy Husbandry Dept), for advice on experimental procedures.
Staff of the No. 2 Dairy Farm (Massey University), who were responsible for providing the grass used in the experiment.
Dr R.R. Brooks (Ch./B.Ch./B.Phys. Depts), for use of the Atomic Absorption Spectrophotometer.
Dr N. Grace (D.S.I.R.), for the mineral analyses of feeds.

The assistance given by the staff of the Massey University Library is also gratefully acknowledged.

Also I sincerely thank Mrs Annabelle Piper for the care she has taken, and for the high standard of typing in the final copy.

It is with deep gratitude that I acknowledge the contribution made by my wife, Magda. In addition to typing the draft copy, she offered me encouragement, and was patient and understanding throughout. Her contribution was of immeasurable value.

TABLE OF CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

INTRODUCTION

Maize is a relatively new introduction to New Zealand agriculture, but it is extremely important to the beef industry in the United States. The principal advantage of maize, compared to other crops, is its outstanding dry matter yielding potential. When properly ensiled, maize silage has a high metabolisable energy content which is not greatly affected by its maturity at harvest. It is also highly palatable, except when produced from very immature maize. Some of the problems with maize silage include ensiling difficulties, low calcium and sodium contents, and an inadequate digestible crude protein content. However, correct ensiling procedures can produce good quality silage without expensive facilities, and the mineral deficiencies are readily and economically remedied. In contrast, the correction of the protein deficiency is expensive when organic concentrates are used, whilst the responses to inorganic nitrogen supplementation may be variable. Hence the type and method of crude protein supplementation is the major problem to be overcome in maize silage based feeding systems.

Maize silage may have a place in the New Zealand farming system. The high dry matter yielding potential, combined with the relatively short growing season of maize, make it an attractive proposition, especially if climatic conditions allow planting and utilisation of a winter green feed between successive maize crops. A maize-Grasslands Tama rotation may be envisaged. Because of the characteristically high crude protein content of winter green feeds, only small quantities would be required to counter the crude protein deficiencies of maize silage.

The Review of Literature (Chapter One) describes maize silage, discusses factors which influence its nutritive value, and relates the energy, crude protein and mineral contents of maize silage to the requirements of young growing cattle. Of the topics reviewed, the influence of fineness of chop and the use of pasture supplements were of particular interest, but both are poorly documented in the literature.

The first part of the experiment, described in Chapter Two, was designed to evaluate silages chopped to different particle lengths when fed to young growing cattle. The parameters measured included digestibility, rate of passage and undigested kernel losses. The second, and longest, portion of the experiment compared and evaluated four rations in which maize silage was supplemented with grass. The grass:silage ratios used were: 0:100, 20:80, 55:45 and 100:0. The principal parameters measured were digestibilities and voluntary intakes.

The results of the experiments are presented in Chapter Three, and are discussed in Chapter Four. Conclusions are drawn in Chapter Five.

CHAPTER ONE

REVIEW OF LITERATURE

Maize silage, a major livestock feed in the United States, has recently become subject to research in many other countries, including New Zealand. The United States literature relating to the composition and feeding value of typical maize silage is extensive, and forms the basis of a brief coverage presented in this review. Unfortunately many results, especially those from outside the United States, do not agree in all respects. This makes extrapolation of data to New Zealand conditions difficult, especially in view of our particular conservation techniques.

The production and conservation practices which influence the nutritive value of maize are discussed. Where possible, experiments involving young growing cattle are referred to, but interpretation of findings are often made difficult by high levels of supplement fed in conjunction with maize silage.

The characterisation of maize silage, and discussion of factors affecting its composition and nutritive value, make up the first four of the seven sections into which this review of literature is divided. The fifth section compares the expected nutrient requirements of young growing cattle, according to accepted feeding standards, with their expected nutrient intakes if maize silage was fed as a sole diet. Protein was shown to be limiting, and the protein supplementation required to meet the minimum requirements is calculated. The literature relating to forage supplementation of maize silage fed cattle is reviewed in Section six, but a paucity of information necessitated inclusion of data gained from dairy cows and from the use of dried and pelleted forages. Throughout this section the significance of crude protein (CP) becomes apparent, and the validity of the feeding standards for protein is questioned.

1.1 CHARACTERISTICS OF THE MAIZE PLANT

The physical components and chemical composition of the maize plant at different stages of maturity are defined in this section. This enables silage produced from maize harvested before maturity, as was the case in this study, to be evaluated in terms of yield and expected feeding value and compared to crops harvested at other stages.

1.1.1 Physical Composition

The maize plant has been the subject of considerable research and breeding, particularly in the United States. It is high in energy and low in protein when mature, and as a crop has very high dry matter (DM) yielding potential. The literature deals primarily with its grain yielding capacity, which is used as a measure of maturity and quality, however, this criteria can also be used as an indication of its value for silage production because maximum grain and DM yields coincide (Hanaway, 1963; Johnson et al, 1966; Cummins, 1970). Physiological maturity is reached when whole plant dry matter content reaches 30-35%, i.e. between dent and glaze stages, (Johnson et al, 1966; Cummins, 1970). Component compositions of the maize plant at various stages of maturity are illustrated in Table 1.1. The data of Cummins and Dobson (1973), in the last column of Table 1.1, illustrates the influence of climate on plant composition. Component composition of plants at various stages of maturity are further illustrated in Figs 1a, c and d.

Table 1.1: The proportion of major components of mature maize plants (DM basis).

Source of Data	Sayre 1955		Hanaway		Cummins 1970		Bryant et al 1968		Cummins & Dobson 1973	
Plant Components									M	P
Leaves	12	18	13	18	20	17	20	14	28	21
Sheaths	6		5							
Stem		23		19	35	29	32	17	17	29
Grain	45	59	46	62	45	54	58	69	55	50
Cob & husk	14		16							
Plant DM%	approx. 34%			35%	29-32%	37%	44%	55%	27 - 34%	

P = Piedmont (A hot, dry climate, typical of United States maize growing regions)

M = Mountain (A cooler, more moist climate than the Piedmont)

1.1.2 Chemical Composition

The chemical composition of the maize plant and its component parts changes with advancing maturity. The CP content prior to silking is similar to that of other forages, however once ear formation commences the protein percentage of plant dry matter decreases. Nitrogen (N) is translocated from the whole plant to its grain, so that at maturity approximately two thirds of the plant's protein is in the grain fraction (Hanaway, 1962). Total plant nitrogen increases with advancing maturity, but may plateau at the early dent stage (Sayre, 1955) or even decrease slightly as physiological maturity is reached (Johnson et al, 1966). Component partitioning of plant N at different stages of growth is illustrated in Fig 1b. The progressive decline in CP percentage from tasseling to maturity is accompanied by a decline in crude fibre (CF) and ash percentages as grain formation takes place, with a consequent increase in nitrogen free extract (NFE) and ether extract (EE) percentages (Owen, 1967). Implicit in the decline in ash percentage is a dilution of the plants' minerals, to levels such that some fail to meet ruminant nutrient requirements. These changes in chemical composition become relatively static once the dough stage of maturity is reached (Owen, 1967). Table 1.2 gives proximate analyses and other data relating to the composition of maize silages, as determined by overseas authorities. Recent New Zealand data are also included, as are data relating to the composition of 'Grasslands Tama' Westerwolds ryegrass (Tama), which was used during part of the study.

Other factors affecting the plants' chemical composition include variety, planting density, soil fertility and climate influences, the first three being discussed briefly in Section 1.2. Chemical composition of maize silage is further influenced by the ensiling process, fineness of chopping and component losses which may occur during cutting and carting. These are discussed in Section 1.4.

1.2 FACTORS INFLUENCING COMPONENTS AND COMPOSITION OF MAIZE GROWN FOR SILAGE

The principal agronomic influences on the composition of the maize plant, which have implications in its suitability for ensiling, are outlined below.

1.2.1 Maturity at Harvest

The maturity at harvest has an important influence on composition and yield of maize destined for silage production. Most authorities recommend harvest at the physiologically mature stage (30-35% DM), (Owen, 1967; Johnson & McClure, 1968; Buck, 1969; Hillman, 1969; Caldwell & Perry, 1971). The nutritive value of maize declines rapidly as the plant matures, but is relatively stable at dry matters above 30-35%. However, this decline is of minor importance compared with the large increase in dry matter yield during maturation (Johnson et al, 1966) which, along with the ensiling technique, usually determines the time of harvest. Because of increased field losses and difficulties in preservation of high dry matter silages when 'gas tight' silos are unavailable, most authorities consider ensiling should be done at dry matters no higher than 38%, and preferably at somewhat lower levels (Owen,

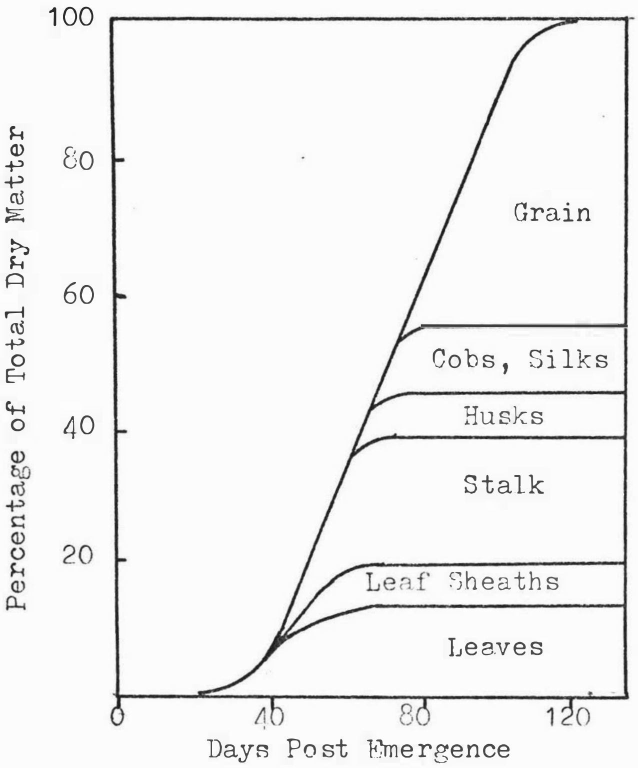

Fig 1a: Dry matter accumulation in the corn plant, and its components in relation to stage of growth (from Hanaway, 1963).

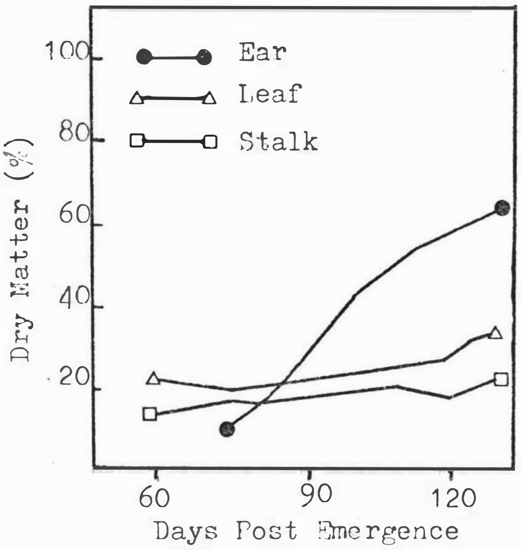

Fig 1c: Effect of maturity on dry matter percentage of plant components (from Johnson et al 1966).

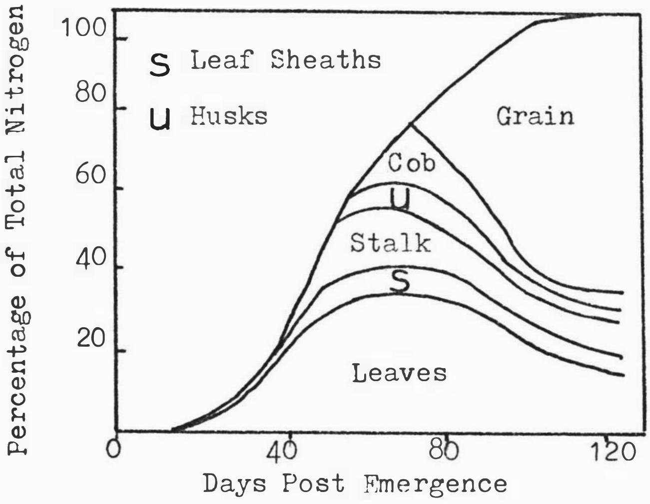

Fig 1b: Nitrogen uptake and distribution within the corn plant in relation to stage of growth (from Hanaway, 1963).

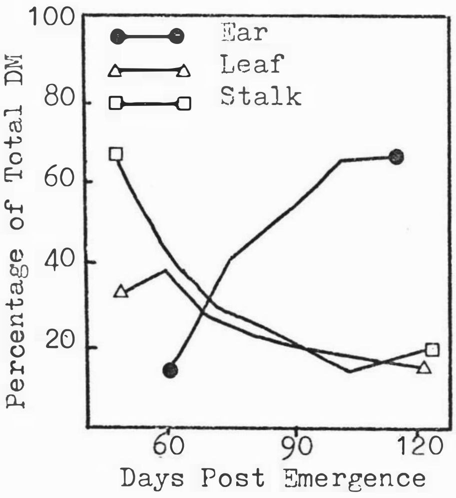

Fig 1d: Effect of maturity on component percentages of the whole corn plant (from Johnson et al 1966).

1967; Hillman, 1969; Lancaster, 1971).

Table 1.2: The chemical composition of maize silage and Tama ryegrass, and their energy contents when fed to beef cattle.

	MAIZE SILAGE						TAMA
Source	NRC 1970		Morrison 1957		≠ US-Canad. 1959	* Smith 1973	+ Wilson
DM%	27.9	40.0	27.6	28.5	25.6 ± 5.2	32.0	14.1
CP%	8.4	8.1	8.3	8.1	8.3 ± 1.4	9.7	27.6
CF%	26.3	24.4	24.2	22.1	25.1 ± 3.5	19.5	12.9
EE%			2.9	3.2	3.0 ± 0.9	3.9	5.9
NFE%			58.7	61.0		59.5	43.7
Ash%			5.8	5.6	6.0 ± 1.5	7.4	9.9
Dig Prot.%	4.9	4.7	4.9	4.6	3.1	5.5	
TDN%	70	70	66.3	69.5		^{a}62.0	^{b}82.5
ME (Mcal/kg)	2.53	2.53				2.21	
NE_m (Mcal/kg)	1.56	1.56					
NE_g (Mcal/kg)	0.99	0.99					
Ca%	0.28	0.27	0.36	0.31	0.33 ± 0.12	0.46	0.53
P%	0.21	0.20	0.25	0.25	0.23 ± 0.09	0.27	0.46
No. of Analyses			343	232	950	1	

≠ NRC (1959) Joint United States - Canadian Tables of Feed Composition.

\+ Analysis for Tama (June sampling) from Wilson & Dolby (1967). Mineral analysis from spring sampling Wilson et al (1969).

* Silage produced at this University.

a Dry Matter Digestibility.

b Organic Matter Digestibility with dairy cows.

1.2.2 Variety

The grain content of silage is frequently used as a criterion of quality in view of its high energy concentration, compared with the stover. Accurate comparison of varieties require silages to be harvested at the same stage of maturity. Goering et al (1969), in a comparison of early and late maturing varieties, found higher CP and lower CF levels in the early varieties which was probably due to the higher proportion of grain characteristic of early maturing maize (Owen, 1967). However higher DM yields are often obtained with late maturing maize varieties (Goering et al, 1969) which compensates for their lower energy content. Nevens et al (1954), pointed out that early maturing varieties had the advantage of reaching maturity before the first frost, however under New Zealand conditions other climatic factors may be more important in determining the variety that is most suitable.

1.2.3 Plant Population

Rutger & Crowder (1967) in their comprehensive study, found the principal effects of high density planting to be increased ear height, reduced stem diameter and an increased risk of lodging. Forage dry matter yields increased with higher planting density, but at a decreasing rate, whilst maximum grain yield occurred at approximately 75% of the planting density which maximised forage yields. The increased forage yields at high plant population has been observed by other workers (Alexander et al, 1963; Goering et al, 1969) and absolute yields of nutrients were reported to rise to a plateau and stabilise by Strafijuck (1962), however general observations suggest a decline in nutritive value of silages made from high plant densities (Denzic, 1960; Strafijuck, 1962; Owen, 1967; Goering et al, 1969; Bartz, 1972). Large increases in plant population have been shown to reduce crude protein content of both grain (Lang et al, 1956) and forage (Alexander et al, 1963; Nandipuri, 1963).

1.2.4 Fertiliser Application

The response to fertiliser application in terms of dry matter yield is well known. The magnitude of the response is dependent on the nutrient status of the soil and the demands imposed by the crop, hence a high plant population will show a greater response to fertiliser application than a low plant population (Lang et al, 1956; Alexander et al, 1963).

The influence of fertiliser (particularly nitrogenous) application on plant constituents are variable. Alexander et al (1963) found a doubling of fertiliser rates increased the CP content of silage by 1.0 percentage unit in high density plantings and by 0.3 percentage unit in low density plantings, whilst NFE and Ash contents were lowered and other constituents unaffected. Cummins et al (1965) and Owen (1967) have reported even greater responses in CP content of heavily fertilised silages, but Zimmerman et al (1962) failed to note any such responses. Again the magnitude of response may be a reflection of the nutrient status of the soil.

1.3 NUTRITIVE VALUE OF MAIZE SILAGE

This section considers the nutritive value of 'typical' maize silage, when fed to adult ruminants, with especial consideration to the requirements of beef cattle. Implicit in this consideration is the ability of maize silage to furnish animal needs of energy, protein, minerals and vitamins, so as to achieve satisfactory levels of production. Recent feeding standards, (Morrison, 1957; ARC, 1965; NRC, 1970), are in general agreement with respect to mineral and vitamin requirements, but the picture is less precise for protein needs and is far from clear for animal energy needs as efficiencies of energy utilisation vary with feed type, productive function and are confounded by intake variations. The inadequacies of the TDN and SE systems are well known (ARC, 1965; Van Soest, 1971), so that energy requirements will be presented in terms of Net Energy (NE) and Metabolisable Energy (ME), with TDN values used for comparative purposes only.

1.3.1 Energy Value and Digestibility

Typical maize silage is produced by finely chopping the whole plant, harvested at 30-35% DM, and when well ensiled results in an energy yield unsurpassed by any other crop according to Coppock (1969). Data in Table 1.2 illustrates the energy contents of maize silage when fed to beef cattle.

Dry matter digestibilities, calculated from protein and mineral supplemented maize silage diets, show a range from 62% (Byers & Ormiston, 1964; Goering et al, 1969) through 68% (Noller et al, 1963; Huber et al, 1965) to 71% as reported by Johnson and McClure (1968) using sheep. Hillman (1969) cites evidence for large between cow variations but suggests a DM digestibility of 68% is generally adopted in the U.S., and this figure is used in NRC (1970) feeding standards for beef.

The low digestibilities recorded in some reports could be a reflection of high DM intakes, as have been demonstrated in concentrate (Moe et al, 1965), roughage (Owen & Howard, 1965; Gordon et al, 1965; ARC, 1965) and maize silage (Watson et al, 1939; Colovos et al, 1970) feeding trials. Watson et al (1939) depressed the DM digestibility of maize silage fed to steers from 70.4%, when fed at a level of 2 kg DM/day, to 61.7% when intakes were raised to over 9 kg DM/day. Low digestibilities have also been recorded when maize silage has been fed without a protein supplement. In New Zealand work where maize silage was fed as a sole diet to lactating cows (Bryant, 1971) and to growing steers (Smith, 1973) DM digestibilities of 60% and 62%, respectively, were recorded.

1.3.2 Voluntary Intake

Data relating to voluntary intake of cattle fed maize silage is difficult to interpret because it is often supplemented with high levels of protein and energy concentrates. Intakes are also confounded by the influence of silage dry matter, this factor being discussed in Section 1.4.1. Because maize silage is both bulky and high in ME content the mechanisms involved in controlling intake may be dependent on the physiological state of the animal. This makes it difficult to transpose intake data from lactating cows to growing cattle.

Overseas work suggests that DM intakes of dairy cows fed a diet incorporating maize silage as roughage will be lower than if fed hay as the roughage (Coppock, 1969), yet milk production will be similar or even higher on the maize silage diet (Brown et al, 1965; Thomas et al, 1970), apparently because of its higher DE content (Hemken & Vandersall, 1969). For example, Brown et al (1965) fed dairy cows diets in which the forage was either maize silage or hay, the 'hay' ones consumed 66% more DM but produced 11% less milk than those fed the maize silage diet!

Several workers report intakes of dairy cows to be in excess of 3% of Body Weight (BW) for rations comprising two thirds maize silage (dry basis) (Huber et al, 1965; Hillman, 1969). Data relating to growing animals is sketchy. Colovos (1970) and Chamberlain et al (1971) reported intakes of young (200 - 300 kg) cattle fed maize silage (with protein supplement) to be approximately 2% of Body Weight, whilst Huber and Santana (1972), reported intakes of 400 kg heifers eating maize silage as a sole diet (8.8% CP) to be 2.08% of BW and 2.33% of BW when CP content was raised to 11.5% by ammonia treatment. Goering et al (1969) found protein supplemented maize silage diets were eaten at 1.83% of BW by yearling heifers but only 1.67% of BW when unsupplemented, whilst Smith (1971) and Wilkinson et al (1973) both recorded intakes of yearling steers fed only maize silage to be 2.7% of BW, the latter authors using silage of 27% DM. Bryant (1971) fed a sole diet of slightly immature silage (29% DM) to 18 month old Jersey heifers and recorded intakes of 2.1% of BW.

For calculation purposes an intake of 2% of BW has been assumed (Section 1.5.2), however increased intakes may be expected under some conditions.

1.3.3 Protein Content

Protein is the most discussed nutrient deficiency of maize silage. Typical silages contain 8-9% CP (DM Basis) with a frequently reported range of 6 to 11%. Digestibilities are low, typical values lying between 50 - 55%. (Morrison, 1957; NRC, 1970; Alexander et al, 1963; Huber et al, 1965; Goering et al, 1969).

The significance of this low dig. CP content is not entirely clear. Goering et al (1969) reported that when fed as a sole diet (with mineral supplement) to a group of steers (body weights varying from 123 - 281 kg) over a period of 166 days apparent crude protein digestibility fell from 52% to -8%. The steers weighing less than 170 kg at the start of trial lost weight, but those over this weight did not. Cattle weighing 290 kg fed similar rations over a ten week period by Alexander et al (1963) did not show any change in CP digestibility, whilst 210 kg steers used by Smith (1973) at this University showed an apparent CP digestibility of 57% after being fed only maize silage for nine weeks.

These observations suggest a greater tolerance of older cattle to low CP contents characteristic of maize silage. The adequacy of the CP from maize silage in relation to the feeding standards is examined in Section 1.5.2. Variations between the CP requirements for young growing cattle suggested in the feeding standards and requirements determined by other workers are discussed in Section 4.4.4 in relation to the findings of this study.

1.3.4 Growth Rates of Cattle

Growth rates are maximised when maize silage is supplemented with protein and/or energy concentrates, however, there are several reports of growth rates made by cattle fed only mineral supplemented silage. These are presented in Table 1.3. As expected, rates of gain increase with older animals, however the magnitude of some gains suggests CP inadequacies may not be as great as implied in the literature, for short periods at least.

1.3.5 Minerals and Vitamins

In relation to ruminant requirements typical maize silage is deficient in calcium and sodium, borderline in phosphorus, sulphur and cobalt, but may be deficient in cobalt and iodine in some areas, whilst Vitamins A and D are usually adequate (Hemken & Vandersall, 1967; Owen, 1967; Coppock, 1969; Hillman, 1969).

Both calcium and sodium are present in only one fifth of their concentration in alfalfa (Coppock, 1969). Calcium supplementation is readily achieved by adding ground limestone at ensiling - usually as 1% of the DM, but there are reports of reduced intakes with this form of supplementation (Owen, 1967). Sodium and micronutrient supplementation is readily achieved with mineralised salt licks. Sulphur and phosphorus deficiencies are less likely when fertilisers containing these elements are used in growing the maize, however additions of urea to the ration heightens the possibilities of sulphur deficiencies (Coppock, 1969). The Vitamin D supply may be inadequate for young calves (Hillman, 1969), whilst only very mature silages will be deficient in carotene content, in which case animals of all ages will respond to supplementation (Coppock, 1969).

Table 1.3: Growth rates of cattle fed mineral supplemented maize silage as a sole diet.

Source	Sex	Age or Weight	Duration of trail (days)	Daily Gain (kg)	CP% of DM
Thomas *et al* 1967	heifers	180 - 300 kg	169	0.83	-
	"	"	57	0.75	-
"	"	"	42	0.59	-
Hammes *et al* 1967	steers	yearling	158	0.95	
Huber & Santana 1972	heifers	400 kg		1.14	
+Raymond 1972	steers	3 - 6 months		0.32	10.2
	"	6 - 9 "		0.59	"
	"	9 - 12 "		0.96	"
Wilkinson *et al* 1973	"	280 kg	70	1.08	8.1
	"	157 kg	75	0.63	9.5
*Smith 1973	"	210 kg	9 weeks	0.52	9.7

+ Quoting work of Wilkinson.

* Overall quality of silage was poor (pers. comm.)

This section has endeavoured to characterise typical maize silage when fed to growing cattle. Indicators of its nutritive value are discussed as well as the ultimate criterion of growth rate, which has added to the confusion surrounding its protein adequacy. One group of cattle were fed only mineral supplemented silage throughout the duration of the study described in Chapter two.

1.4 FACTORS INFLUENCING NUTRITIVE VALUE OF MAIZE SILAGE

This section outlines the principal factors altering the characteristics of maize silage as described in Section 1.3, and indicates the animal responses expected to result from the change. This discussion may allow a better interpretation of results from cattle fed atypical silage, as was the case in this study. Factors which were given special consideration in this study (fineness of chop and whole kernel passage) are given more prominence in this discussion than their significance would deem necessary.

1.4.1 Maturity at Harvest

Dry matter yields are reduced by about 1% for every day harvest precedes maturity (Lancaster, 1971). Losses in the field (Hillman, 1969) and during ensiling (Johnson and McClure, 1968) may become significant with high dry matter silages. However, unless 'gas tight' silos are available, silages with DM contents over 38% are unsatisfactory.

DM digestibility has been determined for silages ranging from 20% to 80% DM using both cattle (Perry et al, 1969) and sheep (Johnson and McClure, 1969). Both groups of authors concluded that DM digestibility rises to a peak in the 24 - 28% DM range, then declines by 2 - 4 percentage units with advancing maturity. This result is in agreement with most others (Bryant et al, 1965; Colovos et al, 1970), although Huber et al (1965) recorded a consistent DM digestibility through the 25 - 33% range with dairy cows, and Noller et al (1963) found peak digestibilities to be at the milk stage of maturity. Byers and Ormiston (1964) recorded a digestibility of 62% when 55% DM silage was fed to dairy cows, and Goering et al (1969) recorded even lower digestibilities with 44% DM silage fed to young cattle, however these results are atypical, and in the latter case can be attributed to a protein deficiency.

Voluntary intake of immature silage is inferior to those of higher DM percentages as demonstrated by Noller et al (1963) who recorded a 28% increase in consumption of growing steers fed silage of 27% DM compared with 22% DM. Colovos et al (1970) and Chamberlain et al (1971) also recorded peak intakes of young growing cattle with silage of 27% DM, whilst Huber et al (1965) recorded an 18% increase in intake of dairy cows by increasing silage DM content from 25% to 33%. Huber et al (1967) and Hillman (1969) both record similar intakes of cows fed silages of 30 and 36% DM, but these declined when silage DM was 45%, yet Byers and Ormiston (1964) recorded a 3% increase in intake of milking cattle fed 55% silage compared with 32% DM. Goering et al (1969) found small non-significant increases in intakes of young cattle with silage DM increasing from 25 to 45%, whilst Ward et al (1966) showed correlations between DM intake and percentage DM of sorghum silages (up to 38% DM) of 0.93 and 0.95 for growing cattle and milking cows respectively.

The conclusions that silage consumption is greatest when mature, as implied in the reviews of Owen (1967) and Hillman (1969) may not be strictly correct in view of the peak intakes reported with young growing animals fed silages of 27% DM by Noller et al (1963), Colovos et al (1970) and Chamberlain et al (1971). However it is not disputed that peak intakes of lactating cows occur with higher DM (33 - 38%) silages. This premise is reinforced by a comment of Goering et al (1969), to the effect that the differences in trends with dairy cows and younger growing animals may be due to a stimulative effect of lactation.

Johnson and McClure (1968) and Noller et al (1963) working with sheep and cattle report a marked drop (approximately 10 percentage units) in CP digestibility at the dough-dent stage of maturity, followed by a steady decline as silage DM increases. This accentuates the effects of the declining CP% of the plant DM, resulting in typical silage having a Dig CP content of approximately 4.6% (8.4%, 55% Dig). Goering et al (1969) have recorded apparent CP digestibilities of under 20% in young animals fed on all silage mineral supplemented diet and suggests this to be caused by dietary protein deficiency, which also reduced intakes and DM digestibility. Hence, the importance of protein supplementation appears greatest when silages are over approximately 24 - 27% DM.

Wiseman et al (1938) has reported carotene contents of 140, 32, and 4 mg/kg DM at the milk, dent and post frost stages of maturity respectively, resulting in deficiencies when mature silages are fed as a major portion of the animals' diet. Other minerals seem less affected by stages of maturity, although Johnson and McClure (1968) report calcium contents of only 0.09% of DM in very mature silages.

1.4.2 Variety

An interpretation of varietal influences on nutritive value must distinguish between effects due to grain content, and intake as influenced by DM content and palatability. Stover silage contains 75 - 85% as much TDN as conventional silage (Dunn et al, 1955; Hillman, 1969) and, as McCullough et al (1964) found 87% of variation in productivity of dairy cows could be accounted for by (TDN) intake, then lowered productivity is to be expected when low grain silages make up a large proportion of their diet. Reduced intakes are associated with immature and stover silages (Huffman and Duncan, 1956; Colenbrander et al, 1971, respectively), and these results are supported by Muller et al (1967) whose heifers consumed 30% of a maize silage diet, (35% DM) and grew 80% faster than when fed urea supplemented stover silage. Hence, the superior production achieved by cattle fed silages produced from high grain varieties can be attributed in part to increased intakes, as well as to a higher energy content.

1.4.3 Plant Population Density

A compromise must be reached between increased forage yields from high density plantings (Section 1.2.3) and the lower nutritive value of such silages, about which there is universal agreement (Dzinic, 1960; Strafijcuk, 1962; Alexander et al, 1963; Owen, 1967; Goering et al, 1969). High population silage has a reduced mineral concentration (Alexander et al, 1963) and digestibilities of all constituents are lower, the most serious being CP, although the reduction in DE is also large (Alexander et al, 1963; Goering et al, 1969).

1.4.4 Fertiliser Application

As well as increasing CP contents, Alexander et al (1963) found increased NPK fertiliser application caused small increases in digestibility of proximal constituents of silage, but not if produced from high planting densities. Cummins et al (1965) observed large increases in CP percentages associated with N fertilisation, but failed to obtain any response when the silage was fed to growing heifers, yet Zimmerman et al (1963) could not detect any component changes, but recorded steer daily gains of 0.80, 0.96 and 1.09 kg from silage produced from control, high N, and high N + P fertilised crops respectively. Jordan et al (1961) increased steer growth rate as a result of increased N fertilisation and Vandersall et al (1962) recorded a small increase in efficiency of milk production, whilst Perry et al (1972b) reported a large increase in growth rate and efficiency of feed conversion in steers fed normal compared with potassium deficient silage, although digestibility of constituents was unchanged.

Hence, some significant improvements in performance have been recorded as a result of fertiliser application, but reasons for them are unclear. Mineral contents are not changed appreciably by fertiliser treatment (Alexander et al, 1963), with the possible exception of sulphur (Coppock, 1969), whilst the effects of raised nitrate concentrations, which have been linked to possible carotene deficiencies (Coppock and Stone, 1965) are unlikely to be significant (Miller et al, 1965; Mitchell et al, 1965; Jones et al, 1966; Jordan et al, 1961).

1.4.5 Conservation Practices

Seepage losses should be minimal in silages over 28% DM (Coppock and Stone, 1965), particularly in horizontal stacks because of low vertical pressures (Gordon, 1967). However the characteristically low densities of maize silage (typical densities being 14 - 16 kg/cu ft (Morrison, 1957; Lancaster, 1971)) encourage air entry which results in heating, mould formation, and rotting, particularly where poorly consolidated and more especially with high DM silages. American findings suggest a fine (0.64 - 1.28 cm) chop is optimal, as it facilitates handling in the silo and enhances compaction. Geasler et al (1967a) demonstrated a 16% reduction in density of silages (28 and 48% DM) when chopped to 1.34 - 2.01 cm instead of 1.00 cm. The literature also emphasises the need to remove silage daily from the entire exposed face, with minimal disturbance of the stack, so as to minimise air entry and prevent mould building up in the otherwise excellent silage.

Work at Massey University has shown that tractor consolidation of low DM (25 - 30%) maize silage in shallow bunkers can produce good fermentation, and densities of 16.7 kg/cu ft were achieved with this technique at Ruakura (Lancaster, 1971). Hence good quality silage can be produced using typical New Zealand ensiling procedures, particularly if it is finely chopped, well covered and not too mature, however, elimination of rodents may be necessary to prevent spoilage according to Smith (1973).

1.4.6 Fineness of Chop

Maize silage chopped to different extents has been studied in relation to animal production. Geasler et al (1967) fed conventional (1.00 cm) and coarse (1.34 - 2.01 cm) chop silages of 28, 48 and 60% DM to steer calves which showed slight but non-significant decreases in growth rates on the coarse chop. Martin et al (1971) chopped silages of identical maturity to 1.0 and 2.0 cm particle size and found the DM of the fine chop silage to be 2 - 5 percentage units higher than that of the coarse chop. This was attributed to a greater moisture loss between cutting and ensiling, and may have an important effect on voluntary intake (see Section 1.4.1). Other workers have studied recutting of conventional silage with a view to reducing the apparent waste of undigested kernels. Results are conflicting. Huber et al (1966) recorded a 13% decrease in DM intake of dairy cows when fed recut maize silage, which reduced kernel passage from 479 to 91 g per day and maintained milk production. Buck et al (1969) found recutting of silages ranging from 22% to 46% DM had no effect on intake, digestibility, or milk production despite 50% reductions in kernel passage, however he mentioned the magnitude of the decrease in kernel passage (approximately 90 g/day) could not affect digestibility by more than one percentage unit anyway. Geasler et al (1967b) found regrinding of 48% and 60% DM silages increased efficiencies of feed conversion but gave similar rates of gain when fed to steers. Regrinding 28% DM silage did not affect efficiency or weight gains.

The limited literature available suggests coarse chopping to be less desirable than conventional (1.00 cm) chop, particularly in view of the reduced ensiling densities reported in Section 1.4.5. Rechopping conventional silage does not appear advantageous, particularly in view of a three fold increase in horse power requirements reported by Buck et al (1969).

Fine (conventional) and coarse chop silages were evaluated in terms of digestibility and kernel passage during this study.

1.4.7 Whole Kernel Passage

Concern is often expressed at the apparent nutrient loss associated with undigested kernels appearing in the faeces of cattle. Several measurements of kernel passage in silage fed cattle have been made; Becker and Gallop (1929) found 4.4% of whole kernels were recovered from cattle fed 30.7% DM silage, whilst Huffman and Duncan (1958) recovered 2.7% using 27% DM silage. Davis and Waldern (1970) recovered 7.2% of whole kernels (1.2% of silage DM) from a 26.8% DM coarse chop (1.9 cm) silage fed to lactating cows. Reports of larger losses are usually associated with grain feeding. Kick et al (1938) suggests silage feeding to result in a relatively dry digesta in which kernels are well mixed and more completely broken down during mastication than they are in grain based diets which are more liquid, so that kernels are less easily regurgitated. Evans and Colburn (1967), using the nylon bag technique, found nearly all constituents of damaged kernels to be more completely digested than were whole kernels, both types being hand separated from silage. This conclusion is confirmed by Wilson et al (1973). These workers found dried grains to be more efficiently chewed than high moisture grains (42% and 22% broken respectively) but rolling or cracking increased digestibilities of both, especially the latter. Both types were fed in conjunction with hay.

It appears that mutilation is the prime factor influencing efficiency of kernel utilisation, however it is not well correlated with kernel DM, particularly with silage feeding programmes where losses are usually small. The expense of recutting does not appear to be justified.

1.5 FEEDING VALUE AND REQUIREMENTS OF YOUNG GROWING CATTLE

This section endeavours to examine the relationship between the nutritive value of maize silage and the nutrient requirements of young (200 - 300 kg) growing cattle, in accordance with British (Agricultural Research Council, 1965) (ARC), and American (National Research Council, Nutrient Requirements of Beef Cattle, 1970) (NRC) feeding standards. By comparing the nutritive value of maize silage with requirements of growing cattle it was hoped that the possible role of a pasture supplement in making up deficiencies could be assessed.

1.5.1 Energy

Both authorities agree with respect to energy requirements for maintenance of cattle of 300 - 400 kg LW, but NRC estimates are approximately 10% lower than ARC, for 200 kg cattle. Furthermore ARC estimates for efficiency of energy utilisation for Live Weight (LW) gain are approximately 10% higher than NRC estimates for comparable feeds and whilst NRC tables of ME requirements fail to differentiate between feed qualities, ARC assumes equal requirements for both sexes. Some of these differences have been demonstrated graphically by Joyce (1971). The Net Energy (NE) system, as defined by Loffgreen and Garratt (1968) has eliminated the need for adjusting requirements in relation to feed types and has been adopted by NRC (1970), hence both this and the ME estimates are presented in Tables 1.4 and 1.5 which relate estimated energy requirements to expected rates of gain.

Tables 1.4 and 1.5 assume intakes of mineral supplemented silage to be 2% of body weight (Section 1.3.2). If protein deficiencies are severe then DM intake may be reduced (Hungate, 1966; Goering et al, 1969) and the normal energy values of maize silage (2.5 Mcal ME/kg DM; NRC, 1970) may be lowered, as indicated by the findings of Smith (1973) who calculated the ME of maize silage fed to yearling steers, without a protein supplement, to be 2.21 Mcal/kg DM. Addition of protein rich forage would increase intakes and restore the energy values, so the typical energy contents of maize silage (Table 1.2) have been used in the calculation of Tables 1.4 and 1.5.

Table 1.4: Estimated Net Energy requirements (Mcal/day) according to NRC (1970), and expected rates of gain for cattle fed maize silage at 2% of LW.

Sex	LW (kg)	NE maint.	NE for the following rates of gain (kg/day)			DM used for *maint.(kg)	Expected daily +gain (kg)
			0.5	0.7	1.0		
Male	200	4.10	1.49	2.14	3.16	2.63	0.45
Male	300	5.55	2.02	2.90	4.29	3.56	0.59
Female	200	4.10	1.66	2.42	3.65	2.63	0.40
Female	300	4.84	2.25	3.27	4.95	3.56	0.53

* Assumes $NE_{maint.}$ = 1.56 Mcal/kg DM

\+ From DM not used for maintenance, assuming NE gain = 0.99 Mcal/kg DM

Tables 1.4 and 1.5 show that despite the differences between ARC and NRC estimates of energy requirements, maize silage consumed at 2% of LW provides sufficient energy to promote gains between 0.4 and 0.6 kg/day. Increasing intakes to 2.5% of LW would allow gains of at least 0.7 kg/day in animals of

200 - 300 kg LW, demonstrating the adequacy of its energy content.

Table 1.5: Estimated ME requirements (Mcal/day) with rations of two energy concentrations (ARC, 1965), and expected rates of gain for cattle fed maize silage at 2% of LW.

LW (kg)	ME content of ration (Mcal/kg)	ME for the following rates of gain (kg/day)				Energy Intake at 2% LW (Mcal)	Expected daily gain (kg)
		0.0	0.25	0.50	0.75		
200	2.2	8.3	9.8	11.5	13.6	8.8	Negligible
200	2.6	8.0	9.2	10.6	12.3	10.4	0.45
300	2.2	10.2	11.9	13.9	16.3	13.2	0.41
300	2.6	9.8	11.2	12.8	14.7	15.6	Over 0.75

1.5.2 Protein Requirements

Estimates of Dig CP requirements differ greatly, those from ARC being lower than American estimates (NRC, 1970; Morrison, 1957) for cattle of all weights. The discrepancy increases with increasing live weight so that minimal requirements for a 400 kg beast suggested by ARC are 50% of the NRC estimate! The ARC approach is factorial and assumes equal efficiency of CP utilisation at all growth rates, regardless of animal size, while maintenance requirements increase with LW but at a decreasing rate. NRC estimates are based on results of feeding trials in which the amounts of protein fed were equated with growth responses obtained. Estimates from both sources are shown in Table 1.6, along with an average of these two estimates, which has been used to assist in formulating grass:silage ratios used in the study and to facilitate discussion of requirements, but it is emphasised that there is no scientific basis for taking this average.

Assuming an apparent Dig CP content of 4.6% (8.4% CP, 55% Dig) for typical maize silage, cattle of 200 and 300 kg fed an all silage diet at 2% LW would be expected to consume 184 and 276 grams of Dig CP/day respectively, which is unlikely to be sufficient for rapid rates of gain, although maintenance requirements would be met (Table 1.6). Supplementing this diet with pasture can be expected to increase intake to at least 2.5% LW according to findings of Bryant (1971), Wilkinson <u>et al</u> (1973) and others, which would provide sufficient energy to support growth rates of at least 0.7 kg/day (Section 1.5.1).

The proportions of fresh pasture (assumed to contain 16% Dig CP) required to supply adequate Dig CP in a maize silage based diet to support gains of 0.75 kg/day when fed to 200 - 300 kg cattle consuming DM at 2.5% of their LW per day are calculated and presented in Table 1.7.

Table 1.6: Estimates of Dig CP requirements (g/day) of young growing cattle, prepared from ARC (1965) and NRC (1970) feeding standards.

Source of Data	LW (kg)	Rate of gain (kg/day)				
		0.0	0.25	0.50	0.75	1.00
*NRC (1970)	200	140	275	355	370	455
	300	190	320	485	590	700
ARC (1965)	200	114	167	220	273	324
	300	134	187	240	293	344
An average of ARC and NRC Estimates	200	127	221	287	322	440
	300	162	253	363	442	522

* Small sex differences have been averaged out.

Table 1.7: Maize silage: grass ratios calculated to satisfy Dig CP requirements of cattle growing at 0.75 kg/day at two levels of intake.

Intake as % BW	BW (kg)	Feed ratios (DM Basis) Silage : Grass*	Dig CP Intake	Dig CP as % of Ratio DM
2	200	70 : 30	320	8.0
2.5	200	84 : 16	320	7.5
2	300	74 : 26	450	6.4
2.5	300	88 : 12	447	6.0

* Assumes grass to contain 20% CP with a digestibility of 80%

It is reiterated that these calculations may not be strictly valid, nevertheless they suggest that 12 - 16% of grass in a maize silage ration (DM Basis) should provide sufficient CP and energy to allow growth rates of

0.75 kg/day, which would be considered quite adequate under a New Zealand wintering system. A 20% level of supplementation was one treatment actually chosen for use during this study.

1.5.3 Minerals and Vitamins

Calcium, sodium and phosphorus are the minerals most likely to be deficient in a maize silage ration fed to young growing cattle (Section 1.3.5). The vitamin A requirements should be met if typical silage is fed (Section 1.4.1), this literature being reviewed by Smith (1973). Table 1.8 gives mineral requirements suggested by ARC (1965), whose estimates of calcium requirements are far higher than those of NRC (1970). The expected intakes of minerals by cattle fed maize silage alone are presented in Table 1.9.

Table 1.8: ARC (1965) estimates of mineral requirements of young growing cattle (g/day).

LW (kg)		Growth Rate (kg/day)								
		0.33			0.50			1.0		
	Mineral:	Ca	P	Na	Ca	P	Na	Ca	P	Na
200		14.0	8.1	3.9	18.0	9.8	4.1	30.0	15.0	4.8
300		18.0	13.0	5.6	21.0	15.0	5.8	33.0	20.0	6.5

Table 1.9 Calcium, phosphorus and sodium intakes of cattle fed maize silage at 2% of BW, assuming mineral concentrations to be 0.30%, 0.23% and 0.03% respectively.

LW (kg)	Ca	P	Na
200	12	9.2	1.2
300	18	13.8	1.8

These figures suggest phosphorus content to be marginal and calcium and sodium to be markedly deficient. The levels of supplementation used in the current experiment are given in Appendix 3.

This section has demonstrated the adequacy of the energy content of maize silage but has emphasised the need for protein and mineral supplementation. The latter is readily and economically achieved, but the optimal level of protein supplementation is not at all clear. It was the aim of part of this study to clarify this requirement, when Tama ryegrass was used as the protein source.

1.6 SUPPLEMENTATION OF MAIZE SILAGE DIETS

Continental winters are often too cold or the ground snow covered to allow grazing, so that there is little mention of grass-maize silage feeding systems in the literature, instead one finds an almost standard reference to supplementation with soybean meal - a concentrate containing approximately 45% crude protein. The high cost of organic nitrogen concentrates has stimulated the intense interest in Non Protein Nitrogen (NPN) forms of supplementation as reviewed by Conrad and Hibbs (1968); Chalupa (1968); Waldo (1968); Oltjen (1969); Helmer and Bartlay (1971) and others and was the topic of a recent thesis at this university, (Smith, 1973). New Zealand's temporate climate allows in situ utilisation of relatively inexpensive green feeds such as Autumn Saved Pasture (ASP), annual ryegrasses and cereals, which could supplement the low protein content of a predominantly maize silage diet fed to animals over the winter period. Tama ryegrass, because of its winter growth habit, offers the possibility of a maize-Tama crop rotation, providing the maize variety is early maturing and the winters not too cold. This rotation, if practicable, would provide high DM yields and may ensure a balanced diet, requiring only mineral supplementation.

1.6.1 Feeding Value of Tetraploid and Other Winter Grasses

There is little information relating to the composition, especially the CP contents of winter green feeds, however Lancaster (1947) and Wallace (1955) suggest CP content of ASP to be about 20%, whilst Wilson and Dolby (1967) found Tama, in mid winter, to contain 26% CP (Table 1.2). Barclay and Vatha (1966) suggested that the DM production of Tama would be equal or superior to that of the cereal green feeds, and that 8600 kg DM/ha could be expected by September, however growth would have to be well under way in the autumn, before the first frosts, to achieve this.

Wilson and Dolby (1967) in a winter grazing trial found Tama comparable to 'Grasslands Paeroa' ryegrass and superior to 'Grasslands Ruanui' ryegrass in terms of milk yield, but milk fat percentage was lower for cows grazing Tama, apparently because of its lower CF content. British workers have also compared productivity of animals fed tetraploid varieties. Adler (1968) found no difference in intakes of sheep and calves fed tetraploid (Reveille and Telila tetrone) and diploid (S22 and S24) varieties, but as the season progressed calves showed superior gains when fed the tetraploids. Thomson (1971) found sheep fed Telila tetrone to consume 14% less than when fed S22 ryegrass in the spring, digestibilities being similar for both varieties, but with regrowths, intakes of both varieties were similar, the digestibility of Telila tetrone being 6 percentage units higher than S22. Castle and Watson (1971) found intakes and milk yields of dairy cows fed silages of Reveille to be superior to those fed S24 silage, and organic matter (OM) digestibility to be approximately 2.5 percentage units higher for Reveille than S24 throughout the season.

It appears that the tetraploids are slightly superior to diploids in terms of animal performance, particularly late in the season. Hence it could probably be assumed that Tama would be superior in its nutritive value to ASP, particularly if the latter becomes long and rank and contains dead matter, as is often the case.

Unforeseen circumstances resulted in both ASP (perennial-white clover) and Tama being used during the study, which allowed a comparison to be made between their respective feeding values.

1.6.2 Responses to Concentrate Supplementation of Silage or Pasture

The ME content of pasture is sometimes greater than that of maize silage, but declines rapidly with onset of flowering. Good quality leafy pasture has a similar ME content to typical maize silage, so when it replaces silage in a diet there is little effect on ration ME content. However responses of growing cattle fed either pasture or maize silage to increasing proportions of corn grain supplement are quite different.

Most workers (Klosterman et al, 1965; Perry and Beeson, 1966; Cash et al, 1971) have recorded increased rates of gain with increasing proportions of grain in a maize silage based ration but responses to additional increments of grain diminish at high levels. Peterson et al (1971) recorded similar results, but the gains were greater when ration CP was raised through soybean and urea supplementation. Responses to grain supplementation of maize silage are presented in Table 1.10. This table also demonstrates responses to grain supplementation of pasture, which tend to be larger and more consistent than for grain supplementation of maize silage. The different rates of gain between years (Perry et al, 1971, 1972a) are a reflection of pasture quality.

The comparative efficiencies of gain between forage and grain feeding are demonstrated by Oltjen et al (1971) who fed 240 kg steers diets of cracked corn, pelleted alfalfa hay and pelleted timothy hay with respective daily gains (kg) and efficiencies (feed:gain ratios) of 1.27, 5.7:1; 1.05, 10.06:1; 0.84, 12.70:1. However, the efficiency of gain in the cracked corn ration may be an overestimate of its real value in view of the increased levels of internal fat associated with heavy grain supplementation of silage (Klosterman et al, 1966; Henderson et al, 1971).

Table 1.10: Rates of gain (kg/day) of yearling steers receiving increased proportions of maize grain in a basal ration of silage or fresh pasture.

Basal Ration	Source of Data	Proportion of concentrates in the DM				
		0	1/9	1/3	2/3	full-feed
Maize Silage	Perry & Beeson (1966)		0.91	1.04	1.05	1.05
	Peterson et al (1973)	1.17		1.21	1.32	1.34
	*Peterson et al (1973)	1.22		1.30	1.51	1.59
Pasture	Perry et al (1971)	0.80		1.10	1.26	1.44
"	Perry et al (1972a)	0.43		0.84	1.07	1.33

* CP level of ration raised to 15% by additions of soybean meal and urea.

1.6.3 Dried Forage Supplementation of Maize Silage

The paucity of information relating to fresh forage supplementation of maize silage necessitates inclusion of data relating to dried forage, i.e. hays and pelleted forages.

1.6.3.1 Dairy Cows

The trend in the United States to use maize silage as the only forage in many dairying systems has increased risks of nutrient deficiencies (Coppock, 1969), despite concentrate rationing in accordance with level of production, so that workers have studied effects of feeding different levels of hay (usually alfalfa) in addition to the silage. This has inevitably increased total DM intake (Waugh et al, 1955; Brown et al, 1965, 1966; Thomas, 1970; Kennett et al, 1971) but in no reports has maximum milk production coincided with maximum DM intake.

Brown et al (1965, 1966) and Thomas (1970) fed a hay supplement at 0.0, 4.5 and 9.0 kg/day and ad libitum to cows also receiving maize silage, but milk production declined with increasing levels of hay, those receiving ad libitum hay producing 89-90% of those not receiving hay. Waugh et al (1955) and Kennett et al (1971) fed hay at 0.0, (0.25), 0.50 and 1.00% of LW to lactating cows also receiving maize silage, the latter workers over 4 lactations. These workers found milk production highest at the 0.50% of BW level, whilst those fed at the 1.00% level gave slightly more milk than those not receiving hay. The two sets of data may not be contradictory. If Brown et al (1965, 1966) and Thomas (1970) used 500 kg cows their feeding levels would be approximately 0.9 and 1.8% of BW, and as the depression reported by Thomas (1970) at the 4.5 kg level was small, it may be concluded that low levels of hay, e.g. 0.50% BW, fed in addition to maize silage to lactating dairy cows may improve milk yields. There is, however, no doubt that higher levels of replacement will depress milk yields.

1.6.3.2 Growing Cattle

The literature relating to silage based rations for growing cattle usually refers to either NPN or protein concentrate supplementation, whilst finishing rations include a proportion of grain. Only recently has interest been shown in forage supplementation, particularly in the United Kingdom where maize is a recent introduction.

Edwards et al (1972) compared ten rations comprising different proportions of maize silage, dehydrated pelleted bermuda grass (18% CP), cotton seed meal and cracked corn, when fed to young cattle (222 kg initial LW). All rations met NRC (1963) requirements. The findings were surprising; for example, cattle on a diet of approximately 6.7 kg maize silage (DM Basis) and ad libitum bermuda grass pellets grew at a similar rate as those fed cracked corn at 1% of BW, 0.68 kg cotton seed meal and ad libitum silage (0.73 and 0.77 kg/day respectively). NRC (1970) suggest ME of bermuda grass hay to be 1.59 Mcal/kg, whilst cracked corn is 3.29 Mcal/kg. A possible explanation for these unexpected similar growth rates lies in the CP content of the rations; that containing the cracked corn was 11% CP, whilst the bermuda grass ration contained 15.2%. Perry and Beeson (1966) fed steer calves (initial weight 232 kg) a basal diet of maize silage plus 1.58 kg of concentrates per day. Increasing the protein concentrates from 0.5 to 1.58 kg/day at the expense of the energy concentrates, whilst maintaining a constant total DM intake, increased growth rates by 8% despite a decline in total energy intake. This marked increase in efficiency suggests CP level may be more important than energy concentration of diets, within limits, for young animals.

The significance of CP content of rations fed to young cattle is further demonstrated by Wilkinson et al (1972) who found addition of urea (at 2% of DM) to a ration consisting entirely of maize silage (10.72% CP) fed to groups of Friesian steer calves initially 3, 6 and 9 months old increased rate of gain by 43, 75 and 11% respectively. Intake data were not presented, but presumably intakes were increased as a response to addition of urea, the latter two groups gaining at over 1 kg/day.

In a more comprehensive trial at Hurley (Wilkinson et al, 1973) two groups of Hereford x Friesian steers, with initial live weights of 157 and 279 kg, were fed maize silage rations with increasing proportions of dried lucerne cobs (19.5% CP). The duration of the trials were 10 and 11 weeks. In both cases the response in live weight gain to rations containing increasing proportions of lucerne cobs was curvilinear, with maximum daily gains of 1.1 and 1.5 kg being achieved with 71 and 62% of lucerne in the ration (DM Bases) for the calves and yearlings respectively. Some data from this trial is reproduced in Table 1.11. The lower growth rates of the calves may have been due to a lower silage quality (Wilkinson et al, 1973).

Variations in intake made interpretation of growth rate responses to lucerne supplementation difficult. The importance of ration CP in relation to energy content is emphasised in the data obtained from the yearlings (Table 1.11). Daily gain was maximised at high lucerne intakes and not when DM intake was at a maximum. The authors considered dietary CP, rather than intake, to be the principal agent which influenced growth rate.

Table 1.11: Intake and performance of yearlings and calves fed various combinations of lucerne cobs and maize silage (from Wilkinson et al, 1973).

Proportion of Lucerne (% DM)	Yearlings						Calves			
	0	9.5	22.1	45.9	67.0	100	0	22.8	46.6	69.8
CP% of Ration +	8.2	9.2	10.7	13.2	15.7	19.5	9.9	11.9	14.1	16.5
Intake: kg DM/day	8.52	7.38	8.59	9.81	9.41	9.02	4.43	5.19	5.67	6.12
kg/100 kg BW	2.70	2.34	2.67	3.00	2.77	2.74	2.46	2.65	2.82	3.04
Average daily gain (kg)	1.08	1.24	1.35	1.46	1.50	1.38	0.63	0.96	1.10	1.13

The gains achieved in this experiment emphasise the potential of a forage supplemented maize silage feeding system. The importance of variations in ration CP and energy contents, when feeding growing animals of different ages, is briefly discussed in Section 4.4.4.

1.6.4 Fresh Forage Supplementation

Little overseas literature comparing maize silage and pasture, or together in combinations, is available. Baxter et al (1973) obtained a 3 - 5% improvement in fat corrected milk production from Jersey cows when part of their maize silage, hay and concentrate diet was replaced by green chop or pasture. Utley et al (1973) fed 380 kg steers diets of maize silage plus 0.45 kg cotton seed meal, cereal pasture alone, or cereal pasture and maize silage. Daily gains were 0.81, 0.88 and 0.83 kg/day, respectively; the only significant effect of feeding pasture was a slight but unimportant yellowing of fat and an increased dressing out percentage especially for those on the mixed diet.

Of the limited research carried out at Ruakura where maize silage has been fed in conjunction with, or been partially replaced by pasture, only the findings of Bryant (1971) need be mentioned, as the silage used in trials conducted by Joblin (1968) was cut with a flail harvester and was of poor quality (Lancaster, 1971). Bryant fed maize silage (29% DM) alone, and with different levels of grass to lactating cows and to growing dairy heifers (Tables 1.12 and 1.13).

The results demonstrated the inferior performance of cattle fed silage as their sole diet, and whilst higher DM intakes were achieved with the mixed rations, milk production from the 25% grass ration was inferior to the all pasture treatment, but the 75% grass ration was slightly superior. Unfortunately not enough data is available (Table 1.12) to suggest preferable grass:silage ratios for milk production.

Table 1.12: Data (from Bryant, 1971) demonstrating the effects of feeding different maize silage:pasture ratios to dairy cows.

	Maize Silage : Pasture Ratios			
	100 : 0	75 : 25	25 : 75	0 : 100
Intake (kg DM/day)	8.4	11.3	12.6	11.0
Milk Prodn (kg/day)	10.8	13.9	15.6	14.9
Milk Fat (%)	4.1	4.3	4.3	4.5
Protein (%)	2.8	3.0	3.2	3.2
DM Digestibility (%)	60	62	69	75

Table 1.13: Liveweight gain, OM intake and digestibility of pasture, and pasture supplemented maize silage fed ad lib to young heifers (from Bryant, 1971). (All pasture was frozen for storage, until required.)

	Maize Silage : Pasture Ratios		
	92 : 8	76 : 24	0 : 100
Trial 1*			
Daily LW Gain (kg)	0.56	0.63	0.78
Daily OM Intake (kg)	3.9	4.0	4.2
OM Dig (%)	70	69	78
Trial 2+			
Daily LW Gain (kg)	0.52	0.60	0.62
Daily OM Intake (kg)	3.7	4.0	4.1
OM Dig (%)	68	70	76

* Initial LW of animals averaged 143 kg, pasture harvested during May-September.

\+ Initial LW of animals averaged 170 kg, pasture harvested during October-November.

In the experiment using growing heifers Bryant (1971) calculated that pasture fed at the 8% and 24% levels of supplementation (Table 1.13) would provide approximately 25 and 75% of the animals' protein requirements. The low daily gains of animals fed the 8% grass supplemented ration suggest this level of supplementation to be inadequate. Although there was a continuing response to increased grass supplementation in trial 1, the similarity of growth rates in the 24% grass and all grass treatments of trial 2 suggests a similar nutritive value of both rations. There was a surprisingly small intake response to supplementation, but this may be due to the pasture being stored frozen. The continuing response to pasture supplementation in trial 1 compared to the similar rates of gain for the 24% and all grass treatments in trial 2 may be a reflection of a lower protein requirement of the heavier animals in this trial, as observed by Goering et al (1969), Bowers et al (1965), Kay and Macdermaid (1973) and Wilkinson et al (1973).

These data (Tables 1.12 and 1.13) do not suggest an optimum level of supplementation, but it appears that the 25:75 grass:silage ratio is similar, but slightly inferior, to an all grass diet. The optimal combination will naturally vary with the age and physiological state of the animal.

This section has demonstrated the high levels of production which have been obtained with dried and fresh forage supplementation of maize silage. A significant observation related to the protein content of the supplement feeds is the necessity of high CP concentrations in diets fed to young growing cattle, which appears to take precedence over dietary energy concentration, within limits. Data obtained from the experiment described in Chapter Two should provide further information on the use of pasture and maize silage combinations as a feed for young growing cattle.

1.7 SUMMARY

Ensiling maize when mature (30-35% DM) maximises both DM and grain yields and results in a total energy yield apparently unsurpassed by alternative crops. Dry matter digestibility of typical maize silage fed to cattle is 68% with a metabolisable energy content of 2.5 Mcal/kg. These levels are most often obtained when the low and inadequate digestible crude protein (approximately 4.6% of the DM) and mineral (especially Ca and Na) contents are raised through supplementation. Intakes and production from unsupplemented maize silage diets are frequently poor, especially when fed to young animals.

The nutritive value of silage decreases at high planting densities, but is less affected when grown on high fertility soils, which can also raise its CP content. Nutritive value is related to grain content and, unlike most crops, digestibility and intake do not decline appreciably if harvesting is delayed, though likelihood of field and ensiling losses increases. Fine chopping encourages good compaction and so reduces ensiling losses at all stages of maturity.

The merits of maize silage are apparent. Mineral inadequacies are easily remedied, so that the major problem faced by workers is the type and extent of protein supplementation needed to meet requirements of high producing stock.

Interest in forages for protein supplementation is new, and may have been stimulated by the high cost of concentrates and the uncertain responses to urea. Most overseas literature considers the merits of pelleted forages, especially lucerne, so that data relating to pastoral supplementation is scarce. Responses to both dried and fresh forage supplementation of maize silage have been excellent, production almost always being greater from cattle fed a combination of feeds than either one alone, however optimal feed ratios for different situations need to be determined.

Emerging from the literature is a marked dependence of growing animals on

CP which often takes precedence over energy concentration, so that some combination of maize silage and pasture should be ideal for growing cattle. The study described in Chapter Two should aid in filling a gap in our knowledge.

CHAPTER TWO

METHODS AND MATERIALS

The experimental work for this thesis consisted of two separate studies. In the first, the merits of fine and coarse chopping of maize silage were examined, when fed as sole diets to young growing cattle. In the second part of the experimental work, two levels of grass were fed with maize silage, and animal performance compared with those fed either maize silage or grass alone. It was intended that Tama ryegrass would be used as the grass supplement, but because of poor early growth, mixed pasture had to be used during the initial stages, and Tama was used in the latter stages of the experiment. As the two types of grass differed in quality, results and analyses were kept separate, so this study was effectively divided into two sections. Thus, overall there were three separate sections: the size of chop evaluation, mixed pasture supplementation, and Tama supplementation of maize silage, and these have been designated Trials 1, 2 and 3, respectively. This terminology is used through the remainder of this, and future chapters.

2.1 EXPERIMENTAL DESIGN

Sixteen rising two year old cattle, consisting mainly of sets of monozygous twins (including 6 steers), were used in the feeding experiments, which were carried out indoors. The cattle were introduced to the feeding barn ten days prior to the commencement of Trial 1. Trial 1 extended from 17/6/72 to 30/6/72 and was considered to be of lesser importance than Trials 2 and 3, so that it provided an extended standardisation or acclimatisation period for these latter trials.

During Trial 1, 6 twin pairs were fed either the coarse or fine chop silages (see Section 2.3.1) as a sole ration (with mineral supplements) at 90% of ad libitum intakes. Feeding levels were determined from intakes recorded prior to the commencement of this trial, when the same (fine or coarse chop) silages were fed. Measurements and treatment comparisons were made using digestibility data, rate of passage data, and estimates of losses of kernels in the faeces. The diurnal variation of chromic oxide in the faeces was also measured. The data were analysed using a completely randomised block design.

Upon completion of Trial 1, fine chop silage was fed ad libitum over a four day period, after which diets were gradually changed to those fed during Trial 2.

During Trials 2 and 3, four rations were fed: all silage, 20% grass and 80% silage, 55% grass and 45% silage, and all grass. Each treatment comprised

PLATE 1: The Maize Crop at Harvest

At harvest the maize was at the early dent stage of maturity. The ears were well developed and ripening, whilst the lower leaves were beginning to senesce.

four cattle. A balanced incomplete block design was used to compare the three main treatments (those containing silage) and the layout required is given in Table 2.1. The design was replicated so that one replicate consisted of steers and the other heifers. It was originally intended that the 'all grass' treatment should consist of four unrelated heifers, but unfortunate circumstances necessitated the inclusion of a set of identical twins.

The experimental dates for Trials 2 and 3 were:

Trial 2: 10/7/72 - 20/7/72
Trial 3: 22/7/72 - 5/8/72

Table 2.1: The allocation of Identical Twins to treatments in Trials 2 and 3.

Twin Set	Treatment		
	All Silage	20% Grass	55% Grass
1	a		a
2	b	b	
3		c	c

All rations were fed ad libitum, the 20% grass ration having been calculated (in Section 1.5.2) to provide sufficient Crude Protein (CP) to sustain daily gains of 0.75 kg, whilst the 55% grass level was chosen to provide an excess of CP. The principal parameters measured for all cattle during these trials were digestibility and voluntary intake, and whilst LW gain was measured, little significance is attached to it in view of the short duration of the trials. Further data were obtained from the 6 steers which were harnessed for faecal and urine collection during Trial 2. Where the all grass treatment entered into treatment comparisons, use of the completely randomised design for statistical analysis was necessitated, but for most other comparisons involving the three main treatments the balanced incomplete block design was more sensitive.

A chronological sequence of events, covering the entire duration of the experiment, is presented in Appendix I.

2.2 THE EXPERIMENTAL ANIMALS

The cattle used in this experiment, obtained from the Massey No. 2 Dairy Herd, were rising two year olds of Jersey or Jersey cross breeding. At the time of introduction to the feeding barn their mean live weights were 207±6 kg, and although gaining weight at this time, their condition prior to preparation for the experiment could be described as below average, several of the steers in particular having lost weight over the previous two months.

The cattle were fed maize silage to appetite for a two week period prior to their introduction to the feeding barn. During approximately seven days of this period they were held in concrete yards for 6 - 8 hours per day to harden their feet and prevent lameness when introduced to the feeding barn. All cattle were drenched for worms with Levamisole (Nilverm, I.C.I. (NZ) Limited) and were later treated for lice with Fenthion (Tiguvon, Bayer Corporation).

They were allocated to individual stalls at random in the feeding barn and each was restrained by a heavy leather collar which was attached by a short length of chain to a loop set in the concrete floor. The animals settled down immediately and were remarkably content throughout the duration of the experiment. Water was available at all times and feed was placed in removable bins, to which the animals had easy access.

Unfortunately two heifers, from separate identical twin sets, died of Leptospira haemorrhagica immediately prior to their introduction to the feeding barn, and their replacement resulted in a twin set being put in the all grass treatment of Trials 2 and 3. A steer also contracted the disease mid way through Trial 1 and although cured, much of the data collected during this trial applies only to the remaining five twin sets. This reduced the sensitivity of the statistical analysis of data from Trial 1.

2.3 FEEDS AND RATIONS USED IN THE EXPERIMENT

This section briefly describes the maize silage, grasses and mineral supplement fed during the experiment.

2.3.1 Maize silage

The maize used to produce the silage was of the late maturing PX610 variety, sown on 10 November 1971 at a 76 cm row spacing, with plant densities of 58 and 75000 plants/ha. Some higher densities, closer row spacings and a range of fertiliser treatments also existed as the maize was harvested from trial plots, however these were avoided in all but the coarse chop silage. Most harvesting was done on the 10th and 11th April 1972, and sampling four days previously revealed a DM of 27.7%, suggesting the early dent stage of

PLATE 2: Interior of the Feeding Barn

The feeding barn in which the experiment was conducted held sixteen cattle in individual stalls. The removable feed bins are in the foreground.

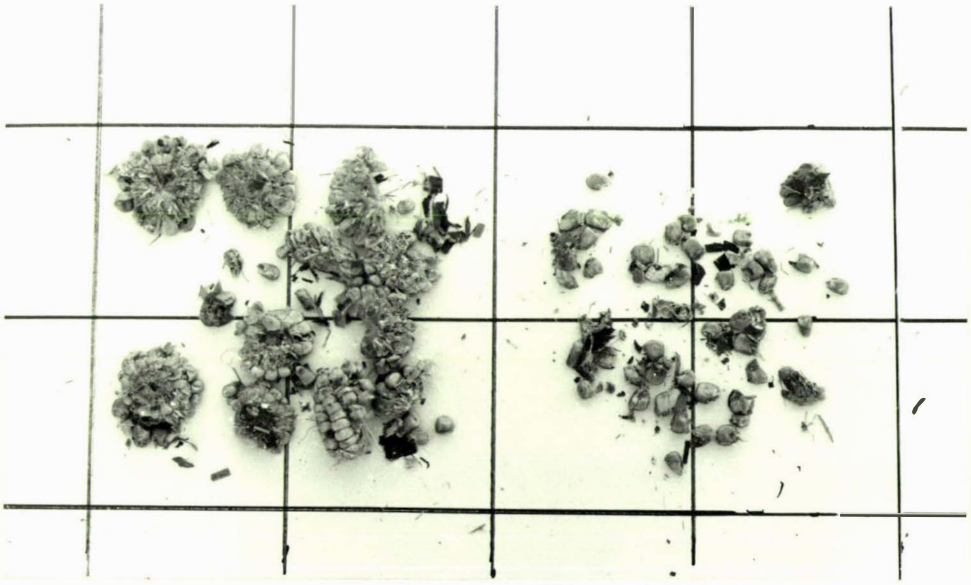

PLATE 3: The Coarse and Fine Chop Silage Kernels

In the coarse chop silage a large proportion of kernels were intact and attached in groups to pieces of cob, but fine chopping separated and mutilated most of the kernels.

maturity had been reached. Production data based on this sampling is presented in Appendix II.

Both fine and coarse chop silages were fed prior to Trial 1 but only the fine chop was fed during the interval between Trials 1 and 2. A shortage of fine chop silage (fed in Trial 2) necessitated the use of a medium chop in Trial 3.

The different degrees of chop, defined in terms of particle sizes, are given in Tables 3.7 a, b, and c and were obtained from the following harvesters:

Fine Chop - PZ Single Row Maize Harvester
Medium Chop - Kempler Maize Wolfe
Coarse Chop - New Holland 717 Precision Chop

The fine and medium chop silages were held in long narrow polythene covered bunkers which, apart from some surface deterioration, produced excellent quality silage that was well accepted by the cattle. The coarse chop silage was stored in deep concrete bunkers and was part of the dairy farm's winter feed reserve. The extent of preservation was similar for all silages, as indicated by their common pH of 3.7.

2.3.2 Grass

The mixed pasture (Trial 2) and the Tama ryegrass (Trial 3) was harvested daily, at approximately 8 a.m., with a tractor powered sickle bar mower.

2.3.3 Mineral Supplementation

The mineral deficiencies of maize silage (see Section 1.5.3) were countered by sprinkling steamed bone flour and trace mineralised salt on top of silage rations each day. The calculated requirements and quantities of supplement used are presented in Appendix III.

2.4 EXPERIMENTAL PROCEDURES

This section outlines the important factors in the day to day running of the experiment as well as describing techniques used for measurement and analyses. These include physical and chemical analysis of feeds, techniques involved in determination of voluntary intake, digestibility, kernel passage, mean retention time, nitrogen balance and live weight gains.

2.4.1 Physical Analysis of Feeds

Four days prior to harvest, six 1.5 meter row lengths of maize were sampled at random from that part of the crop used for production of the fine chop silage. The groups of plants were weighed, separated into components, reweighed, and dry matters of chopped samples of the whole plant and its constituents were determined by drying in a forced draft oven at 80°C for 48 hours (72 hours for whole cobs). The botanical composition of the mixed pasture was determined by random sampling of herbage from the paddock during Trial 2.

Throughout the experiment daily samples of all feeds were taken and bulked in 5 - 7 day composites, corresponding to the 'collection periods' within trials, and stored at -10°C. Sub samples were taken from these composites, freeze dried, ground through a 2 mm sieve in a Wiley mill and stored in air tight jars for chemical, mineral and energy determinations. Particle sizes of the chopped silages were determined by hand separation and by sieving of 800 g (approx) wet samples, after which the separated particles were dried in a forced draft oven for 48 hours at 75°C.

2.4.2 Chemical and Mineral Analyses of Feeds

A proximate analysis was performed on the dried and ground samples using standard methods (AOAC, 1965), and energy determinations were made with an Adiabatic Bomb Calorimeter. Calcium, sodium and phosphorus contents of the feeds were determined using atomic absorption spectroscopy (see Grace and Wilson, 1971).

2.4.3 Voluntary Intake

All animals were individually fed at approximately 8.30 a.m. and 4.00 p.m. daily with refusals being removed prior to the morning feeding. Sufficient feed was offered so that at least 10% was refused during all periods except Trial 1, when intakes were restricted. Any refusals were returned during Trial 1 and only in rare cases where there was a substantial refusal was it discarded. With the all silage and all grass treatments approximately half of the daily ration was given at each feeding, but with the 55% grass treatment the grass was fed at the morning feeding and the silage at the p.m. feeding, so that the mixing of feeds in the refusals was virtually eliminated. With the 20% grass treatment, the grass was offered at the commencement of the morning feeding programme and was eaten by the time the other animals were fed so that silage could be given without mixing the feeds.

All feeds and refusals were weighed to an accuracy of 0.25 kg (wet matter) with a spring balance. Feed dry matter determinations were made with duplicate samples of silage (approx 200 g wet weight) and of grass (approx 100 g wet weight), dried in a forced draft oven at 75°C for 24 hours. Refusals were treated in a similar manner except that only one sample per animal per day was taken.

2.4.4 Digestibility Determinations

The apparent digestibilities of rations were calculated with the aid of a chromic oxide marker, which enabled faecal output to be estimated. The technique involved daily administration (8.00 a.m.) of a capsule containing 10 g of Cr_2O_3, which was released in the animal's throat with the aid of a balling gun. Dosing was initiated 10 days before faecal collections commenced, and in estimating digestibilities a two day lag was assumed between ingestion of rations and the recovery of the faeces. Representative daily faecal samples (approx 400 g wet weight) were composed of several small samples in an effort to minimise the effects of diurnal variation, however the extent of diurnal variation was measured during Trial 1. Faecal samples were bulked over 5 - 7 day 'collection periods' within each of the trial periods. The bulked samples were stored at -10°C prior to subsampling and oven drying at 75°C for 96 hours, after which they were ground through a 2 mm sieve in a Wiley mill (care being taken to avoid loss of chromic oxide dust) and stored in air tight jars for analysis. The chromium contents of the faeces were determined by the method of Williams _et al_, 1962, using the atomic absorption spectrophotometer, and the digestibilities were calculated in terms of DM and OM.

Because some difficulties were experienced both in the administration of chromic oxide pellets (some animals were able to regurgitate them, with a consequent loss of contents) and in the method of analyses, an attempt was made to establish the accuracy with which the marker determined faecal output. The six steers were bagged for total collection in Trial 2, and digestibilities by both techniques were compared.

2.4.5 Passage of Undigested Corn Kernels

Some workers have recorded appreciable quantities of undigested grain in the faeces of cattle fed maize silage as part of their diet, so it was decided to investigate these losses, as affected by fineness of chop, in Trial 1. The faeces from each of the twelve animals fed the silage diets were collected over a 24 hour period. These were diluted with voluminous quantities of water and the suspended matter decanted off and passed through a 2 mm sieve which retained small particles of grain. The small particles and the residue of whole grains were combined and dried in a forced draft oven at 75°C for 48 hours, but in view of the negligible grain losses (see Section 3.3) the process was repeated only once.

2.4.6 Rate of Passage of Silages

The rate of passage of the fine and coarse chop silages fed to the twelve animals in Trial 1 were measured using a manganese marker. Mean retention times of the manganese treated portions of the ration were calculated in accordance with the method of Castle (1956).

This method, dependent upon a low and constant level of manganese in the plant material, required each silage to be steeped in a 2% w/v solution of potassium permanganate for 30 minutes (the manganese ions complex with lignin) after which they were washed copiously and dried to approximately 20% DM (hopefully to increase palatability). The treated samples were offered at approximately 4% of daily intake, food having being removed 12 hours previously, and normal feeding resumed thereafter. Faecal samples (approx 200 g wet weight) were taken from each animal at the following time intervals (hours after feeding treated silage): 0, 12, 24, 28, 32, 36, 42, 48, 52, 56, 61, 72, 84, 96, 104, 120, 144, 168. The samples were stored at -10°C, then dried in a forced draft oven at 75°C for four days, ground through a 2 mm sieve (Wiley Mill) and stored in air tight jars for analysis. Chemical analysis involved ashing a 1 g subsample, which was then dissolved in 2 N hydrochloric acid and digested in a water bath for 15 minutes prior to being made up to 100 ml and the manganese concentration determined with the atomic absorption spectrophotometer.

A cumulative percentage of the total manganese output over the 7 day collection period was calculated and the results expressed graphically.

2.4.7 Nitrogen and Energy Balances

Nitrogen and energy balance studies were carried out in Trial 2 with the 6 steers (on the all silage, 20% grass and 55% grass treatments) in conjunction with bagged digestibility determinations. Each animal was harnessed with standard faecal collection apparatus and the urine funnels were those designed and described by Smith (1973).

Faeces were collected daily at 8.30 a.m., weighed to ±0.010 kg (wet weight), stirred thoroughly, and sampled for dry matter determination. Samples were also taken for chromium, nitrogen and energy determinations. These were bulked and stored at -10°C for analysis.

The urine was maintained at a pH of 2 or below by the addition of sulphuric acid, and 1% of the daily output was retained for bulking and storage at -10°C. Liquid urine samples (5 ml) were used for nitrogen determinations, whilst 20 ml samples were freeze dried for energy determinations. Faeces used in all analyses were oven dried and ground as described in Section 2.4.4.

Nitrogen determinations were undertaken using the Kjeldahl method (AOAC 1965), and nitrogen balances were determined for individual animals. Energy determinations were made with the Adiabatic Bomb Calorimeter, enabling calculations of digestible energy and metabolisable energy to be made for each treatment.

2.4.8 Daily Live Weight Gain

Because of the short duration of this experiment and the changing of rations between trials, which may have led to large errors in body weight measurements, live weight gain has not been credited with much importance in this experiment. Nevertheless several weighings were made with respect to Trials 2 and 3, each after a 16 hour starve in order to reduce the influence of variations in gut fill. Weighings were made on Avery scales accurate to 0.25 kg.

2.5 STATISTICAL ANALYSIS

The analysis of variance technique was used to determine significance levels associated with treatment comparisons. All comparisons arising from Trial 1 were analysed with a completely randomised block design (CRBD). The majority of comparisons in Trials 2 and 3 yielded lowest significance levels when a balanced incomplete block design (BIB) was used, although some comparisons necessitated use of a completely randomised design (CRD).

Where possible actual probability percentages, corresponding to the calculated 'student t' values derived by computer, are presented in the results in preference to standard significance levels. Only when the probabilities were greater than 0.20 were the comparisons considered non significant (NS).

2.5.1 Analysis of Trial 1

The analysis of the mean retention time, dry matter, and organic matter digestibility data are based on a completely randomised block design. One of the block x treatment interaction degrees of freedom is due to a sex x treatment interaction, which has been removed from the error, so the models are:

Ha : $Y_{ij} = u + b_i + t_j + (bt)_{sj} + e_{ij}$

Ho : $Y_{ij} = u + b_i + (bt)_{sj} + e_{ij}$

where: u = a general mean

b_i = effect of the i th block $i = 1 - 6$

t_j = effect of the j th treatment $j = 1,2$

$(bt)_{sj}$ is the sex x treatment interaction

e_{ij} = the residual error which is assumed to have zero mean and constant variance.

In the analysis of dry matter and organic matter digestibility data the results from one twin pair were ignored due to sickness, in which case b_i becomes the effect of the i th block, where $i = 1 - 5$.

AOV tables for each parameter are presented in Appendix IV.

2.5.2 Analyses of Trials 2 and 3

Analyses of Trials 2 and 3 were carried out in two parts.

(a) Comparisons among three treatments (all silage, 20% grass, 55% grass) were in the context of a balanced incomplete block (BIB) design (Kempthorne, 1962; Townsley, pers. comm.).

(b) Comparison of the all grass treatment (and the others in part (a)) with the all silage treatment was in the context of a completely randomised design (CRD).

Analysis of the BIB design involves combination of intra and inter block information. However, two steps were taken before combining the intra and inter block analyses.

(a) Sex x treatment interactions for each variable of interest were investigated by intra block analysis. This was necessary since the presence of sex x treatment interactions would affect the interpretation of the error mean square (EMS) in the inter block analysis (Townsley, pers. comm.). In no case was sex x treatment interaction significant and as a result these effects have been ignored in the analyses (sex x treatment interaction terms have been included in the error).

(b) Following Kempthorne (1962): Where the block mean square (BMS) was less than the EMS in the intra block analysis, the data was analysed in the context of a completely randomised design (CRD) with two replicates (sex). Where BMS was greater than EMS, both intra and inter block analyses were performed and the information combined, using the technique demonstrated in Appendix V.

The complex nature of the BIB analysis, particularly the adjustments required when BMS is greater than EMS, makes it difficult to present useful AOV data in tabular form. Furthermore, the computer presentation of data relating to the CRD would have little meaning if expressed in tabular form. Because of this, it was decided not to include AOV data relating to analysis of Trials 2 and 3 in the appendices, save for the method of combining intra and inter block analysis in the BIB design (Appendix V). However, the writer has lodged the original data with the Dairy Husbandry Department, Massey University.

CHAPTER THREE

RESULTS

The results presented in this section follow, as closely as possible, the chronological order in which the experiments were performed. A 'diary of events', which also summarises much of the material given in Chapter Two, is given in Appendix I.

An abbreviated nomenclature has been adopted in this section, and is used in Chapter Four, so that the all silage, 20% grass, 55% grass and all grass treatments are termed t_1, t_2, t_3 and t_4 respectively.

3.1 FEED AND RATION COMPOSITIONS

The actual proportions of feeds eaten in each treatment during the three trials are presented in Table 3.1. The ratios of grass to silage closely approximated those aimed for, which, along with the small standard deviations, reflected the precision with which the rations were controlled.

Table 3.1: Feed components of rations during trial periods (standard deviations include animal and day variations).

Trial	Treatment	Component Feeds as Percentages of Rations (DM Basis)		
		Maize Silage	Grass	Mineral Supplement
1	All Silage	98.80 ± 0.05		1.20 ± 0.05
2	All Silage (t_1)	98.80 ± 0.05		1.20 ± 0.05
	20% Grass (t_2)	77.52 ± 0.55	21.48 ± 0.55	1.00 ± 0.05
	55% Grass (t_3)	44.26 ± 0.84	55.24 ± 0.84	0.50 ± 0.05
	All Grass (t_4)	100.00		
3	All Silage (t_1)	98.90 ± 0.05		1.10 ± 0.05
	20% Grass (t_2)	78.22 ± 0.40	20.78 ± 0.40	1.00 ± 0.05
	55% Grass (t_3)	44.36 ± 0.61	55.14 ± 0.61	0.50 ± 0.05
	All Grass (t_4)	100.00		

The feeding of rations in treatment 2 required the grass to be restricted and the silage fed ad libitum, however with treatment 3 all but one animal showed a preference for silage, which was therefore restricted and the grass fed ad libitum. Overall preferences for either feed in treatment three appeared to be slight, so that intakes are unlikely to have been restricted through the controlling of the feed ratios.

The complete data relating to the yield of the maize crop prior to ensiling (19,500 kg DM/ha) are given in Appendix II. The proportions of the various components in the DM of the maize are summarised in Table 3.2.

Table 3.2: Physical composition of maize plants determined four days prior to ensiling (DM basis).

Component	Percentage Composition
Leaves and Sheaths	18.5 ± 1.3
Stem	22.6 ± 1.9
Grain	37.2 ± 1.4
Cob (rachis)	12.3 ± 0.4 } Ear = 58.9
Husks	9.4 ± 1.7

These data strictly apply only to the maize used for fine chop silage fed during Trial 1, and while proximate analyses of silages (in Table 3.4) suggest the others to be less mature, the differences are probably small, representing only a 1 - 2 percentage unit reduction in grain content of the less mature silages. These variations may be due to the range of planting densities and fettiliser treatments from which the coarse and medium chop silages were harvested.

The botanical composition of the pastures used in Trials 2 and 3 is given in Table 3.3.

Table 3.3: Botanical analysis of grasses fed during Trials 2 and 3.

Trial	Grass Variety	Percentage Composition (DM Basis)		
		Grass	Clover	Weeds
2	Mixed Pasture	74.3	17.0	8.7
3	Tama	99.0		1.0

The weeds in Trial 2 were primarily docks, thistles and plantains, whilst those in Trial 3 were primarily stinging nettle, derived from the paddock perimeter.

The basis for the amounts of mineral supplement provided is given in Appendix III. Bone flour and rock salt were used, as calcium and sodium were shown to be deficient in maize silage.

3.2 CHEMICAL ANALYSES OF FEEDS AND RATIONS

The proximate analyses, mineral contents and energy contents of the feeds and the rations used in the three trials are presented in Tables 3.4, 3.5 and 3.6. The ash content of the mixed pasture fed during Trial 2 was much higher than expected (19.04% of DM). However, subsequent chemical analysis (dissolving and digesting the sample in 2NHCl, and filtering to leave the soil residue) indicated that 9% of the DM was soil derived, which accounted for the high ash percentages in this feed. Contamination of the mixed pasture occurred because of the very wet soil conditions during its harvest, however the Tama was not soiled.

Table 3.4: Proximate analysis of feeds (DM basis).

Type of Feed	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fibre %	NFE %	Ash %	Gross Energy Kcal/kg
Coarse Chop Silage	24.7 ± 0.4	8.98	6.76	23.79	55.25	6.02	4413
Fine (Trial 1) Chop	27.6 ± 0.3	9.10	5.62	16.07	64.91	4.30	4426
Silage (Trial 2)	24.5 ± 0.4	9.13	5.80	22.59	57.50	4.98	4455
Medium Chop Silage (Trial 3)	24.3 ± 0.3	9.03	6.01	24.09	55.39	5.48	4361
Grass (Trial 2)	16.3 ± 0.4	18.23	5.58	18.10	39.05	19.04	4007
Tama (Trial 3) Ryegrass	9.9 ± 0.8	25.80	7.75	16.13	39.65	10.85	4345
Mineral Supplement	95.0 ± 0.1	18.40				81.60	

Table 3.5: Calcium, sodium and phosphorus contents of feeds.

Feed	Percentage of Component (DM basis)		
	Calcium	Sodium	Phosphorus
Coarse Silage	0.29	0.06	0.31
Fine Silage	0.26	0.05	0.26
Grass (Trial 2)	0.45	0.33	0.45
Tama (Trial 3)	0.49	0.51	0.50

Table 3.6: Proximate analysis of rations in trial periods (DM basis).

Trial	Treatment	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fibre %	NFE %	Ash %	Gross Energy Kcal/kg
1	Coarse Silage	25.5	9.09	6.68	23.50	53.81	6.92	4360
	Fine Silage	28.5	9.20	5.55	15.87	64.16	5.22	4372
2	All Silage	25.3	9.24	5.73	22.32	56.81	5.90	4401
	20% Grass	23.4	11.22	5.68	21.39	53.96	8.76	4314
	55% Grass	20.3	14.57	5.64	20.00	47.02	13.15	4193
	All Grass	16.3	18.23	5.58	18.10	39.05	19.04	4007
3	All Silage	25.1	9.14	5.93	23.80	55.61	5.49	4309
	20% Grass	22.0	12.60	6.31	22.19	52.27	6.64	4314
	55% Grass	16.7	18.32	6.93	19.57	46.73	8.46	4330
	All Grass	9.9	25.80	7.75	16.13	39.65	10.85	4345

3.3 PARTICLE SIZE, RATE OF PASSAGE, KERNEL PASSAGE AND DIURNAL CHROMIUM VARIATION OF SILAGES IN TRIAL 1

Two techniques were used to describe the coarse and fine chop silages (on a wet basis) in terms of particle size. The first system (hand separation of particles), (Table 3.7a), enabled cob and grain components to be separated from the remainder, and enabled an accurate assessment of the long narrow particles to be made as these were able to pass through relatively small sieve apertures.

The method most often used to define particle size involves sieving, and results using this technique are given in Table 3.7b. Mean particle lengths determined by this technique for the fine, medium and coarse chop silages were 0.93, 1.16, and 1.48 cm respectively. The fine chop silage was therefore similar to typical silage fed in the U.S.A. (see Section 1.4.6).

Table 3.7a: Percentages of grain, cob and forage particles hand separated into stated lengths (DM basis).

Particle Length (or component)	Percentage of sample, by weight		
	Fine Chop	Medium Chop	Coarse Chop
Over 10 cm	0.8	2.7	3.5
4 - 10 cm	4.7	5.0	8.9
2 - 4 cm	7.1	10.2	13.4
Under 2 cm	65.2	57.3	50.8
Grain	14.5	16.7	13.9
Cob	7.7	8.1	9.5

Table 3.7b: Percentages of the stated particle sizes determined by sieving entire silage samples (DM basis).

Particle Length	Fine Chop	Medium Chop	Coarse Chop
Over 1 cm	21.5	30.2	46.1
0.5 - 1 cm	33.8	34.7	29.7
Under 0.5 cm	44.7	35.1	24.2

Because of the inaccuracies in Tables 3.7a and 3.7b, resulting from difficulties in hand separation of small particles and because long narrow particles were able to pass through small sieve apertures, the data has been combined and is presented in Table 3.7c. This involved the incorporation of data relating to particles over 2 cm in length, from Table 3.7a, into Table 3.7b in place of the data relating to the proportions of particles over 1 cm in length. The grain and cob fractions (Table 3.7a) were assumed to be less than 1 cm in length (most passed through a 1 cm sieve), so the proportions of particles over 2 cm in length were adjusted accordingly, prior to their incorporation. Hence Table 3.7c contains a wider range of particle sizes

wording

($<$0.5 cm to $>$10 cm) than any of the previous tables. According to this method, the mean particle lengths of the fine, medium and coarse chop silages were 1.24, 1.47 and 2.20 cm respectively.

Table 3.7c: A combined estimate of particle size based on data in Tables 3.7a and 3.7b.

Particle Length (cm)	Fine Chop	Medium Chop	Coarse Chop
Over 10	1.0	3.6	4.6
4 - 10	6.1	6.6	11.6
2 - 4	9.1	13.6	17.5
1 - 2	5.3	6.4	12.4
0.5 - 1	33.8	34.7	29.7
Under 0.5	44.7	35.1	24.2
Mean Length (cm)	1.24	1.47	2.20

The rate of passage data for the fine and coarse chop silages are presented in Table 3.8 and Fig 3.1. The mean retention times, based on measurements from twelve animals (6 per treatment), involved 18 faecal collections over a seven day period. Statistical analysis of the mean retention times from individual cows was performed using the model presented in Section 2.5.1, but as the F value was greater when block effects were ignored, these were omitted from the analyses (see Appendix IV). The mean retention times for the fine chop silage (44.6 hours) were significantly shorter ($P<0.05$) than those for the coarse chop silage (49.0 hours).

Only very small amounts of kernel were recovered from the faeces of cattle in Trial 1, and the amounts recovered were not related to the fineness of chop of the silages. Nearly all the kernel particles consisted of pericarp, without the internal contents, so that intact kernels were quite rare. Reasons for this negligible loss are discussed in Section 4.2.3.

The diurnal variation in faecal chromium concentration measured during Trial 1 (fineness of chop effects were ignored) are presented graphically in Fig 3.2. Standard deviations, indicated by the vertical lines, are derived from the values for individual animals. The magnitude of the diurnal variation demonstrates a need for representative faecal samplings in digestibility determinations.

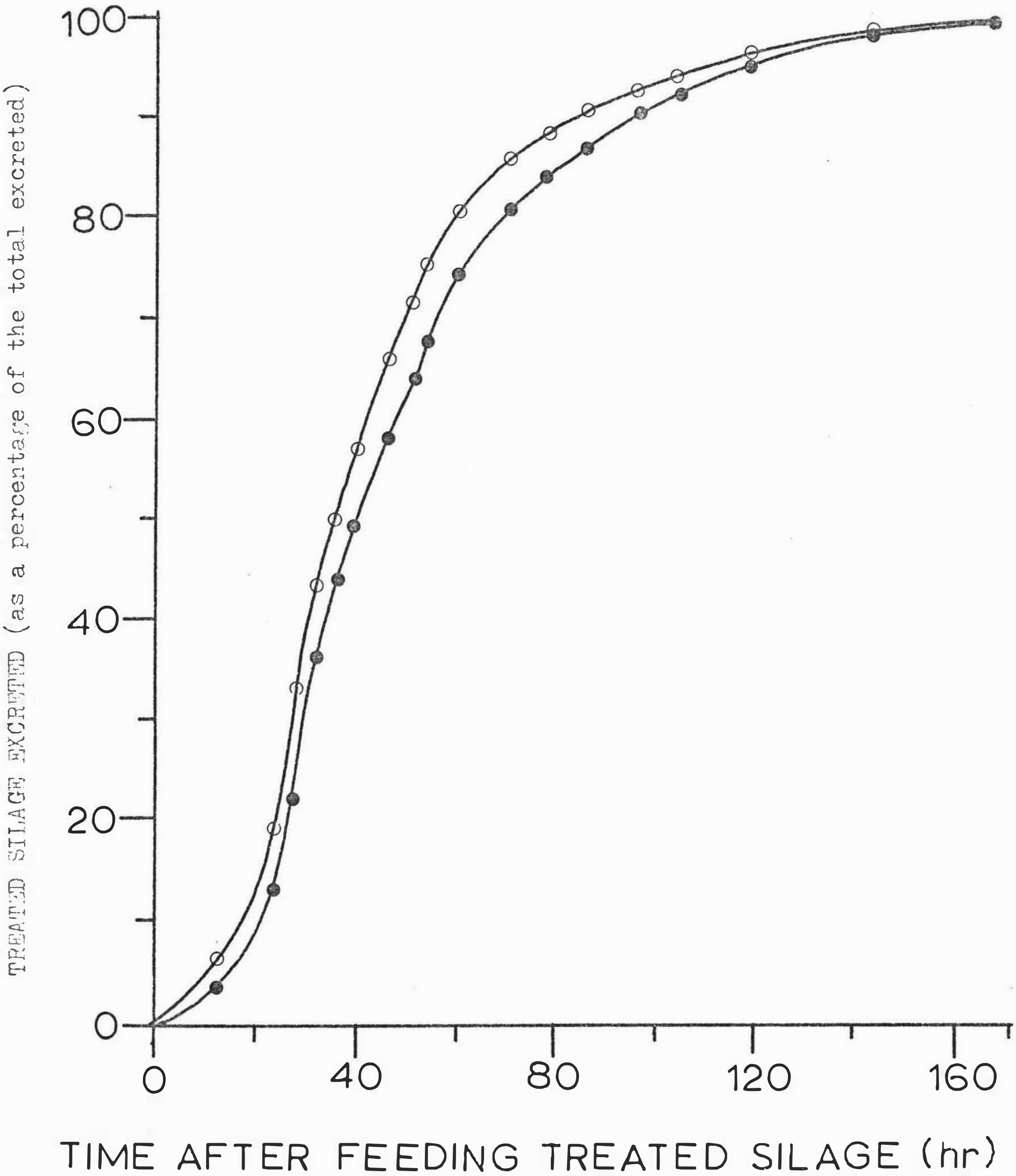

FIGURE 3.1: Mean values for the excretion of undigested treated silage residues at intervals after feeding the fine and coarse chopped silages.

● Coarse chop silage ○ Fine chop silage

Table 3.8: Mean retention times for fine and coarse chop silages and the time intervals, after initial feeding, at which stated percentages of the recovered silage had passed through the animals.

Percentage of 7 day total	Post Feeding Interval (hours)	
	Coarse Chop	Fine Chop
5	16	14
15	24	23
25	28	27
35	32	30
45	38	34
55	45	40
65	52	47
75	63	56
85	79	70
95	113	105
TOTAL	490	446
Mean Retention Time (hours)	49.0 ± 1.5	44.6 ± 0.7

3.4 DIGESTIBILITY OF RATIONS

The dry matter and organic matter digestibility data, and the probability percentages for statistical comparisons between treatments are given in Table 3.9. Intakes were restricted in Trial 1, but rations were fed ad libitum in Trials 2 and 3.

During Trial 1 dry matter digestibility of the coarse chop silage (65.1%) was slightly, but non significantly, greater than that of the fine chop silage, (62.7%), and the digestibility of the all silage rations declined over the duration of the experiment, particularly in Trial 3 (54.4%). During Trials 2 and 3, increased proportions of grass in the rations resulted in progressive increases in digestibilities. Because of soil contamination of the mixed pasture fed in Trial 2, OM digestibilities provide a better measure than DM digestibilities for comparisons between treatments in this trial. The OM digestibilities in Trial 2 for t_1, t_2, t_3 and t_4 were 63.6%, 68.0%, 73.0% and 80.4% respectively, however only comparisons between t_1 and treatments 3 and 4 were statistically significant ($P < 0.006$ and $P < 0.000$ respectively).

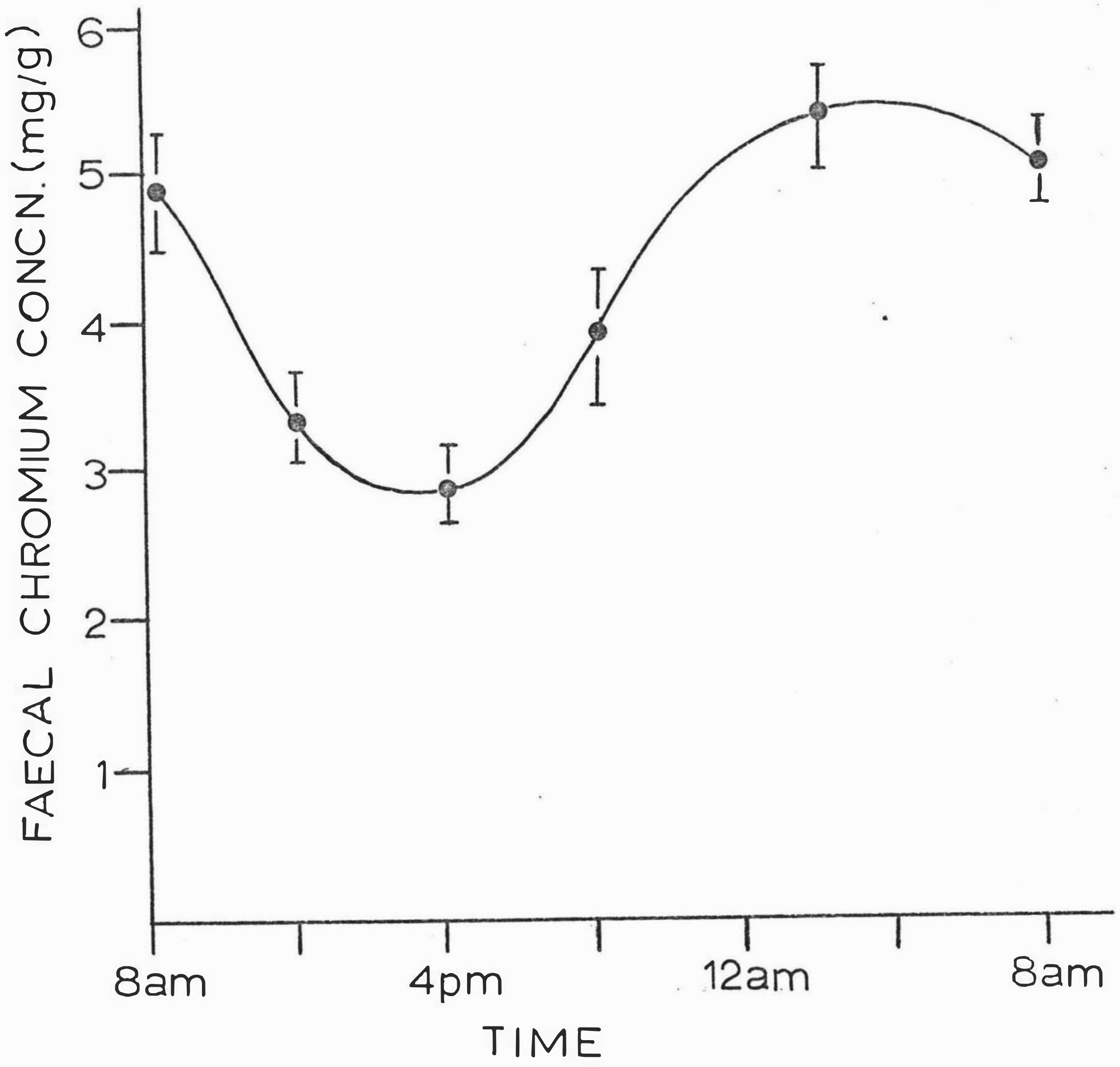

FIGURE 3.2: Diurnal variation of faecal chromium concentration in cattle fed an all silage diet.

● Sampling times

Table 3.9: Mean dry matter and organic matter digestibilities of the rations, and probability percentages relating to treatment comparisons.

Trial	Treatment	Digestibility (%)	
		Dry Matter	Organic Matter
1	Fine Silage Coarse Silage	62.7 ± 1.4 65.1 ± 1.3	65.4 ± 1.5 67.9 ± 1.2
2	All Silage t_1 20% Grass t_2 55% Grass t_3 All Grass t_4	61.2 ± 3.6 63.4 ± 0.6 65.2 ± 1.5 65.5 ± 1.7	63.6 ± 4.0 68.0 ± 0.5 73.0 ± 1.2 80.4 ± 1.0
3	All Silage t_1 20% Grass t_2 55% Grass t_3 All Grass t_4	54.4 ± 3.9 64.2 ± 1.2 66.2 ± 1.8 74.4 ± 1.7	57.2 ± 3.8 68.7 ± 1.2 72.8 ± 1.7 83.2 ± 1.4

Trial	Treatment	Probability Percentages for Comparisons of the above Parameters	
1	Fine - Coarse Silage	NS	NS
2	$t_2 - t_1$ $t_3 - t_1$ $t_4 - t_1$ $t_3 - t_2$	*47.906 *21.606 *18.068 NS	*18.799 *0.618 *0.005 20.0
3	$t_2 - t_1$ $t_3 - t_1$ $t_4 - t_1$ $t_3 - t_2$	0.5 0.1 *0.006 10.0	0.1 *0.040 *0.000 NS

* Probability percentages derived from completely randomised design.

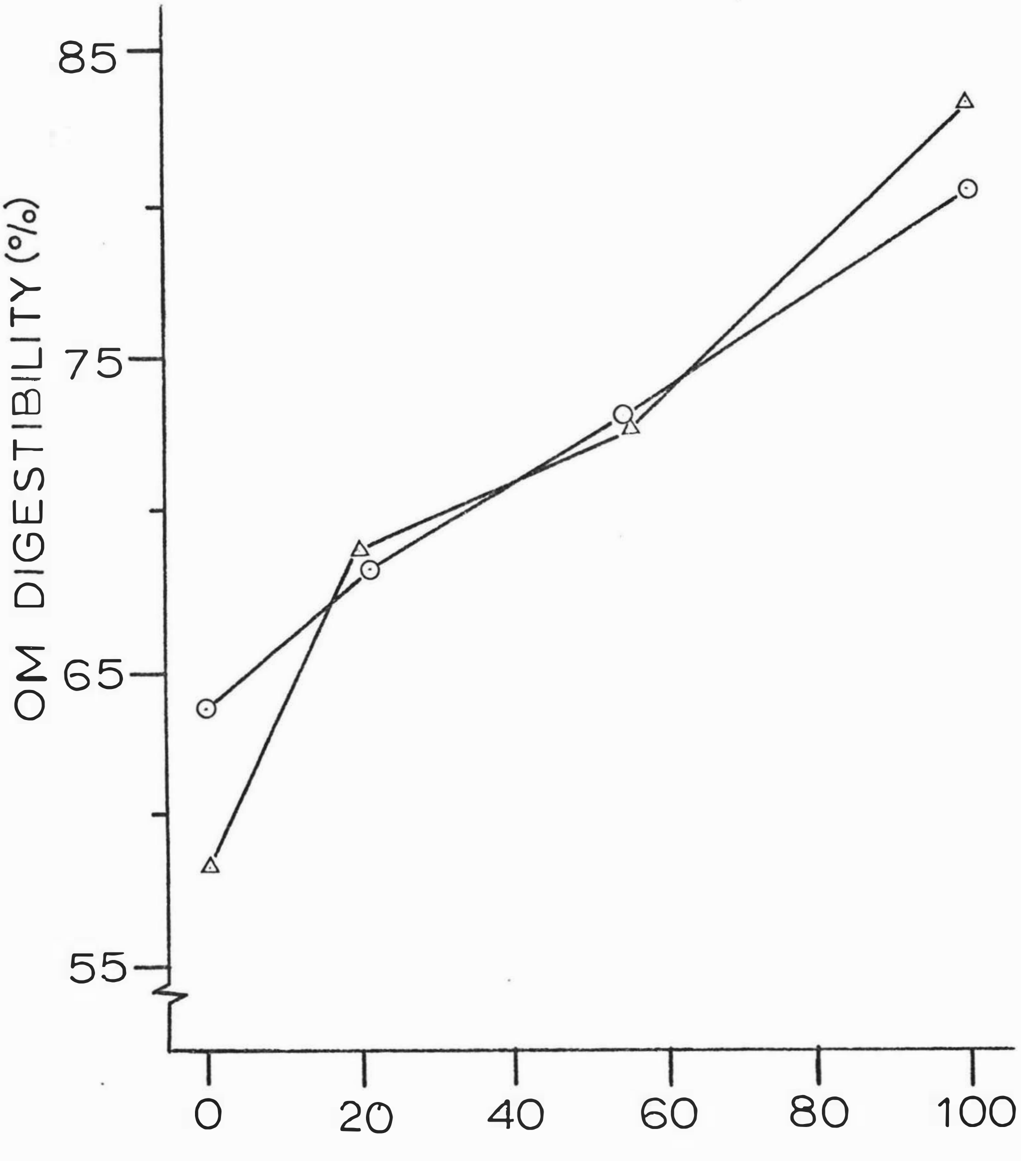

FIGURE 3.3: Grass content and organic matter digestibility of rations fed during trials two and three.

○ Trial Two △ Trial Three

Similar digestibilities were obtained for treatments containing grass in Trial 3, although Tama fed alone had a higher OM digestibility (83.2%) than that of the mixed pasture (80.4%). Comparisons between t_1 and treatments 2, 3 and 4 were highly significant in this trial ($P < 0.001$ (t_2), $P < 0.000$ (t_3 and t_4)), however the comparison between t_3 and t_2 was again non significant.

Organic matter digestibility was positively related to the grass content of the rations (Fig 3.3).

3.5 VOLUNTARY INTAKES

Voluntary intake data and probability percentages relating to treatment comparisons are presented in Tables 3.10, 3.11 and 3.12. Intakes are expressed in several different forms, as an aid to their interpretation and to enable easy comparison of findings with results of other workers. Intakes during Trial 1 were restricted and do not require statistical analysis, so they are presented separately in Table 3.10. Digestible DM intakes are presented in Table 3.13, and form an important basis for ration evaluation in Chapter Four.

Table 3.10: Mean daily intakes of silages fed at restricted levels during Trial 1, and for a 3 day period following this, when fine chop silage was offered ad libitum.

Treatment	Restricted Intake Period			
	DMI kg/day	DMI % $BW^{1.0}$	OMI kg/day	DMI g/kg $BW^{.75}$
Coarse Silage	4.56	1.94	4.20	76.0
Fine Silage	4.69	2.14	4.50	81.0
	Ad Libitum Intake Period			
	DMI kg/day	DMI % $BW^{1.0}$	OMI kg/day	DMI g/kg $BW^{.75}$
Previously on Coarse Silage	5.50	2.31	5.22	90.8
Previously on Fine Silage	5.30	2.32	5.08	90.4

The data in Table 3.10 indicates a lower DM intake of the animals fed coarse chop silage (76.0 g/kg $BW^{.75}$) in Trial 1, than those fed the fine chop silage (81.0 g/kg $BW^{.75}$), however when fed fine chop ad libitum, both groups had very similar intakes (approximately 90.6 g/kg BW$^{.75}$). These unexpected differences become of major importance during the discussion of particle size effects in Section 4.2.

Data from Tables 3.11 and 3.12 show that during Trial 2 the DM intakes of the all silage ration (84.3 g/kg BW$^{.75}$) were lower than those of treatments 2, 3 and 4 (102.1, 108.8, and 101.6 g/kg BW$^{.75}$ respectively).

Table 3.11: Mean daily dry matter intakes of cattle for the treatments in Trials 2 and 3 and the probability percentages relating to treatment comparisons.

Trial	Treatment	DM of Ration %	Dry Matter Intakes		
			kg/day	% BW$^{1.0}$	g/kg BW$^{.75}$
2	All Silage	25.3	5.11 ± 0.15	2.14 ± 0.06	84.3 ± 2.5
	20% Grass	23.4	6.09 ± 0.43	2.62 ± 0.01	102.1 ± 4.0
	55% Grass	20.3	6.68 ± 0.65	2.76 ± 0.11	108.8 ± 5.7
	All Grass	16.3	6.02 ± 0.27	2.61 ± 0.12	101.6 ± 4.7
3	All Silage	25.1	5.94 ± 0.15	2.42 ± 0.06	95.9 ± 2.3
	20% Grass	22.0	6.54 ± 0.42	2.72 ± 0.15	107.0 ± 5.6
	55% Grass	16.7	7.77 ± 0.90	3.07 ± 0.17	122.3 ± 8.5
	All Grass	9.9	5.24 ± 0.44	2.28 ± 0.19	88.9 ± 7.4
Trial	Treatment Comparisons		Probability Percentages for Comparisons of the above Parameters		
2	$t_2 - t_1$		1.0	0.002	0.1
	$t_3 - t_1$		0.5	0.000	0.1
	$t_4 - t_1$		*14.882	*0.649	*1.623
	$t_3 - t_2$		20.0	5.0	10.0
3	$t_2 - t_1$		NS	2.387	4.23
	$t_3 - t_1$		1.0	0.031	0.042
	$t_4 - t_1$		*38.54	*53.090	*45.048
	$t_3 - t_2$		5.0	2.5	1.0

* Probability percentages derived from a completely randomised design.

Table 3.12: Mean daily intakes of wet matter and organic matter of cattle for the treatments in Trials 2 and 3, and the probability percentages relating to treatment comparisons.

Trial	Treatment	Wet Matter Intake g/kg $BW^{.75}$	OMI kg/day	OMI g/kg $BW^{.75}$
2	All Silage	336 ± 10	4.89 ± 0.15	80.7 ± 2.4
	20% Grass	464 ± 17	5.68 ± 0.40	95.3 ± 3.9
	55% Grass	566 ± 33	5.87 ± 0.62	95.5 ± 5.7
	All Grass	625 ± 26	4.87 ± 0.24	82.2 ± 4.6
3	All Silage	392 ± 9	5.66 ± 0.15	91.5 ± 2.2
	20% Grass	556 ± 28	6.15 ± 0.39	100.7 ± 5.2
	55% Grass	866 ± 56	7.14 ± 0.83	112.4 ± 7.8
	All Grass	831 ± 66	4.67 ± 0.40	79.2 ± 6.6
Trial	**Treatment Comparisons**	**Probability Percentages for Comparisons of the above Parameters**		
2	$t_2 - t_1$	0.019	2.5	0.5
	$t_3 - t_1$	0.000	2.5	0.5
	$t_4 - t_1$	*0.000	*NS	*NS
	$t_3 - t_2$	0.1	NS	NS
3	$t_2 - t_1$	0.129	NS	6.11
	$t_3 - t_1$	0.000	5.0	0.112
	$t_4 - t_1$	*0.002	*18.840	*16.440
	$t_3 - t_2$	0.1	20.0	2.5

* Probability percentages derived from a completely randomised design.

The comparisons between t_1 and the other treatments were highly significant ($P<0.001$ (t_2, t_3); $P<0.002$ (t_4)). The OM intakes of t_2 and t_3 were similar in this trial (95.3 and 95.5 g/kg $BW^{.75}$ respectively) and significantly greater ($P<0.005$) than that of the all silage ration (80.7 g/kg $BW^{.75}$). The OM intake of t_4 was similar to that of t_1. During Trial 3 the DM and OM intakes of all rations, except t_4, were higher than their counterparts in Trial 2. The DM intake of t_1 (95.9 g/kg $BW^{.75}$) was again lower than those of t_2 and t_3 (107.0 and 122.3 g/kg $BW^{.75}$ respectively) and the intake of Tama fed alone (88.9 g/kg $BW^{.75}$) was lower than that of the all silage ration.

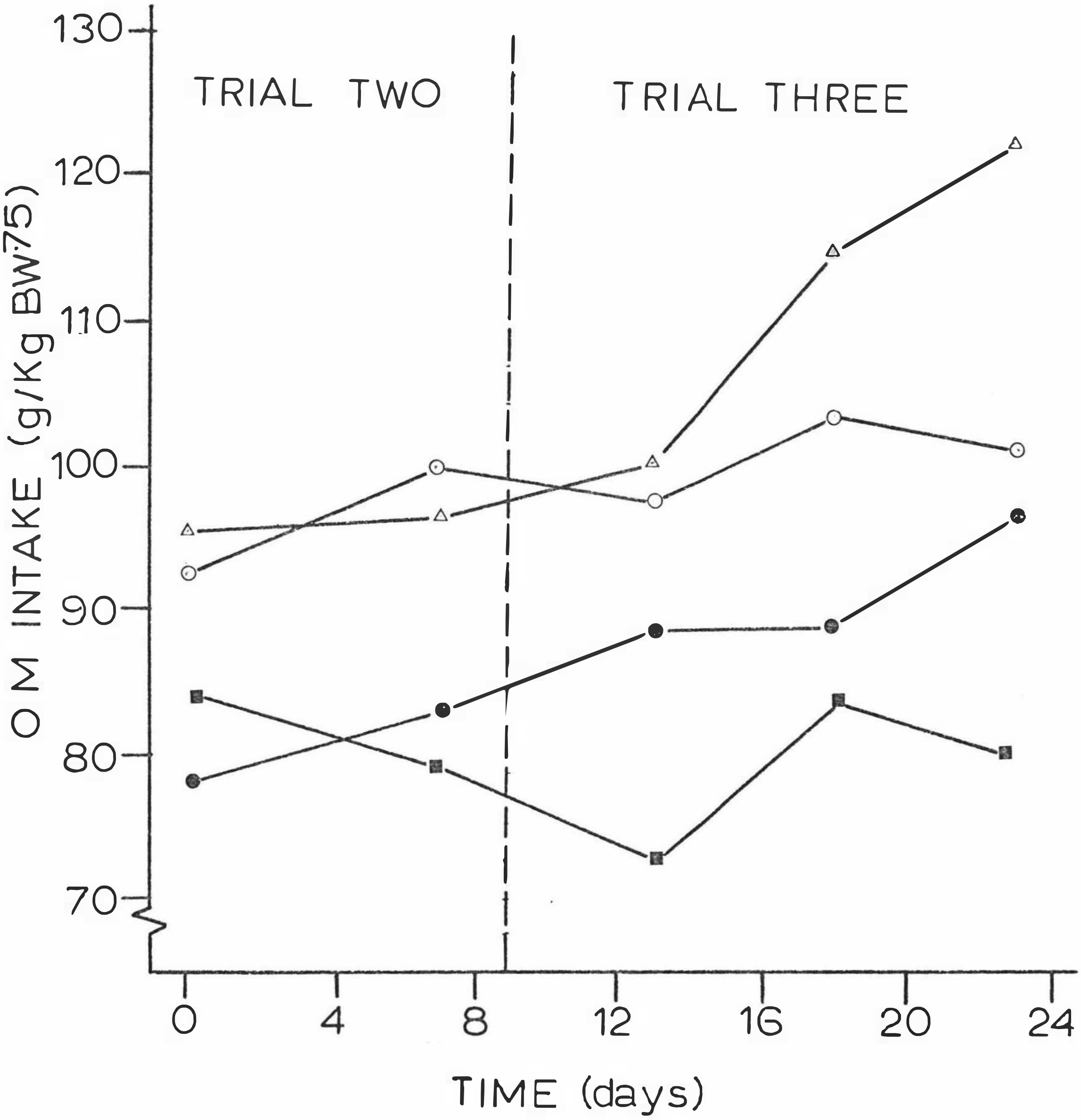

FIGURE 3.4: Mean daily OM intakes of treatments for each collection period during trials two and three.

● All silage ○ 20% grass △ 55% grass ■ All Grass

Comparisons between t_1 and treatments 2 and 3 were again significant ($P<0.05$ (t_2), and $P<0.000$ (t_3)), but the comparison between t_1 and t_4 was non significant Comparisons between intakes of treatments 2 and 3 were more significant in Trial 3 ($P<0.025$) than in Trial 2 ($P<0.10$).

Table 3.13: Mean daily digestible dry matter intakes (Dig DMI), expressed as g/kg $BW^{.75}$, for cattle in Trials 2 and 3, and the probability percentages relating to treatment comparisons.

Treatment	Trial 2	Trial 3
All Silage (t_1)	51.50 ± 3.23	51.89 ± 2.73
20% Grass (t_2)	64.81 ± 3.14	68.49 ± 2.46
55% Grass (t_3)	70.83 ± 3.50	80.69 ± 4.52
All Grass (t_4)	66.56 ± 3.39	66.54 ± 5.68
Treatment Comparisons	**Probability Percentages for Comparisons of the above Parameters**	
t_2 - t_1	0.095	1.00
t_3 - t_1	0.007	*0.030
t_4 - t_1	*0.750	*2.574
t_3 - t_2	10.00	2.5

* Probability percentages derived from a completely randomised design.

Table 3.13 is derived from the DM digestibilities presented in Table 3.9 and the DM intakes (g/kg $BW^{.75}$) presented in Table 3.11. These data, applying to Trials 2 and 3, represent the intake of digestible nutrients of the cattle, and form an important part of the evaluation of the rations (see Section 4.4). The Dig DM intakes of the all silage rations were similar in both trials (approximately 51.7 g/kg $BW^{.75}$) as were intakes of the all grass rations (66.5 g/kg $BW^{.75}$). Comparisons between the all silage and all grass treatments were significant at the $P<0.025$ level in Trial 2 and the $P<0.008$ level in Trial 3. Intakes of t_2 in Trials 2 and 3 were 66.81 and 68.49 g/kg $BW^{.75}$ respectively, and values for t_3, in Trials 2 and 3, were 70.83 and 80.69 g/kg $BW^{.75}$ respectively. All comparisons with t_1 were highly significant ($P<0.01$). As the data suggests, the comparison between t_2 and t_3 was significant at a higher level in Trial 3 ($P<0.025$) than in Trial 2 ($P<0.10$).

Organic matter intakes are plotted against time in Fig 3.4, and digestible DM intakes (Table 3.13) are related to ration composition in Fig 3.5, and to organic matter digestibilities in Fig 3.6.

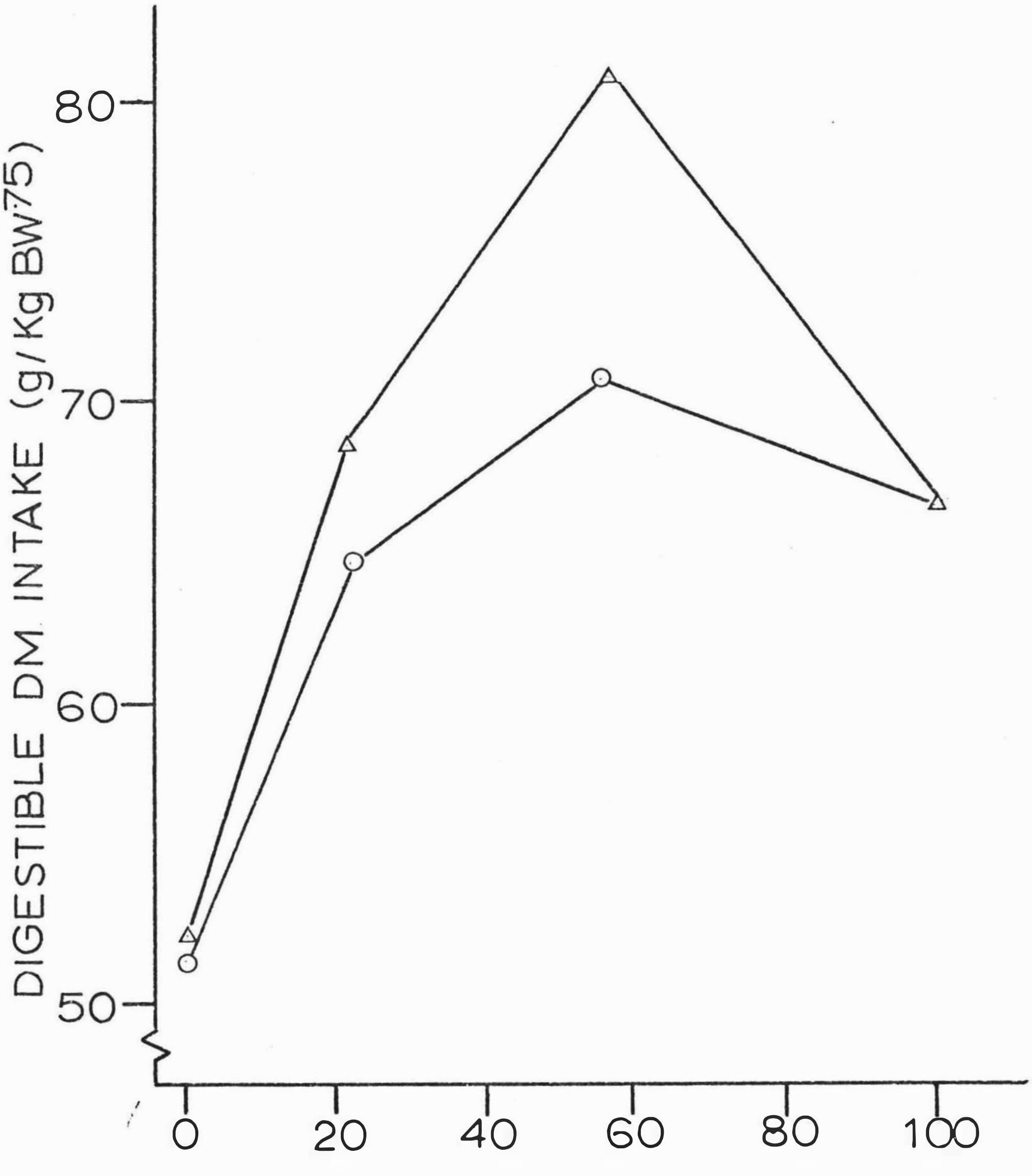

FIGURE 3.5: Grass content and mean daily digestible dry matter intakes of rations fed during trials two and three.

○ Trial Two △ Trial Three

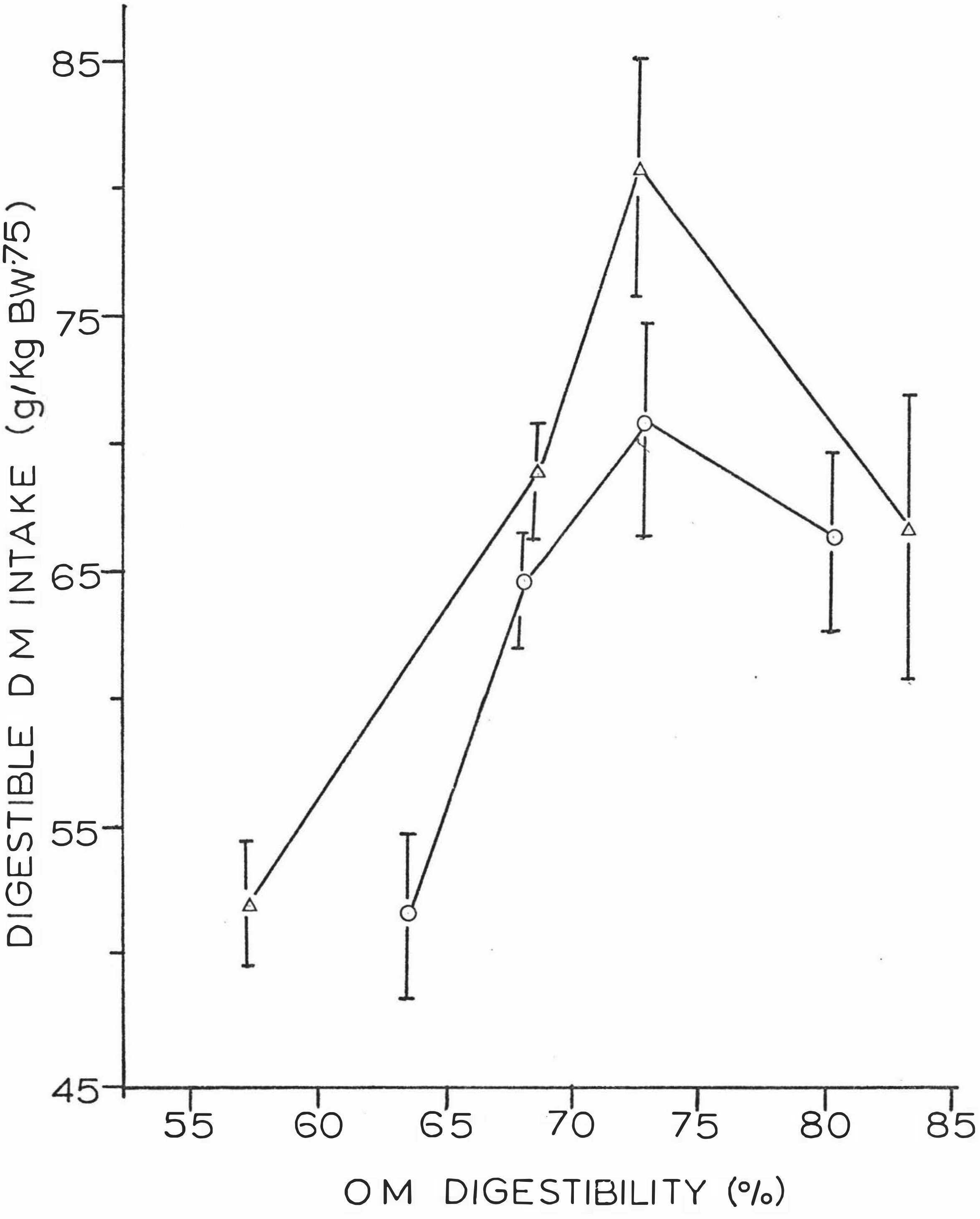

FIGURE 3.6: Organic matter digestibility and mean daily digestible dry matter intakes of rations fed during trials two and three.

○ Trial Two

△ Trial three

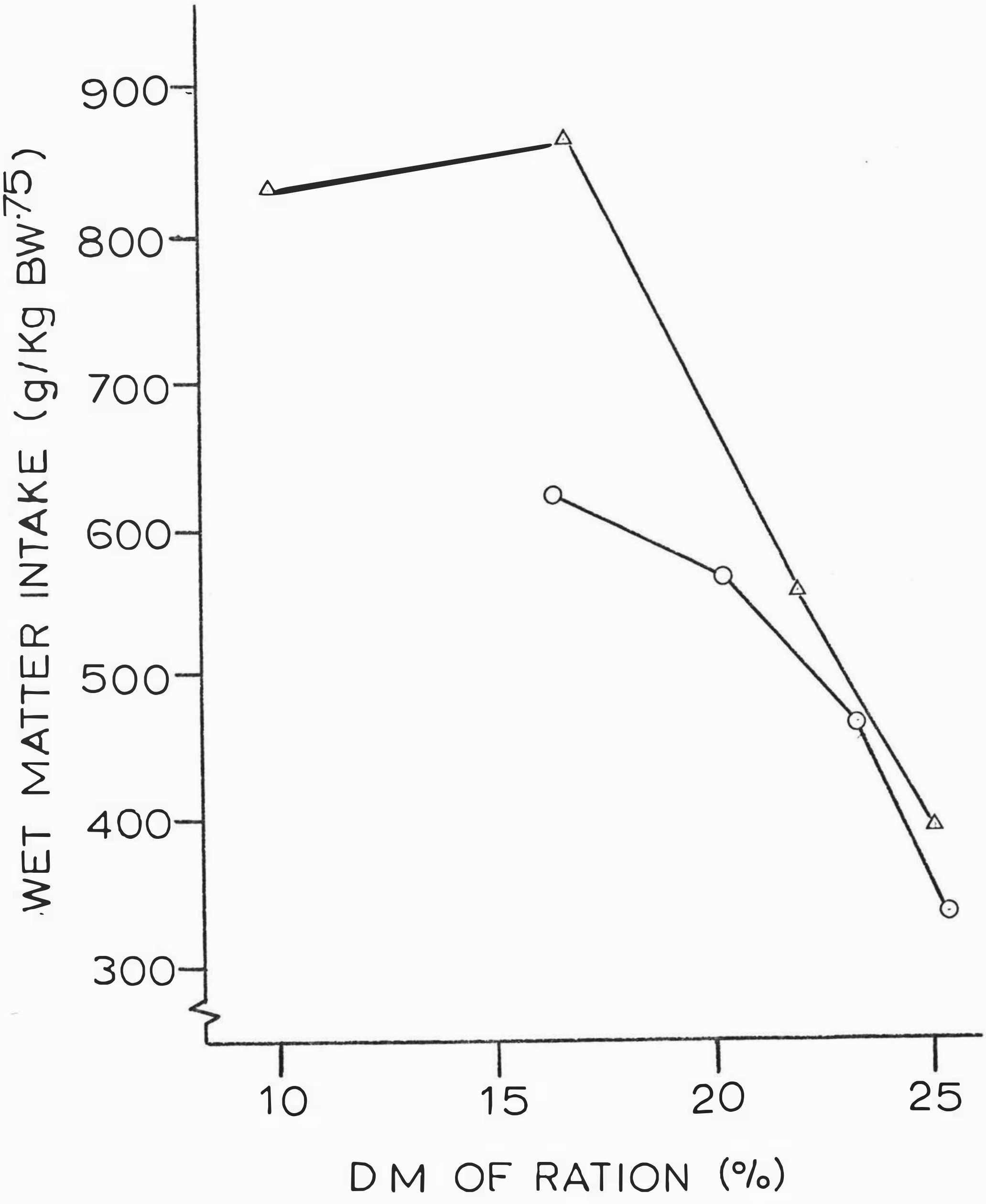

FIGURE 3.7: Dry matter percentages and mean daily wet matter intakes of rations fed during trials two and three.

○ Trial Two △ Trial Three

Wet matter intakes (Table 3.12) are plotted against ration DM percentages in Fig 3.7 as an aid to the interpretation of some anomalies which become apparent in the discussion.

3.6 STEER DATA: Digestibility estimates, nitrogen and energy balances

This section summarises results obtained from the six steers which were bagged and harnessed for dung and urine collection in Trial 2. Table 3.14 compares digestibility estimates derived from chromic oxide techniques (using analytical methods of Williams et al (1962), and Stevenson and de Langen (1960)), with values obtained from the total collection of faeces. The digestibilities of the all silage ration determined using total collection procedures were 6.1 percentage units below the values obtained using the method of Williams et al (1962) and 3.9 percentage units below the value obtained with the method of Stevenson and de Langen (1960). The magnitude of the variations between methods of determination was less in diets containing increased proportions of grass. These discrepancies are discussed in some detail in Section 4.3.1.2.

Table 3.14: Dry matter digestibilities determined by two chromic oxide analyses and by total faecal collection. Chromic oxide method 'A' was used for determinations in Table 3.9.

Treatment	DM Digestibility Estimates				
	Total Collection (T)	Chromic Oxide (A)	Difference (A - T)	Chromic Oxide (B)	Difference (B - T)
All Silage	58.4 ± 1.0	64.5 ± 2.1	+ 6.1	62.3 ± 1.6	+ 3.9
20% Grass	61.4 ± 0.9	64.3 ± 1.6	+ 2.9	63.3 ± 0.7	+ 1.9
55% Grass	63.8 ± 0.8	63.8 ± 1.5	-	62.7 ± 1.6	- 1.1

'A' Chromium determination according to the method of Williams et al (1962)

'B' Chromium determination according to method suggested by Ruakura based on Stevenson and de Langen (1960)

Table 3.15 summarises the nitrogen balance data, and demonstrates an increased N intake of the cattle fed rations containing increased proportions of grass. Nitrogen retentions increased from 22.1 g/day in cattle fed t_1 to 36.3 and 36.6 g/day in those fed treatments 2 and 3 respectively.

Table 3.16 summarises the energy balance data, and shows increased energy intakes and digestibilities in the steers fed rations containing increased proportions of grass. The estimated ME and DE intakes are calculated and presented in Table 3.17. ME intakes increased from 10.0 Mcal/day for t_1 to 14.8 and 18.1 Mcal/day for cattle in treatments 2 and 3 respectively.

As each treatment was represented by only two animals, no statistical analysis of the results was attempted.

Table 3.15: Mean daily nitrogen (N) balances of the steers in treatments 1, 2 and 3, and an estimate of their nitrogen retentions. All data in g/day.

Treatment	N Intake	Faecal N	Urinary N	N Balance
All Silage	75.8	37.6	16.2	22.1 ± 2.3
20% Grass	117.1	48.8	32.0	36.3 ± 3.7
55% Grass	176.7	55.2	84.2	36.6 ± 8.1

Table 3.16: Mean daily energy balances of the steers, determined by bomb calorimetry, and an estimate of energy digestibility. All data, unless specified, is in Mcal/day.

Treatment	Intake	Faeces	Urine	Methane*	Digestibility %
All Silage	22.1	9.7	0.7	1.7	56.0 ± 0.6
20% Grass	28.6	10.8	0.9	2.2	63.5 ± 1.1
55% Grass	32.5	10.1	1.7	2.6	68.6 ± 0.3

* Daily Methane losses were assumed to be 8% of GE (ARC, 1965)

Table 3.17: Estimated metabolisable energy intake of the steers, and the ME content of rations.

Treatment	Daily ME Intake (Mcal)	Daily ME Intake (Kcal/kg $BW^{.75}$)	Estimated ME* Content of Rations
All Silage	10.0 ± 0.4	166 ± 6	1.90
20% Grass	14.8 ± 1.0	244 ± 6	2.22
55% Grass	18.1 ± 1.0	277 ± 11	2.32

* Not corrected for intake

3.7 LIVE WEIGHT GAIN

Daily live weight gains were of secondary importance to the other parameters measured in this experiment, and the results from the cattle fed the all grass rations have been omitted because of large 'gut fill' problems (see discussion in Section 4.5). The daily gains of the cattle fed treatments 1, 2 and 3 are presented in Table 3.18 and apply to the period over which Trials 2 and 3 were conducted. The relationship between live weight gain and Dig DM intakes of the individual animals in these treatments is presented graphically in Fig 3.8.

Table 3.18: Daily live weight gains for treatments 1, 2 and 3 during Trials 2 and 3.

Treatment	Daily Gain (kg)
All Silage (t_1)	0.58 ± 0.08
20% Grass (t_2)	0.70 ± 0.12
55% Grass (t_3)	0.83 ± 0.13

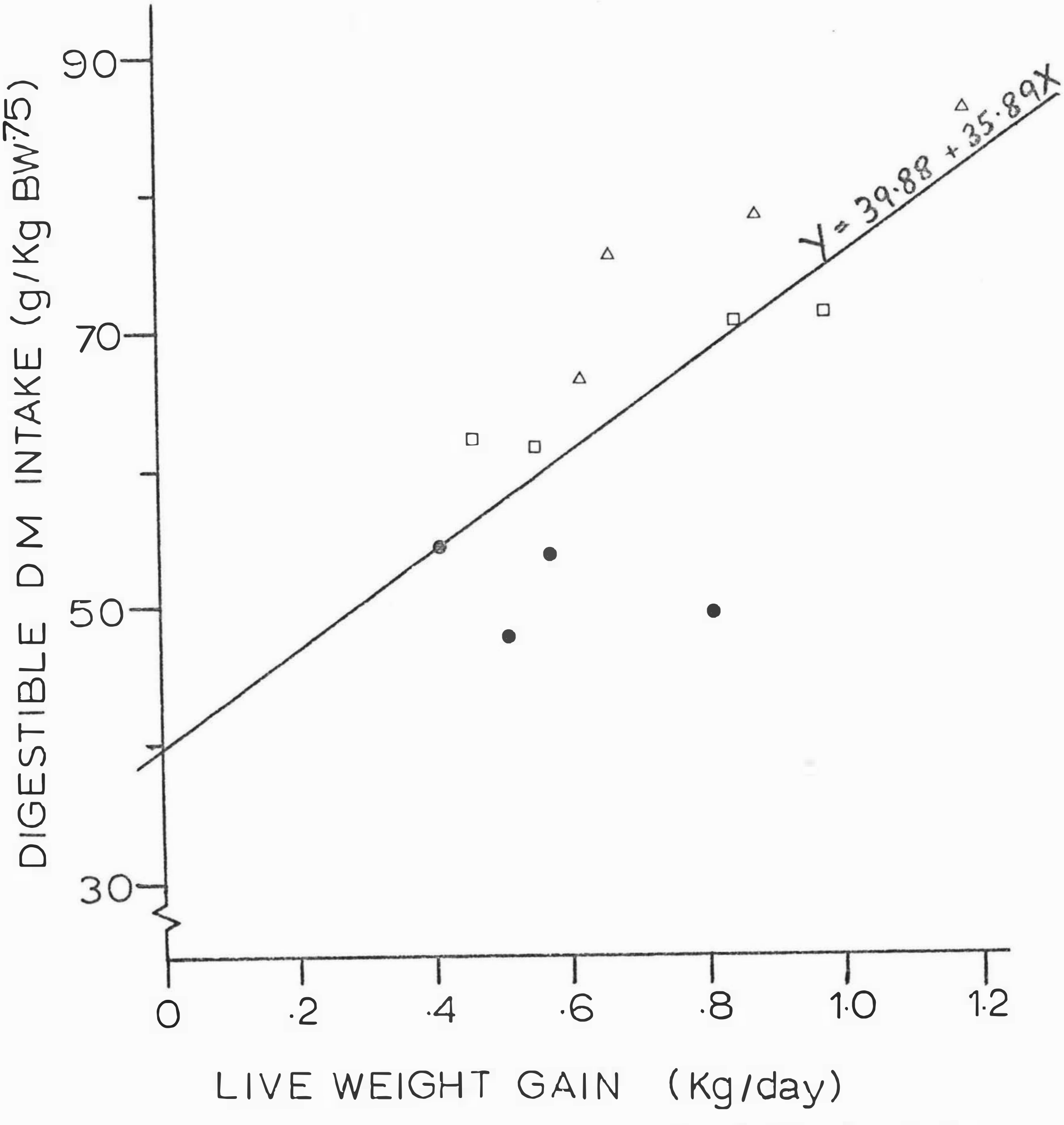

FIGURE 3.8: Live weight gains and mean daily digestible dry matter intakes of individual animals over the duration of trials two and three.

● All silage   □ 20% grass   △ 55% grass

CHAPTER FOUR

DISCUSSION OF RESULTS

This chapter discusses the results presented in Chapter Three. It comprises five sections. The order in which the topics are discussed approximate their presentation in Chapter Three, so that the first section deals with the feeds and rations and the second considers the fineness of chop effects, which enables an evaluation of the two silages to be made. Sections 3 and 4 consider the digestibility and voluntary intake data, and comprise the largest portions of the discussion, and finally in Section 5, a brief consideration is given to the live weight gain data.

The experimental design, which involved the use of identical twins, enabled the maximum use of the facilities to be made. The statistical methods (Section 2.5) used in the analysis of the chosen treatment comparisons were highly sensitive, and enabled a precise evaluation of the data. These proved satisfactory in all respects, and therefore do not require further discussion.

4.1 FEEDS AND RATIONS

This section evaluates the feeds used during the experiment in relation to the findings of other workers (presented in Chapter One). Brief comment is made regarding ration composition.

4.1.1 Physical Composition of the Maize

The maize ensiled for use in this experiment was, for reasons beyond the control of the writer, harvested prior to maturity. This is indicated by the low grain content of the maize and the low dry matter percentages of the silages (Tables 3.2 and 1.1, and Fig 1a). However, with the exception of the unusually high cob and husk percentages (which inflate the ear percentage) the component composition of the maize appears similar to others harvested at comparable maturities, particularly in view of the influence of environmental factors as shown by Cummins and Dobson (1973) (see Table 1.1).

Implicit in premature harvesting is a reduced forage yield. Judging by the component compositions, the extent of denting of kernels, the negligible senescence of lower leaves (Plate 1) and the dry matter percentages of the silages, it seems likely that the harvested yield (Appendix 2) was only 83-88 percent of the potential yield. The associated low grain percentage may have reduced the digestible energy content of the silage (Section 1.4.2), whilst the low dry matter contents are likely to have depressed voluntary intakes (Section

1.4.1). Although in Section 2.3.1 it was suggested that variations in fertilisation and planting density may have reduced the nutritive value of the coarse chop silage, the similarity of the silages in chemical composition (Table 3.4) suggests that any effects on the physical composition would be slight.

4.1.2 Chemical Analyses of the Silage

With the exception of the fine chop silage used in Trial 1, the other silages were similar in dry matter percentage and proximate composition. Comparisons of Tables 3.4 and 1.2 suggest CP and EE percentages of the silages to be higher than overseas findings, but the CP percentage was lower than that of the silage produced by Smith (1973) at this University. Variations in CP content probably reflect differences in fertilisation and planting density. With the exception of these constituents, the composition of the silages (except the fine chop in Trial 1) appears similar to those produced overseas, and although the very low CF and Ash contents of the fine chop used in Trial 1 are atypical they do conform to the changes in composition associated with maturity.

It is difficult to account for the higher dry matter of the fine chop silage used in Trial 1. The dry matters of all silages were determined in the same manner and none of the silages suffered from entry of water to the stack. Hence, in view of the differences between the proximate analyses of the silages, the dry matter percentage of the fine chop used in Trial 1 appears to be a true reflection of its maturity.

Of the mineral analyses (Table 3.5), both calcium and phosphorus percentages were in line with overseas findings, but the sodium content was about twice the typical value of 0.03% (of the DM). The calcium percentage reported by Smith (1973) in Table 1.2 is unusually high.

The dry matter percentages of the silages correlate well with their proximate compositions, and with a minor exception in the fine chop silage fed in Trial 1, their compositions correspond with overseas and New Zealand findings. Despite a degree of immaturity, the chemical analysis suggests a high nutritive value.

4.1.3 Physical and Chemical Composition of the Grasses

The composition of the 'grasses' used in Trials 2 and 3 were vastly different. This can be attributed in part to the botanical analysis, reported in Table 3.3; whilst the mixed pasture contained clover it also contained a proportion of dead matter and had a higher weed content than did the relatively pure Tama stand. Wet conditions during Trial 2 resulted in soil contamination of the herbage during harvesting, which accounts for the high ash content of this grass (Table 3.4), however the Tama was not significantly soiled during harvesting.

Taking the soil contamination of the mixed pasture into account, its CP content appears typical of winter pastures, reported in Section 1.6.1. The composition of the Tama was similar to that reported by Wilson and Dolby (1967) in Table 1.2, and although dry matters were very low they increased during the last five harvests. This accounts for the high standard deviation for Tama dry matter content. Calcium and phosphorus levels of the mixed pasture and Tama (Table 3.5) were similar to levels recorded from early spring samplings of Wilson et al (1969) and Wilson and Dolby (1967), but the sodium concentration in the mixed pasture was three times their recorded level.

Hence, although the composition of the grasses was similar to findings of other workers, the apparent nutritional superiority of the Tama was amplified by the soil contamination of the mixed pasture.

4.1.4 Ration Composition

The close proximity of the feed components in the mixed rations (Table 3.1) to their predetermined ratios, along with their low standard deviations, reflects a precise control of the daily feed allocation. The levels of supplementation with the grasses provided a range of crude protein contents in the rations fed during Trials 2 and 3 (Table 3.6), and this was an important aspect of the study.

The minerals supplements, comprising steamed bone flour and trace mineralised salt, were fed in accordance with requirements calculated in Appendix III. Salt supplementation may have exceeded requirements, in view of the high sodium concentrations in both the silage and the mixed pasture, but it is unlikely to be deleterious to animal health (ARC 1965).

4.2 FINENESS OF CHOP EFFECTS

The evaluation of fineness of chop effects (Tables 3.7a, b and c) involved measurements of digestibility, rate of passage and undigested kernel losses from the fine and coarse chop silages fed during Trial 1. Statistically significant differences were only obtained in the comparison of mean retention times, which were 49.0 and 44.6 hours for the cattle receiving coarse and fine chop silages, respectively, this 9% difference being significant at the 1% level. The respective DM digestibilities were 65.1% and 62.7%, and kernel losses were negligible in both groups.

Intakes of the coarse and fine chop silages during Trial 1 were 16.3% and 10.0% (metabolic body weight basis) lower than ad lib intakes of the fine chop silage fed to both groups after this trial (Table 3.10). This factor must be taken into account when assessing the digestibility and rate of passage results. Also the dry matter percentage of the coarse chop (24.7%) was lower than that of the fine chop (27.7%), and this is known to reduce DM intakes (Section 1.4.1) so that the actual effects of fineness of chop (particle size) are confounded. Particle size may have influenced intake directly, but the possible influence of DM percentage makes a precise evaluation of results impossible, so that only a generalised discussion is presented in the following sections.

4.2.1 Rate of Passage

There is general agreement among workers that reducing the particle size of feeds, especially roughages, whether by mechanical processing or rumination, increases their rate of passage through the alimentary tract (Balch and Campling, 1965; Church, 1969). These workers, and others (Campling and Freer, 1966), suggested that grinding frequently results in a rapid initial excretion of feed residues, apparently, because the particles are small enough (2 mm and under) to pass rapidly out of the reticulo-rumen and are subjected to intestinal digestion. The data in Table 3.8 and Fig 3.1 demonstrates a more rapid rate of passage, indicated by a shorter mean retention time, of the finely chopped silage but as no initial increase in excretion of residues is apparent, it may be assumed that the process of digestion was unchanged. Aside from intake effects, the more rapid rate of passage of the fine chop silage could be attributed to its increased surface area volume ratio, which would facilitate microbial degradation.

Strong negative relationships exist between intakes and mean retention times of roughages fed to ruminants (Blaxter et al, 1961; Shellenberger and Kesler, 1961; Campling and Freer, 1966; Leaver et al, 1969). Campling and Freer (1966) found mean retention times of hay fed to dry cows at approximately 0.85 and 2.06% BW to be 66 and 53 hours respectively, and a correlation of -0.66 was calculated between intakes and mean retention times of lactating cows by Shellenberger and Kesler (1961). Although intakes were controlled in this trial the differences between animals were sufficient to allow a correlation of -0.39 ($P > 0.05$) to be calculated between intakes and mean retention times.

It is evident that trends observed in this trial, relating both particle size and intake to rate of passage, are in line with findings of other workers, however the literature does not include reports of mean retention times for cattle fed maize silage as a sole diet. Disregarding the difference between the silages, their curves (Fig 3.1) fall mid-way between those determined with dry cows fed concentrates or long hays (Balch, 1950), and their mean retention times are similarly placed relative to results of Reed et al (1966) (concentrates) and Campling and Freer (1966) (medium quality hay or dried grass). These findings are not unexpected in view of the highly digestible grain, and less digestible stover fractions characteristic of maize silage.

4.2.2 Particle Size and Digestibility

Particle size is only one of several factors which affect digestibility. A positive relationship between mean retention time and digestibility has been demonstrated in non lactating cattle by Campling et al (1961), Campling and Freer (1966), and McCullouch (1969), whilst the majority of evidence suggests an inverse relationship between digestibility and voluntary intake (Watson, 1938; Blaxter and Wainman, 1961; Brown, 1966; Corbett, 1969; Leaver et al, 1969; McCullouch, 1969). The extent of the effect of intake on digestibility is dependent on feed type (Blaxter et al, 1961; Reed et al, 1966) and lactating cows do not necessarily conform to this pattern (Shellenberger and Kesler, 1961; Hutton, 1963; Braumgardt, 1970).

The longer mean retention times and the lower intakes of the coarse silage fed in this study may both have contributed towards its higher digestibility, even though it was not statistically different from that of the fine chop. Unfortunately, the difference in intakes of the silages, particularly if it was a function of dry matter percentage, has masked the influence of particle size per se. A correlation of +0.26 ($P > 0.05$) was calculated between individual digestibilities and mean retention times, but the possible influence of silage dry matter percentages precludes further evaluation of findings.

4.2.3 Undigested Kernel Passage

It was expected that the passage of whole kernels would be reduced by fine chopping the silage (see Review 1.4.6, 1.4.7). However the conclusion of Buck et al (1969), that losses were nutritionally relatively unimportant, is borne out in this trial (Section 3.3). The negligible whole kernel loss in the faeces of cattle fed the fine chop silage is expected in view of their greater mutilation during harvest (Plate 3), and whilst there was a greater proportion of whole kernels in the coarse chop silage, it is suggested that their absence in the faeces may be attributable to the low DM of this silage; the softness of the kernels rendering them more susceptible to damage during chewing and rumination.

Regardless of reason, the undigested kernel losses from both silages fed in this trial were nutritionally unimportant and no advantage has been gained, in this instance, by fine chopping. Nevertheless, fine chopping may be important in the reduction of whole kernel losses from silages produced from more mature maize, although evidence from Buck et al (1969), who used silages ranging from 22 to 46% DM, indicates chopping more finely than 1 cm particle size (similar to the fine chop) is not worthwhile.

4.2.4 Conclusion

It is considered unlikely that fine chopping was itself responsible for the higher DM content of the fine chop silage. The evidence in Section 1.4.1 shows low DM silages to be associated with reduced voluntary intakes, so that one may assume the lower intakes of the coarse chop silage to be due, at least in part, to its lower DM percentage. If this was the case, then the use of silages with similar dry matter contents may have given reduced differences in mean retention times and digestibilities. However, undigested kernel passage from the coarse chop silage may have been greater if its dry matter percentage was higher.

On the basis of these results it would seem likely that feeding either of the two silages would lead to similar live weight gains. The choice of harvesting method may be influenced more by ease of ensiling, in which case the fine chop would be preferable (Section 1.4.8), however output in tons/horsepower hour would be greater for coarse chop harvesters (Baker, pers. comm.), but the capital outlay for the New Holland harvester is much greater than that for the PZ harvester. Obviously the choice depends on an individual's requirements, but the greater ensiling ease of the fine (conventional) chop silage makes it a little more attractive.

4.3 DIGESTIBILITY

Dry matter digestibility was one of the major parameters measured during this experiment. Before the results (Table 3.9) are discussed, the problems encountered in the chromic oxide method of estimating faecal output are considered.

4.3.1 Chromic Oxide as an Estimator of Faecal Output

Diurnal variation in faecal Cr_2O_3 concentration is a possible source of error in digestibility determinations, so that the importance of the findings from Trial 1 (Fig 3.2) are considered. The suitability of the techniques used in the analysis of faecal chromium are also discussed, as there were differences between the bagged and chromic oxide digestibility determinations with the steers in Trial 2 (Table 3.14).

4.3.1.1 Diurnal Variation

Variation in faecal Cr_2O_3 concentration may be a source of error in the digestibility estimates. The pattern of variation was determined in Trial 1 by analysing faecal samples collected on five occasions over a 24 hour period from each of the twelve animals, fed an all silage diet. The average Cr_2O_3

concentrations are plotted in Fig 3.2, along with their standard deviations, and reveal a sinoidal curve with a maxima of 127%, of the mean (recorded at approximately 4 a.m., 4½ hours prior to dosing) and a minima of 60%, of the mean (recorded approximately 7½ hours after dosing).

Evidence of other workers suggests diurnal variation to be influenced by feeding time, feed type, intake, time and number of Cr_2O_3 administrations per day. Experiments of Hardison and Reid (1953) and Smith and Reid (1955), in which all animals were dosed at 7 a.m., showed the time of maximum Cr_2O_3 recoveries to be reversed in stall feeding and grazing situations and results were also reversed when grazing lactating cows and grazing steers were compared, so that any comparison of recovery times (in Fig 3.2) with findings of other workers appears inadvisable. Trends relating to the magnitude of the diurnal variations appear more straightforward. Smith and Reid (1955), using grazing animals, showed lactating cows to have less variation than steers, and Hardison and Reid (1953) demonstrated less variation in stall fed than grazing steers; the maximum and minimum percentage recoveries for the respective groups are: 141, 65: 183, 52: 130, 80: 180, 50. This data was obtained from animals dosed once daily, but twice daily dosings appeared to reduce the diurnal variation. Wilkinson and Prescott (1970) found maxima and minima of steers dosed twice daily to be 110% and 88% of the mean, and data of Kane <u>et al</u> (1952), reinterpreted by Hardison and Reid (1953), in which lactating cows grazing pasture were dosed twice daily showed maxima and minima of 108 and 94% respectively.

On the basis of these findings the results presented in Fig 3.2 appear typical, and although detailed comparisons with findings of others may be inadvisable the magnitude of the diurnal variations, particularly with once daily dosing, emphasises the importance of representative sampling. Fortunately, throughout this experiment, care was taken to obtain representative faecal samples, so that diurnal variation is unlikely to be a source of error.

4.3.1.2 The Suitability of the Cr_2O_3 Method Used for Digestibility Determinations

The accuracy of the Cr_2O_3 technique for estimating digestibility, using analytical methods described by Williams <u>et al</u> (1962), was assessed by collecting faeces from harnessed steers during Trial 2 and comparing the actual and estimated faecal outputs. Percentage recovery of chromium, ideally 100%, varied between animals and collection periods, and often resulted in elevated digestibility estimates (Table 3.14). Difficulty was also experienced in obtaining repeatability with some samples.

Mean recoveries for individual animals varied from 92 to 124%, and when grouped into treatments recoveries were 118%, 110% and 100% for treatments

1, 2 and 3 respectively. It is difficult to account for the excessive recoveries in t_1 and t_2, or for the variability between animals. Any loss of Cr_2O_3 during grinding or dosing would reduce the recovery rate and the digestibilities, yet Cr_2O_3 digestibility estimates for treatments 1 and 2 are markedly higher than the bagged determinations (Table 3.14). It is possible that the recovery of chromium for t_1 was elevated because of an 'end point error' in faecal output of a steer in this treatment, but this would account for only a small part of the excessive recovery. Errors in dry matter determinations of feeds (discussed in Section 4.3.7) would affect intakes, but any inaccuracy would have a similar effect on both the bagged and chromium digestibility estimates. Overdrying of faecal samples used to determine the dry matter of the faeces collected in bags may have been a source of error, but if this had occurred then the true bagged digestibilities would be lowered further, and the percentage recoveries raised. While under-drying these samples could account for the anomalies, the 96 hour drying period (Section 2.4.4) and the small size of the samples (approx 90 gm wet matter) renders this suggestion unlikely. Other factors which may be responsible for the digestibility disparities include effects relating to the silage content of the ration, the analytical procedures used for estimating the chromium content of the faeces, and variations in chromic oxide content of the pellets; however, the latter possibility has been disproved (Clark, pers. comm.).

The increasing disparities associated with rations containing increased proportions of silage suggests a possible relationship, but correlations between feed type and recovery percentages have not been found by other workers (Troelson, 1955; Putnam et al, 1957; Wilkinson and Prescott, 1971), and although variations between animals have on occasions been large, in no case has recovery consistently exceeded 100%. Furthermore, Hatten and Owen (1970) fed diets containing a large proportion of maize silage to dairy cows and obtained usual recoveries.

The method of analysis is more suspect. Difficulty was experienced in stabilising chromium absorption during its determination on the atomic absorption spectrophotometer. This sometimes resulted in divergent readings and necessitated several repeats with some samples, however it does not explain recoveries which were in excess of 100%. A colorimetric technique similar to that of Stevenson and de Langen (1960) was used in a redetermination of chromium concentrations in the faecal samples of the steers. All digestibility estimates were lowered by 1 - 2 percentage units with this technique (Table 1.14), so that recoveries were reduced and a better agreement with bagged estimates in treatments 1 and 2 was obtained. However the same trends relating to ration composition persisted, suggesting some other factor to be the principal cause of the poor agreement.

Although the writer has been unable to explain the high recoveries of Cr_2O_3 and the poor agreement between bagged and chromic oxide digestibility estimates for treatments 1 and 2 (Table 3.14), the generally good agreement between duplicate determinations throughout the other trials suggests the fault to be related in some way to the bagged digestibility determinations. Evidence presented above, although admitting some difficulties in the technique of Williams et al (1962), fails to reveal any major inadequacies in the method by which digestibilities were determined. In this light it seems reasonable to accept the digestibility estimates, as presented in Table 3.9, and to give little weight to the total collection data presented in Table 3.14.

4.3.2 The Influence of Intake on Digestibility of Rations

The majority of evidence (reviewed by Brown, 1966) indicates that increased feed intakes are associated with depressions in digestibility. Two distinct relationships between digestibility and intake became evident, and were dependent upon feed quality (ME content). These relationships need to be considered prior to the adjustment of the digestibility data in Table 4.1.

Workers frequently express levels of intake as multiples of maintenance, so that a greater depression in digestibility of poor quality feeds can be expected, per unit increase in intake, because larger quantities are needed to meet maintenance requirements. This trend has been convincingly demonstrated with dried forages fed to sheep and cattle by several workers (Blaxter, 1962; Armstrong, 1964; Waite et al, 1964), and is adopted by ARC (1965) in its factorial estimation of ruminant feed requirements. However, some recent work involving mixed rations incorporating a range of hay:concentrate ratios has demonstrated a reverse relationship. The depression in digestibility per unit increase in intake has been greater with high concentrate rations than with those containing high proportions of hay. Brown (1966) fed cows rations with hay:concentrate ratios of 4:1, 1:2 and 1:4 and respective declines in DM digestibility units per maintenance increment increase in intake were 1.6, 2.0 and 3.8. A similar trend was produced in a comprehensive study by Wagner and Loosli (1967) and was also shown with wethers by Leaver et al (1969), whilst Blaxter and Wainman (1964) found reductions to be of a similar magnitude for diets comprising a range of hay:concentrate ratios when fed at two levels of intake to wethers and steers. Although curvilinear relationships between intake and digestibility have been observed by some workers (Forbes et al, 1928; Leaver et al, 1969), a linear relationship will be assumed in this discussion.

The apparent departure of mixed rations from the accepted trends relating feed quality to intake and digestibility (ARC, 1965; Corbett, 1969) suggests a need for caution in the interpretation of digestibility data. Adjustments to eliminate depressions in digestibility due to intake differences (derived from data in Tables 3.10, 3.11, and 3.12) have been made in Section 4.3.5. This was done using both the ARC (1965) system, and using data obtained from the findings of Brown (1966) and Wagner and Loosli (1967), both of whom worked with mixed rations.

4.3.3 Digestibility of Silage Fed Alone

In view of the distinctive decline in digestibility of the all silage ration over the three trial periods (Table 3.9) it was felt advisable to discuss this treatment separately. Dry matter digestibilities of the all silage rations, with the exception of the coarse chop in Trial 1, are well below the typical value of 68% reported in overseas literature (Section 1.3.2). Mean digestibilities of the fine and medium chop silages (only these are strictly comparable, on the basis of particle size, with 'typical' silage) declined from 62.7% in Trial 1 to 61.2% and 54.4% in Trials 2 and 3 respectively. Associated with this decline are increased standard deviations, which became abnormally large in the latter two trial periods. Factors associated with the range of digestibilities include fineness of chop (which has been discussed in Section 4.2.2), DM intake, duration of the feeding period and the nutritional adequacy of the diet.

Review writers (Morrison, 1957; Coppock, 1969; Hillman, 1969), feeding standards (NRC, 1970) and the literature in general leave no doubt as to the consistency of digestibility values of typical (and immature) maize silage, however in nearly every case some form of protein supplement (organic or inorganic) has been fed as part of the ration. The point is often overlooked by New Zealand writers. A comparison of the digestibilities obtained in this experiment (particularly in Trials 1 and 2) with findings of other workers who have fed silage without a protein supplement, suggests the values to be in line with the majority of results. Smith (1973) at this University, fed yearling steers a diet of mineral supplemented silage for 11 weeks and recorded DM digestibilities of 62.0 ± 1% (intakes 2.7% of BW), whilst Bryant (1971) at Ruakura recorded DM digestibilities of 60% when maize silage was fed to lactating cows over a 4 week period, but a value of 69% was recorded with 18 month old heifers fed this diet for 3 weeks at 2.1% BW. Comparable overseas data is scarce but Watson et al (1939) recorded a value of 61.7% for mature steers fed maize silage ad lib (but under 2% of BW), however other reports (Table 1.3) do not include digestibility data.

Too lengthy

Whilst the value recorded in Trials 1 and 2 may be comparable to other findings where maize is fed as a sole diet, the 6 percentage unit digestibility depression, compared to the 'typical' overseas values, strongly suggests a need for protein supplementation.

The 6.9 percentage unit decline in digestibility, from 61.2% in Trial 2 to 54.4% in Trial 3, may be attributable in part to increased dry matter intakes over this period (from 2.14 to 2.42% of BW). Calculations based on ARC (1965) feed requirements and their equations to correct for intake effects, reveal a likely digestibility depression of only 2 percentage units associated with this increase in intake, so other factors appear to be responsible for a large proportion of this decline.

The writer suggests that, in view of the recognised low and inadequate digestible crude protein content of maize silage, prolonged feeding has resulted in a declining ability of some animals to maintain their digestive function. This theory is reinforced by the increased variability of the digestibility coefficients (signified by the high standard deviations) of the all silage treatments in Trials 2 and 3 compared with those in Trial 1. Supporting evidence comes from Goering <u>et al</u> (1969) who fed young steers a maize silage diet at 85% of ad libitum over a 166 day period which caused mean DM digestibilities to decline from 69.6% to 54.2%. Associated with this was a decline in apparent CP digestibilities from normal to negative values, and whilst the steers weighing under 170 kg at the commencement of the trial showed negative weight gains the heavier animals gained weight. Supplementation of the maize silage with 454 gm of soybean meal per day prevented declines in CP and DM digestibilities in a similar group of steers.

This evidence, although not conclusive, adds weight to the writer's suggestion that the digestible CP content of maize silage was inadequate and resulted in a declining digestive efficiency. This theory is strengthened by the fact that the digestibilities of the 20% grass ration (Table 3.9) did not change during the experiment. Whilst different live weights may have influenced the tolerance of individual animals to the low CP content of the diet (further discussion in Section 4.4.4) the writer considers the poor condition of some animals prior to the commencement of the experiment (Section 2.2) may have contributed to the increased variability in digestibilities during Trials 2 and 3. Hence, in the absence of other factors, it may be concluded that mineral supplemented maize silage fed as a sole diet is nutritionally inadequate, and this has been the principal cause of the declining DM digestibilities over the duration of the experiment. In this light the statistical comparisons of treatment digestibilities with the all silage digestibilities in Trial 3 (Table 3.9) could lead to a misinterpretation of data.

4.3.4 Digestibility Comparisons Between Treatments

In view of the soil contamination of the grass fed during Trial 2 (Table 3.4), discussion in this section and in Section 4.3.5 is based on organic matter digestibilities, which are presented in Table 3.9. This removes the effects of soil contamination and enables a more accurate assessment of results to be made as well as facilitating comparisons between Trials 2 and 3.

Progressive replacement of the silage with grass resulted in a near linear increase in organic matter digestibilities during both trials, as demonstrated in Fig 3.3, but in general the digestibilities of rations containing grass in Trial 3 are slightly higher than their counterparts in Trial 2. This becomes more apparent when digestibilities are corrected for intake (Table 4.1), and is probably a reflection of the higher digestibility of the Tama ryegrass. The digestibilities of the treatments incorporating grass have low standard deviations compared with the all silage rations in these trials.

In Trial 2, comparisons between treatment 1 and treatments 3 and 4 both resulted in highly significant statistical probabilities, which is not surprising as their respective OM digestibilities were 9.4 and 16.8 percentage units greater than the value for t_1. Other comparisons in this trial were not significantly different yet the 20% grass treatment, which was 4.4 percentage units above t_1, was of major nutritional significance in that digestibilities of this ration were maintained in Trial 3, in contrast to the all silage ration. The statistical comparisons between t_1 and treatments 2, 3 and 4 in Trial 3 have limited meaning in view of the depressed digestibility of the all silage ration, however the digestibilities of the rations containing grass were similar to those in Trial 2. Although differences between t_2 and t_3 in Trials 2 and 3 were 5.0 and 4.1 percentage units respectively, these levels were too small to attain statistical significance.

4.3.5 Associative Effects

? Speculative

Ignoring the depressed value for treatment 1 in Trial 3, the relationship between organic matter digestibility and ration composition, as presented in Fig 3.3, indicates an apparent absence of associative effects in the mixed ration digestibilities. However, the very high intakes for some of the mixed rations (Tables 3.11 and 3.12) would, according to evidence presented in Section 4.3.2, be expected to depress digestibilities and so mask any associative effects. In this section an attempt is made to adjust digestibilities in relation to the intakes of the rations and to estimate digestibilities at the maintenance level of intake, which will enable the true extent of the associative effects to be determined. As the relationships between intake and digestibility of mixed rations may not follow conventional trends, the digestibilities have been adjusted using both the ARC (1965) system and the data relating exclusively to mixed rations (see Section 4.3.2). The techniques and assumptions involved in the adjustments are outlined below.

Metabolisable energy (ME) intakes of the respective treatments were calculated from DM intakes presented in Table 3.11 (grass intakes in Trial 2 were adjusted to remove the effects of soiling), assuming ME values of 2.2 and 2.6 Mcal/kg DM for the all silage rations and for the rations in treatments 2, 3 and 4, respectively. These were related to maintenance ME requirements (ARC, 1965) and enabled intakes to be expressed as multiples of maintenance in Table 4.1 Only the digestibility of the all silage treatment in Trial 2 was used in the calculations.

The mixed ration digestibilities were adjusted by two systems:

a) The ARC (1965) technique which required an iterative approach and reduced digestibilities by: 11.9 - (0.119 x Dig. at Maintenance) percentage units per maintenance increment increase in intake.

b) The writer, using findings of Brown (1966) and Wagner and Loosli (1967), reduced digestibilities by 1.5 percentage units per maintenance increment increase in intake.

These 'adjusted digestibilities' are presented in Table 4.1 and any associative effects in the mixed rations are determined by their comparison with 'expected digestibilities'. The 'expected digestibilities' are determined by a combination of the 'adjusted digestibilities' of the all silage and all grass treatments in accordance with grass:silage ratios in Table 3.1.

The writer is aware of the shortcomings in the methods by which digestibilities were adjusted and the associative effects determined in Table 4.1, however both methods of calculation demonstrate marked associative effects in treatment 2 of both trials, but associative effects for treatment 3 tended to be smaller, particularly in Trial 3. The magnitude of the interaction in treatment 2 of both trials is such that it could not be due to errors in the method of calculation, nor can it be attributed to the reduced silage digestibility in Trial 2, compared with that in Trial 1. A recalculation of the data using the digestibility of the fine chop in Trial 1 (65.4%) resulted in associative effects of 1.4 and 1.6 percentage units for treatment 2 in Trials 2 and 3 respectively, whilst corresponding values for treatment 3 were 0.5 and -0.2.

1.4 1.6

diffs too small to prove point.

The writer considers these calculations strongly suggest that an associative effect resulted from supplementation of silage with 20% grass. Whilst the interactions for treatment 3 appear smaller, a possible underestimation of intakes (levels of maintenance) in Trial 3 may have depressed the calculated values. Hence, a true representation of the relationships between digestibility and grass content of the rations in Fig 3.3 should demonstrate a slight upward curvature for the mixed rations, particularly for the 20% level of grass supplementation.

Table 4.1: Estimated associative effects on the organic matter digestibility percentages of the mixed rations in trials 2 and 3.

	Trial 2				Trial 3		
	t_1	t_2	t_3	t_4	t_2	t_3	t_4
OM Dig. (Table 3.9)	63.6	68.0	73.0	80.9	68.7	72.8	83.2
Intake (x Maintenance)	1.24	1.79	1.86	1.55	1.93	2.27	1.54
ARC Technique:							
'Adjusted digestibility'	64.7	71.0	75.3	81.6	71.8	76.5	84.3
'Expected digestibility'	64.7	67.6	71.4	81.6	68.1	75.2	84.3
Associative effects		+3.4	+3.9		+3.7	+1.3	
Mixed Ration Method:							
'Adjusted digestibility'	64.0	69.2	74.3	81.2	70.1	74.7	84.0
'Expected digestibility'	64.0	66.9	73.2	81.2	67.5	74.8	84.0
Associative effects		+2.3	+1.1		+2.6	-0.1	

4.3.6 Nitrogen Digestibility and Retention

Although digestible crude protein has been implicated as the factor responsible for the decline in digestibility of the all silage ration in Trial 3, no nitrogen balance data from this trial is available to substantiate this claim. Circumstances necessitated faecal and urine collections from the steers to be made during Trial 2. The nitrogen digestibilities (calculated from data in Table 3.15) for treatments 1, 2 and 3 were 50%, 58% and 69% respectively. Although the value for the all silage treatment is low, it is also typical of the findings of other workers (see Section 1.3.3). The higher digestibilities in t_2 and t_3 are to be expected in view of the higher CP digestibility of grasses.

The nitrogen retention data is more meaningful. The daily retention of 22.1 g for the all silage fed steers is similar to values recorded by Smith (1973) (24 g/day) when silage containing 9.7% CP was fed to yearling steers. Variability increased when the diets contained increasing proportions of grass, but the mean retention of 36.3 g/day by animals fed the 20% grass ration supports the idea that the CP content of the all silage ration was inadequate. The similar level for the 55% grass ration (36.6 g/day) is unlikely to be representative of this ration in view of the large differences between retentions and intakes of the two steers.

A correlation of +0.94 ($P < 0.01$) was calculated between daily N retentions and daily live weight gains of the individual steers which suggests the nitrogen retention data may be reasonably accurate, however the limited number of animals, possible errors in measuring live weight, and the variability in treatment 3 prevents any conclusions being drawn regarding the optimal level of grass supplementation. Only the inability of maize silage, fed as a sole diet, to meet animal crude protein requirements has been clearly indicated.

4.3.7 Accuracy of Dry Matter Determinations

Accurate dry matter determination of feed and faecal samples is essential in the calculation of voluntary intakes and digestibilities of rations. The inaccuracies resulting from oven drying at 100°C are well known (Minson and Lancaster, 1963; Brahamakshatriya and Donker, 1971; Danley and Vetter, 1971), but the magnitude of the errors varies between reports. Smith (1973) found a 1.3 percentage unit depression in dry matter of maize silage oven dried at 90°C, compared with freeze drying, whilst Brahamakshatriya and Donker (1971) in their comprehensive experiment, dried maize silage for 48 hours at 70°C in a forced draft oven and recorded depressions (relative to freeze drying) of 0.41 and 2.34 percentage units for silages of 47.70 and 32.51% dry matter respectively.

Toluene distillations provide the most accurate measure of dry matter content, but they would have been impractical under the conditions of the present experiment. However, a comparison between 24 hour oven drying at 75°C (used for feed DM determinations throughout the experiment) and freeze drying demonstrated a depression of only 0.50 percentage units in dry matters determined by oven drying. This difference was too small to markedly affect intake or digestibility determinations, and even if they were slightly underestimated the similarity of the drying procedures to those used by most other workers renders the findings of this experiment comparable, if not strictly accurate.

The 96 hour drying period of the faeces may have resulted in a loss of volatiles, but the only mention of such losses in the literature, cited by Brahamakshatriya and Donker (1971), related to losses caused by high oven temperatures. In view of the 75°C drying temperature used in this study, such losses seem unlikely.

4.3.8 Conclusion

Although some difficulty was experienced in reconciling bagged and chromic oxide digestibility determinations, the evidence suggests the digestibility data presented in Table 3.9 to be representative and valid. Increasing the grass supplementation of the silage resulted in a progressive increase in ration digestibility (Fig 3.3), whilst digestibility of the all silage ration declined over the duration of the experiment.

The marked decline in the all silage digestibility over time, along with limited evidence gained from nitrogen retention studies, implicates a low digestible crude protein content as being primarily responsible for the decline. Only a nutritional imbalance could cause a digestibility depression of the magnitude recorded in this experiment. Adjustment of digestibilities to remove effects due to voluntary intake differences revealed the existence of associative effects in the mixed rations. These were greatest in the 20% grass ration, where digestibilities were increased by 2 - 3 percentage units. The interaction appeared to be smaller in the 55% grass ration, but difficulties in the calculations prevented a more concise evaluation.

Perhaps the most significant finding demonstrated in this portion of the experiment was the nutritional inadequacy of maize silage fed as a sole ration, and the ability of a 20% grass supplement to overcome the deficiencies and allow an efficient utilisation of both feeds.

4.4 VOLUNTARY INTAKE

Voluntary intakes are expressed in terms of dry matters and organic matters, and are presented in several forms (Tables 3.11 and 3.12), to aid comparison with findings of other workers. These include kg/day, percent of body weight (% BW), and in relation to metabolic weight (g/kg $BW^{.75}$). The writer is aware of the possibility of greater errors when intakes are expressed in terms of body weight, but as this form of expression has often reduced standard deviations and increased the significance levels in treatment comparisons (Tables 3.11 and 3.12), it appears to be desirable. Braumgardt (1970) suggests intake should be related directly to body weight up to the point where it is no longer regulated by fill, after which he advocates the use of metabolic weight ($BW^{.75}$). However, difficulties in determining the method of regulation, along with possible palatability influences (especially in Trial 2), has prevented the use of this approach, and in view of the generally close relationship existing between intakes expressed in terms of live weight and metabolic weight, the writer has chosen to use the latter during most of this discussion.

Spelling

4.4.1 Relationships Between Voluntary Intakes of Rations

Intake data from Trials 2 and 3 are discussed separately so as to avoid confusion arising from the inflated ash contents of the grass fed in Trial 2. Apart from possible palatability effects, which are discussed later, the high ash contents have changed the relationships between treatments according to the units in which intakes are expressed.

When intakes are expressed as dry matters, the relationship between the treatments in Trial 2 is:

$$t_1 < t_4 < t_2 < t_3$$

The all silage intakes are considerably less than those of the other rations, so that statistical comparisons between t_1 and the other treatments are frequently highly significant ($P < 0.01$), as demonstrated in Table 3.11. When expressed in terms of organic matter the intakes of treatments 1 and 4 and treatments 2 and 3 are nearly identical, the mixed rations being 18 - 20% greater than the silage or grass intakes. Statistical comparisons between the mixed and individual rations were significant at the 0.5 and 2.5% levels, depending upon the method of expression, but other comparisons were not significant. The magnitude of the differences between DM and OM intakes was dependent upon the proportion of grass in the rations. Although the superiority of the mixed rations was evident, the changing of relationships between treatments which resulted from the soil contamination of the grass makes it inadvisable to draw further conclusions from the findings of this trial.

The relationships between treatments in Trial 3 are not affected by the method of expression:

$$t_4 < t_1 < t_2 < t_3$$

Intakes of treatment 3 (55% grass) were considerably higher than those of treatment 2 (20% grass), in this trial, so comparisons between t_2 and t_3 were statistically significant in most instances. However comparisons between these treatments and t_1 were significant at lower levels than in Trial 2, and in some instances comparisons between t_1 and t_2 were not significant. A 13% increase in intakes of the all silage ration, from Trial 2 to Trial 3, was responsible for the reduced significance levels in these comparisons, whilst a decline in intakes of the Tama relative to the grass fed in Trial 2, along with the increased silage intakes, resulted in a reversal of the order of these treatments, however the t_1 - t_4 comparison was not statistically significant.

A comparison of results from Trials 2 and 3 shows the intakes of cattle in treatment 2 to be approximately 5% higher when fed Tama (in Trial 3) and the feeding of Tama in treatment 3 raised intakes by 11 - 18 % (depending on the method of expression). The magnitude of the increases was roughly proportional to the quantity of grass in the respective rations and although the nutritive value of the Tama is known to be superior to that of the mixed pasture, part of the increase may be a reflection of improved palatability (it was not soiled). These trends serve to emphasise the unexpectedly low intakes of the 'all grass' rations. The increased intake of the all silage ration is also surprising in view of its similar dry matter and chemical composition to that fed in Trial 2. This increase may be related in some way to its declining digestibility, as Dig DM intakes remained the same in each trial (Table 3.13).

The physical and chemical compositions, digestibilities, intakes of the mixed rations, and other factors, all suggest the Tama to be of a higher nutritive value than the mixed pasture, yet when fed as a sole diet both DM and OM intakes of the Tama were below those of the mixed pasture. It is inconceivable that metabolic controls could be limiting intake, and its palatability appeared superior to the mixed pasture, however the levelling off of wet matter intakes at approximately 850 g/kg $BW^{.75}$ (Table 3.12, Fig 3.7) suggests a possible upper limit where bulk becomes an intake regulator. Findings of Verite and Journet (1970) lend support to this theory; their results suggest intakes of cattle may be decreased when pasture DM is below 18%, although this effect may not be apparent in lactating cows until dry matters fall below 15%. This implies an intake control related to feed bulk, and as the mean dry matter of the Tama was only 9.9%, compared with 16.3% for the mixed pasture, it is quite possible that its intake was restricted through the mechanism.

The intakes recorded during these trials were compared with findings of other workers. The intakes of treatment 3 in Trial 3 appear to be exceptionally high (137 g/kg $BW^{.73}$) as ARC (1965) suggested a DM intake of 140 g/kg $BW^{.73}$ (obtained by feeding dried grass to steers (Blaxter <u>et al</u>, 1962)) to be a near maximum for this class of animal. During the final collection period of this trial (see Fig 3.4) intakes rose even higher, to 149 g/kg $BW^{.73}$, with one animal consuming 169 g/kg $BW^{.73}$. The suggestion of Raymond (1969) that intakes may be elevated in lean animals is unlikely to apply to the animals in this treatment, so, in the absence of any other causative factors, the writer can only conclude that the ration was highly palatable and provided a near optimal balance of nutrients. Intakes of t_3 in Trial 2, and the intakes of the other treatments in Trials 2 and 3, were similar to intakes of young growing cattle fed conventional roughage and pasture rations. The treatment 2 ration was consumed at a similar level to a maize silage ration supplemented with approximately 24% grass and fed to yearling heifers by Bryant (1971), whilst organic matter intakes of the all grass rations correspond to values obtained from stall fed Jersey two year olds by Hutton (1962, 1963), and to the findings of Taylor and Wilkinson (1972). Despite the increased intakes of the all silage ration over this period, the values were similar to those in other studies (see Section 1.3.3).

Hence the intakes of the silage, grass, and the 20% grass rations during both trials appear similar and comparable to findings of other workers. The mixed rations were consumed to a greater extent than were their component feeds when fed individually (discussed in Section 4.4.2), and whilst intakes of rations incorporating 55% grass were greater than those containing 20% grass, the outstanding levels attained with t_3 in Trial 3 may serve to demonstrate the importance of grass quality.

4.4.2 Digestible Dry Matter Intake

The digestible dry matter intakes (Table 3.13) reflect the nutritive value of the rations, and their comparison enables a realistic evaluation of the rations to be made. The Dig DM intakes were nearly identical in both trial periods for the all silage (51.5 and 51.9 g/kg $BW^{.75}$) and all grass (66.5 g/kg $BW^{.75}$) treatments, with the latter values being approximately 27% higher than values for t_1, but the order of the remaining treatments differed between trials:

Trial 2 $t_1 < t_2 < t_4 < t_3$
Trial 3 $t_1 < t_4 < t_2 < t_3$

This change resulted from small increases in digestibility and intake of animals on t_2 during Trial 3, nevertheless Dig DM intakes of treatments 2 and 4 were similar in both trials. The superiority of the 55% grass ration in both trials is not unexpected in view of the very high intakes of animals fed this ration. Although there is a continuing response in Dig DM intake to grass supplementation of maize silage up to the 55% level, the magnitude of the response decreases between the 20% and 55% levels (Fig 3.5). Responses in each trial are similar up to the 20% level suggesting grass quality not to be of great importance, however the divergent responses at higher levels suggest grass quality and palatability to be of major importance. The associative effects in the mixed rations (deviations from linearity) are presented in Table 4.2. These enable comparisons to be made between trials and between treatments so that the importance of grass, quality and quantity can be evaluated.

Care is required in the interpretation of data in Table 4.2. The associative effects were similar for both treatments in Trial 2, but in Trial 3 interactions were larger and appear related to the proportion of grass in the rations. It is possible that the magnitude of the interactions in Trial 3 is inflated because of the depressed intakes of Tama in this trial, apparently due to its low DM percentage (Section 4.4.1). If this is the case, then the 'expected' Dig DM intakes of the mixed rations used in the calculation of the associative effects may be low, and not indicative of their true nutritive value. Whatever the true values, all interactions (in both trials) appear highly significant in terms of the nutritive value of the mixed rations.

Table 4.2: Associative effects on the digestible dry matter intakes ($g/kg\ BW^{.75}$) of the mixed rations in Trials 2 and 3.

Trial	Treatment	t_1	t_2	t_3	t_4
2	Dig DM intakes	51.5	64.8	70.8	66.5
	'Expected intakes'	51.5	54.5	59.7	66.5
	Associative effect	-	10.3	11.1	-
	Percentage increase	-	19.0%	18.6%	-
3	Dig DM intakes	51.9	68.5	80.7	66.5
	'Expected intakes'	51.9	54.7	54.6	66.5
	Associative effect	-	13.8	21.1	-
	Percentage increase	-	25.2%	35.4%	-

The most significant effect in Table 3.13 and in Fig 3.5 is the elevation of Dig DM intakes achieved by the supplementation of maize silage with 20% grass. The Dig DM intakes of this ration are comparable to those of grass fed alone, and whilst the response to grass supplementation in Trial 2 appears largely due to the increased intake of the mixed ration, in Trial 3 the improvement is due to the upholding of an otherwise declining digestibility of the silage component. In long term feeding trials the latter effect is likely to be the predominant influence of low level grass supplementation and probably reflects the nutritional inadequacy of maize silage when fed as a sole feed, the grass providing sufficient CP to allow normal digestive function. In both trials the Dig DM intakes of rations containing 55% grass were well above those of other treatments, however, the outstanding intakes achieved in Trial 3 suggest the response to be highly correlated with grass quality and palatability. It is possible that when grass is offered at low levels its protein content but not palatability is the critical factor, but with higher levels palatability and other 'quality' factors have a major influence on the Dig DM intakes.

4.4.3 Energy Intakes of the Steers in Trial 2

Data obtained from the six steers (Tables 3.16 and 3.17) which were harnessed for urine and faeces collection in Trial 2, enables a comparison of the rations to be made with findings of other workers. The daily DE intakes were 207, 294 and 339 kcal/kg BW$^{\cdot 75}$ for treatments 1, 2 and 3 respectively, whilst the corresponding ME intakes were 166, 244 and 277 kcal/kg BW$^{\cdot 75}$. Braumgardt (1970) presents findings of two workers who fed diets containing a range of DE contents to steers and recorded maximum DE intakes of 316 and 308 kcal/kg BW$^{\cdot 75}$, and McCullouch (1969) recorded maximum ME intakes of 256 kcal/kg BW$^{\cdot 75}$ from steers fed a range of hay and concentrate rations.

Comparison of the results obtained in this trial with those of Braumgardt (1970) and McCullouch (1969) show the intakes of the all silage ration to be markedly inferior, those of the 20% grass ration to be similar, and the intakes of treatment 3 to be considerably higher than their findings. It would be inadvisable to extend the findings from these steers to the remainder of the experiment but there is little doubt that intakes of treatment 3, particularly in Trial 3, were exceptional, whilst intakes of the all silage ration, in both trials, were quite low. The 20% grass ration appears similar to the maximum intkes recorded by other workers feeding balanced rations to growing steers.

4.4.4 Possible Effects of Ration Crude Protein Content

Improved performance has been demonstrated in young growing cattle when the CP content of the ration was higher than levels suggested in the feeding standards. For example, several workers have demonstrated maximum rates of gain in 200 - 250 kg cattle when fed rations containing 14 - 15% CP (Zimmerman et al, 1961; Fotenot and Kelly, 1963; Hammes et al, 1967; Haskins et al, 1967; Morris et al, 1967; Kay and Macdermaid, 1973; Wilkinson et al, 1973). When fed rations containing higher levels of CP (16 - 19%), 200 - 250 kg cattle generally exhibit near maximum rates of gain, but the performance of heavier animals is frequently depressed (Erwin et al, 1961, 1963; Kay et al, 1968; Kay and Macdermaid, 1973; Wilkinson et al, 1973).

Font

D

Crude protein has been implicated throughout the discussion as the principal factor responsible for declining silage digestibilities and is the principal nutrient supplied through grass supplementation of the silage. Although it may be a chance effect, digestible DM intakes increase in relation to the CP content of the ration in all treatments, except t_4 which is probably limited by other factors. The respective CP percentages of t_1, t_2 and t_3 (Trial 2), and t_2 and t_3 (Trial 3) are 9.9, 11.2, 14.6, 12.6 and 18.3, whilst the corresponding Dig DMIs are 51.7, 64.8, 70.8, 68.5 and 80.7 g/kg BW$^{\cdot 73}$. A correlation co-efficient of 0.96 ($P<0.01$) was calculated between these two sets of data (Snedecor and Cochran, 1971). However not too much weight should be placed on this relationship because many other factors may have influenced Dig DM intake.

4.4.5 Conclusion

Both the proportion of grass in the ration and the quality of the grass supplement had marked effects on voluntary intakes of the rations. Intakes of the all silage rations were consistently below those of the mixed rations, and whilst the intakes of the all grass and 20% grass treatments were similar in Trial 2, the all grass ration fed in Trial 3 was consumed at levels below that of the all silage ration. The depressed intake of Tama fed alone may have been due to its very high moisture content. Voluntary intakes of treatments 1, 2 and 4 were nevertheless similar to the findings of other workers using comparable rations, but exceptionally high intakes were recorded with treatment 3, particularly in Trial 3, which are difficult to account for.

The most realistic evaluation of ration nutritive value is probably made by comparing their digestible dry matter intakes. This form of expression reveals the gross inadequacy of maize silage fed as a sole diet, compared to the other treatments, and demonstrates the superiority of the treatment 3 ration. These trends were also apparent for DE and ME intakes calculated from the harnessed steers in Trial 2. The Dig DM intakes of the all grass treatments, and the treatment 2 rations, were all similar, and the responses resulting from 20% grass supplementation of the silage were quite spectacular when compared to the Dig DM intakes of the all silage rations. There were marked associative effects in the mixed rations fed during both trials, but because of the depressed intakes of Tama fed alone, some caution was required in their interpretation.

The discussion suggests that there may be two types of response to grass supplementation. Low levels of supplementation appear to act primarily through a correction of the nutritional deficiencies of maize silage, in which case the crude protein content of the grass would be crucial whereas other factors, such as palatability, would be of lesser importance. Responses to higher levels of supplementation appear more dependent on grass 'quality and palatability factors' and less on the ration crude protein content. This relation is demonstrated by the divergent results between treatments 2 and 3 in Trials 2 and 3, as presented in Fig 3.5.

4.5 LIVE WEIGHT GAIN

Although live weight gain is the ultimate criterion for ration evaluation, daily gains are only featured to a minor extent in this discussion. Inaccuracies arising from the short duration of the experiment, variations in grass quality, and confounding influences resulting from dietary changes (which affect live weight determinations) all combine to increase the probability of error in the live weight gain data.

The daily gains of animals fed the all silage ration (0.58 kg/day) are comparable to findings of Smith (1973), whose cattle gained at 0.53 kg/day, but are lower than the findings of other workers reported in Table 1.3. However, variations in size and condition of the animals, the duration of the feeding periods and the CP content of the silages used in other experiments could have marked effects on rates of gain, so such comparisons have limited meaning. The daily gain of the cattle fed treatment 2 (0.70 kg) is similar to the findings of Bryant (1971), who fed younger cattle maize silage supplemented with approximately 25% grass, and recorded gains of 0.60 and 0.63 kg/day. No data is available from experiments using rations similar to t_3, so it is not possible to compare their rate of gain (0.83 kg/day) with other findings.

The close relationship between live weight gain (LWG) and Dig DM intake of the individual animals in Trials 1, 2 and 3 ($r = 0.70$, $P < 0.01$) is illustrated in Fig 3.8, and the point at which the regression line intercepts the Y axis corresponds to the maintenance requirement for these animals. This level is similar to the maintenance requirements suggested by Ruakura workers. However, assuming this level of maintenance (40 g Dig DM/kg $BW^{.75}$) is applicable to all treatments, then the intakes surplus to maintenance, derived from Table 3.13, would suggest that rates of gain in treatments 2 and 3 should be approximately 2 and 3 times those of the all silage ration. Although this may be an overestimate, it is apparent that the daily gains recorded for treatments 2 and 3 (0.70 and 0.83 kg respectively) underestimate the nutritive value of the rations.

It would appear that errors arose through inaccuracies in live weight measurements, resulting from changes in gut fill and rate of passage. All cattle were fed the all silage ration prior to Trial 2, but they were not all returned to a common ration prior to weighing at the conclusion of the experiment. Hence the extent of the underestimation of daily LWG with the mixed rations may be related to the proportion of grass in the rations, however daily gains of cattle in treatment 1 should be relatively unbiased.

In conclusion, the measured live weight gains (Table 3.18) appear to underestimate the superiority of the mixed rations, relative to each other and to the all silage ration. The daily gains for cattle receiving the all silage ration appear to be realistic, but on the basis of the Dig DM intakes, the animals receiving the 20% grass ration might have been expected to gain 0.8 - 0.9 kg/day; whilst cattle receiving the 55% grass ration should have gained in excess of 1 kg/day.

CHAPTER FIVE

GENERAL CONCLUSIONS

In the comparison of fine (conventional) and coarse chop silages, the fine chop silage had a lower digestibility (NS) and passed through the animals more quickly, the mean retention time of the feed residues being significantly lower ($P < 0.01$). However intakes of the fine chop silage were greater than those of the coarse chop, possibly because the fine chop silage was more mature. Hence the responses to fine chopping may have been due, at least in part, to intake and maturity differences, which made an evaluation of fineness of chop per se impossible.

At the beginning of the experiment the digestibility of the silage was similar to comparable data reported in the literature. The digestibility was lower than values recorded by other workers for protein supplemented silage, and furthermore, the digestibility declined at an increasing rate as the experiment progressed. However, cattle fed silage supplemented with 20% grass had a constant digestibility over the duration of the experiment, so that the low CP content of maize silage was implicated as being primarily responsible for its low and declining digestibility. Therefore maize silage cannot be regarded as a satisfactory diet for young growing cattle.

Grass supplementation of the silage at both the 20% and 55% levels resulted in high digestible DM intakes. The largest response in ration digestibility, to an increased proportion of grass in the ration, was obtained with the 20% level of supplementation. Interpretation of voluntary intakes was made difficult by soil contamination of the mixed pasture, but in most instances the intakes of mixed rations were greater than those of silage or grass fed alone. Cattle fed the 55% level of grass supplementation had much higher intakes than those receiving the 20% grass rations.

The digestible DM intakes of the silage ration were approximately 27% lower than those of the all grass rations. Cattle fed the 20% grass and all grass rations had similar Dig DM intakes, but intakes of those fed the 55% grass rations were much higher. The response to the 20% grass supplement appeared to be mainly due to the raised digestibility, but the responses to the higher level of supplementation were more closely related to increased intakes. Hence it is suggested that low levels of grass supplementation acted through the provision of adequate crude protein, but when protein requirements were satisfied, responses to higher levels of grass became increasingly dependent upon grass quality.

APPENDIX I

A Diary of Events

Date	Event
10.11.71	Maize planted.
20.3.72	Cattle were selected for use in the experiment and weighed.
10-11.4.72	Harvest and ensiling of the maize crop.
20.5.72-6.6.72	Cattle offered maize silage free choice, initially in the paddock and later in cattle yards which served to harden their feet, and enabled frequent handling. Animals were drenched and weighed during this period.
7.6.72	Cattle introduced to feeding barn and allocated stalls at random.
7-14.6.72	Coarse chop silage was fed ad libitum as a sole diet to those animals used in Trial 1, to determine their intakes so as to calculate restricted feeding levels in Trial 1. These animals were dosed daily with chromic oxide.
15.6.72	Feeding of fine and coarse chop silages at restricted intakes prior to Trial 1.
17-30.6.72	Duration of Trial 1 (restricted intakes).
20 & 21.6.72	Faeces collected for kernel passage determination.
27.6.72	Cattle fed treated silages for rate of passage determinations.
1-3.7.72	All cattle fed fine chop silage ad libitum.
5.7.72	Cattle weighed after a 16 hour overnight starve.
10-20.7.72	Duration of Trial 2. Steers were harnessed for faeces and urine collection during this period.
22.7.72-5.8.72	Duration of Trial 3.
8.8.72	Cattle weighed after a 16 hour overnight starve.
	Conclusion of Experiment.

APPENDIX II

Maize Silage Yield Data

The following data, and those in Table 3.2, were obtained from samples of the maize used to produce the fine chop silage. Six samples, each of 1.5 m row length, were taken from different parts of the crop four days prior to harvesting. They were weighed, separated into their components, reweighed, and then chopped and dried in a forced draft oven at 80°C for 48 hours (grain and cobs for 72 hours). Mean DM was 27.7%.

Table II(i): Components of fresh maize plants, and their dry matter contents (%).

Component	Component Percentage of the Whole Plant (Wet Matter Basis)	Dry Matter Percentage of the Components
Grain	20.6 ± 0.6	
Cob	6.8 ± 0.2	49.4 ± 1.1
Husks	11.1 ± 1.0	24.5 ± 0.7
Leaves and Sheaths	23.0 ± 0.6	23.4 ± 0.9
Stem	38.5 ± 0.9	16.8 ± 0.8

Table II(ii): Total crop and component yields on a dry matter basis.

Component	DM Yields (kg/ha)
Total	19,500 ± 1100 (17,400 ± 1000 lb/acre)
Grain	7,300 ± 400
Leaf and Sheaths	3,600 ± 350
Stem	4,400 ± 300
Cob and Husks	4,200 ± 400

APPENDIX III

Basis for Mineral Supplementation Levels

The daily requirements for calcium (Ca), sodium (Na) and phosphorus (P), according to ARC (1965), are presented in Table 1.8. As discussed in the review, the phosphorus content of maize silage appears adequate, so only Ca and Na levels of supplementation are considered below, however the inclusion of steamed bone flour (10% P) in the supplement ensured that the P requirement was met.

Calculated mineral intakes in Table III(i) assume DM intakes of 2% BW, and is based on a Ca and Na concentration of 0.30% and 0.03% in maize silage (Morrison, 1957; Joint United States-Canadian tables of feed composition, 1959; NRC, 1970) whilst the Ca and Na levels in mixed pasture are assumed to be 0.50% and 0.15% respectively (Wilson et al, 1969; Grace and Wilson, 1972).

Table III(i): Expected daily intakes of Ca and Na (g) of cattle fed the specified rations at 2% BW.

Live Weight (kg)	Mineral	Maize Silage : Pasture Ratios			
		100 : 0	80 : 20	45 : 55	0 : 100
200	Ca	12.0	13.6	16.5	20.0
	Na	1.2	2.1	3.8	6.0
300	Ca	18.0	20.4	24.6	30.0
	Na	1.8	3.2	5.7	9.0

The expected intakes (Table III(i)) were compared with the expected requirements (Table 1.8) and the Ca and Na deficits are presented in Table III(ii). The amounts of bone flour and rock salt required as a supplement are given in Table III(iii), and these levels were supplied to the animals during the experiment.

Table III(ii): Expected calcium and sodium deficits in cattle fed the specified rations at 2% BW, based on requirements for different rates of gain (Table 1.8). Data in g/day.

Maize Silage : Pasture Ratio	Live Weight (kg)	Daily Live Weight Gain (kg)					
		0.33		0.05		1.0	
		Ca	Na	Ca	Na	Ca	Na
100 : 0	200	2.0	2.7	6.0	2.9	18.0	3.6
	300	-	3.8	3.0	4.0	15.0	4.5
80 : 20	200	0.4	1.8	4.4	2.0	16.4	2.7
	300	-	2.4	0.6	2.6	12.6	3.3
45 : 55	200	-	0.1	-	0.3	13.5	1.0
	300	-	-	-	0.1	8.4	0.8
0 : 100	200	-	-	-	-	10.0	-
	300	-	-	-	-	3.0	-

Table III(iii): Amounts of steamed bone flour (30% Ca) and rock salt (40% Na) required to meet calcium and sodium deficits in 300 kg cattle fed at 2% BW and gaining 1 kg/day.

Maize Silage : Pasture Ratio	Steamed Bone Flour (g/day)	Rock Salt (g/day)
100 : 0	50	15
80 : 20	50	15
45 : 55	30	5
0 : 100	-	-

APPENDIX IV

Statistical Analysis of Trial 1 Data

The model used for these AOV analyses is presented in Section 2.5.1.

Table IV(i): AOV for dry matter digestibilities.

Source	df	ss	ms	F
TRSS (Ha)	7	40847.6752		
TRSS (Ho)	6	40837.8337		
Difference	1	9.8415	9.8415	1.27 (1,3)
ESS (Ha)	3	23.2376	7.7459	NS
Total	10	40870.9128		

Table IV(ii): AOV for organic matter digestibilities.

Source	df	ss	ms	F
TRSS (Ha)	7	44444.1552		
TRSS (Ho)	6	44432.4562		
Difference	1	11.6990	11.6990	1.21 (1,3)
ESS (Ha)	3	28.9509	9.6503	NS
Total	10	44473.1061		

Table IV(iii): AOV for mean retention time data.

Source	df	ss	ms	F
TRSS (Ha)	8	26298.2825		
TRSS (Ho)	7	26242.3825		
Difference	1	55.9000	55.9000	38.11 (1,4)
ESS (Ha)	4	5.8675	1.4669	Sig @ 1% level
Total	12	26304.1500		

APPENDIX V

Combination of Intra and Inter Block Information from the Balanced Incomplete Block Design

When the block mean square (BMS) is greater than error mean square (EMS) in the intra block analysis of the balanced incomplete block design (BIB), then information from both the intra and inter block analyses is combined to provide a more sensitive analysis. The method by which this information is combined, based on Kempthorne (1962), is described below and uses data from the dry matter digestibility analysis (Trial 2) to aid in the explanation.

Throughout this appendix the subscript 'B' refers to the inter block analysis, and the subscript 'I' refers to the intra block analysis.

Data from the 'blocks eliminating treatments' regression AOV is used to estimate inter block variance of the treatment comparison, in this example $(t_2 - t_1)$.

$$\mathrm{Var}\ (\widehat{t_2 - t_1})B = \frac{Cjj}{k}\ (k\,\sigma_b^2 + \sigma^2)$$

where Cjj is a constant = 4 (Townsley, pers. comm.)

k = plots / block (2)

σ_b^2 = Eb_i^2 - b_i's are assumed to be random variables and are IID $(0,\sigma_b^2)$

σ^2 = errors independent of the b_i's IID $(0,\sigma^2)$

This expression simplifies to Var $(\widehat{t_2 - t_1})_B = 2(\widehat{2\sigma_b^2 + \sigma^2})$

The BMS and EMS data are combined according to the following formula (Kempthorne, 1962):

$$\frac{k\ (b - c)\ (BMS)\ -\ (t - k)\ (EMS)}{bk - t - k(c - 1)}$$

where: b = no. of blocks (6)

t = no. of treatments (3)

k = plots / block (2)

c = no. of reps (2)

This expression simplifies, using the stated values for b, t, k and c, to

$$\frac{8(\text{BMS}) - (\text{EMS})}{7} = (2\sigma_b^2 \,\widehat{+}\, \sigma^2)$$

The BMS and EMS values for the $(t_2 - t_1)$ comparison in the blocks eliminating treatments regression are:

BMS = 23.643092
EMS = 6.8092267

these combine so that: $\dfrac{8(\text{BMS}) - (\text{EMS})}{7} = 26.04793$

and as $\text{Var}\,(t_2 \,\widehat{-}\, t_1)_B = 2(2\sigma_b^2 \,\widehat{+}\, \sigma^2)$

$$\text{Var}\,(t_2 \,\widehat{-}\, t_1)_B = 52.0958598 \qquad = \underline{\underline{\sigma_B^2}}$$

The intra block variance for this treatment comparison is derived from its standard error in the intra block regression analysis.

$$\text{se}\ (t_2 \,\widehat{-}\, t_1)_I = 2.13060610$$

$$\therefore\ \text{Var}\,(t_2 \,\widehat{-}\, t_1)_I = 4.53948235 \qquad = \underline{\underline{\sigma_I^2}}$$

These inter and intra block variances (σ_B^2 and σ_I^2 respectively) are used in the calculation of the weights for the combining the regression co-efficients, and in the determination of the 'combined' standard error.

The intra and inter block weights (W_B and W_I respectively) are calculated as follows (Townsley, pers. comm.):

$$W_I = \frac{\sigma_B^2}{\sigma_B^2 + \sigma_I^2} = 0.9198472$$

$$W_B = \frac{\sigma_I^2}{\sigma_B^2 + \sigma_I^2} = 0.0801528$$

the regression co-efficients in this comparison $(t_2 - t_1)$ were:

$$(t_2 \,\widehat{-}\, t_1)_I = 8.7700$$

$$(t_2 \,\widehat{-}\, t_1)_B = 13.00$$

The combined regression co-efficient is determined by:

$$(t_2 - t_1) = \frac{\sigma_B^2 \, (t_2 \widehat{-} t_1)_I \; + \; \sigma_I^2 \, (t_2 \widehat{-} t_1)_B}{\sigma_B^2 + \sigma_I^2}$$

$$(t_2 - t_1) = \underline{\underline{9.109046}}$$

The standard error, used to determine the 't' value of this combined regression co-efficient, is determined by weighing the respective variances and taking their square root.

$$\text{se } (t_2 \widehat{-} t_1) = \sqrt{W_I^2 \; \sigma_I^2 + W_B^2 \; \sigma_B^2}$$

$$\text{se } (t_2 \widehat{-} t_1) = 2.0434358$$

$$\therefore \; t = \frac{9.109046}{2.0434358} = 4.46, \text{ 8df}$$

$$= \text{sig at the } 0.5\% \text{ level}$$

The 't' value determined from the intra block analysis of this treatment comparison (ignoring the inter block effects) was 3.561, which was significant at the 0.738% level. Although in this particular example the significance level is only slightly increased (lowered probability) by combining the two sets of information, a comparison of the 't' values demonstrates its merit.

ABBREVIATIONS USED IN THE TEXT

AOV	Analysis of variance
ASP	Autumn saved pasture
BIB	Balanced incomplete block
BW	Body weight
CF	Crude fibre
CP	Crude protein
CRD	Completely randomised design
Cr_2O_3	Chromic oxide
DM	Dry matter
Dig DM	Digestible dry matter
DE	Digestible energy
EE	Ether extract
I	Intake
LW	Live weight
Mcal	Megacalorie
ME	Metabolisable energy
N	Nitrogen
NE	Net energy
NFE	Nitrogen free extract
OM	Organic matter
t_1	treatment one (all silage)
t_2	treatment two (20% grass)
t_3	treatment three (55% grass)
t_4	treatment four (all grass)

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