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**Physiological Criteria for Improvement of
Production Efficiency in Beef Cows Subjected to
Nutritional and Environmental 'Stress' Due to
Fluctuating Seasonal Grazing Conditions**

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ABSTRACT

The behavioural and physiological characteristics of beef cows grazing seasonal Mediterranean range was studied under different stocking rates and feed supplementation regimes in Israel and the USA. The fluctuating range conditions, as well as the supplementation treatments created a range of management situations that included periods of feed scarcity when the cows were subjected to nutritional stress, especially during the summer dry season and the autumn transitional season. The performance of the animals as well as their behavioural and physiological responses were monitored over three years.

It was found that superior beef cows do have identifiable physiological characteristics that may have potential value for selection. In particular, low lactic dehydrogenase and glucose together with high Mg levels in the blood of dry cows during the dry season appear to be related to superior performance over the three year study period. Response of animals to imposed treatments was dampened by interactions with pasture quality and availability so that it was not possible to identify specific responses to nutritional stress per se in the data of our experiment. High quality supplementation during the periods of poor pasture quality did improve performance, but only to a limited extent because of significant replacement of pasture by supplement intake and because of greater energy expenditure. On the other hand, low energy supplement failed to eliminate the effect of heavy stocking rates on herd performance, while deferment of grazing during the autumn transitional period, even with supplementation, can deprive beef cows of highly nutritious feed and offset some of the later benefits of deferment.

Characteristic values of a range of blood parameters of beef cows grazing Mediterranean pasture at heavy stocking rates and with low energy concentration supplementation were established. Additional results and conclusions are given in detail in the body of the report.

Objectives of original research proposal

- a) To establish the physiological and behavioural response of beef cows to feed scarcity from range and low levels of supplementation while grazing under harsh environmental conditions;
- b) To determine physiological and behavioural indices that could be used to identify nutritional stress in beef cows. These indices could help formulate supplementation strategies for more efficient beef production from limited range resources.

Part 1. INTRODUCTION

Beef production on the range depends on the number of cows in a herd and on production per cow, which is determined largely by the amount of nutrients available for production after meeting maintenance requirements. As grazing pressure increases, these factors come into conflict with each other as production per cow drops due to increasingly severe nutritional deficiencies. Nutritional stress can be aggravated by environmental stress, like summer heat, when temperatures prevailing in the area are not favorable for physical activity. Water limitation, under some range conditions can prevent optimal production from existing food resources. Under Israeli conditions the calving season is in autumn and "stress" can be increased by cold and wet conditions in the beginning of winter. It is often observed that as "stress" increases differences in response between individual animals become greater. Some animals maintain condition, while others lose condition rapidly (Rowlands, Payne, Dew and Manstone, 1974). The animals that are adapted to the harsh conditions are also more productive and often more efficient feed converters. If the physiological and behavioural characteristics of such animals are known, it may be possible to identify animals more suitable for systems where nutritional and environmental "stress" is common. Such are most range pastoral systems of the world where-ever the range is fully used. Comparatively little is known about the physiological and metabolic characteristics of grazing animals that perform under "stress". Information on their feed intake, blood profile, water turnover and energy balances should facilitate identification of variations in physiological responses to nutritional stress among animals in a herd. Such information could guide management and supplementation practice under "stress" conditions and thus contribute directly to more efficient beef production.

1.1. Stress and beef production on the range

Beef production from range is characteristically subject to fluctuations in feed availability and quality of forage. Dry matter intake is often limited by total feed available, terrain or inaccessibility of range forage and palatability.

The digestibility of grazed herbage varies considerably through the year. Pasture quality decreases with maturity so that dry season feed has low digestibility and low protein concentration. Decrease in digestibility reflects not only the seasonal effect on plant composition, but also the effect of continuous selection of better quality feed by the herbivore. This effect increases with grazing pressure. The primary requirement in ruminant nutrition is for dietary energy (Blaxter, 1967; Crampton (1956). However, there is also a minimum protein requirement for the microbial breakdown of ingested food in the rumen, which has been estimated, as 6 to 8.5% crude protein in the feed (Blaxter and Wilson, 1963; Minson and Milford, 1967). If the dietary protein concentration is below this level, intake will be reduced. As full supplementation is often impractical, protein requirements cannot always be met. Under such conditions animals are sometimes "stressed" nutritionally for varying periods of time. These "stress" periods often occur under environmentally unfavourable conditions, and can be aggravated by heavy grazing, early calving and the increased requirements for lactation. Maximum profitable production from a ranch generally involves relatively high animal population density, so that frequent stress is virtually unavoidable under extensive production conditions.

The term "stress" is derived from the physical sciences, where it refers to an external force that acts on an object and induces some change, i.e. strain, in the object (Finch, 1983). In animal production terms, "strain" refers to adverse physiological effects which ultimately result in a decline in production, reflected by weight loss or infertility.

Frazer, Ritchie and Frazer (1975) have proposed the following definition: "An animal is said to be in a state of "stress" if it is required to make abnormal or extreme adjustments in its physiology or behavior in order to cope with adverse aspects of its environment and management. A husbandry system can be said to be stressful if it makes abnormal or extreme demands on the animals".

The adaptive changes in the domesticated herbivore to fluctuating nutritional situations must have developed during natural selection prior to domestication. Changes in nutritional status represent a challenge to the ability of the animal to maintain physiological homeostasis. The extent to which an animal retains energy is determined by the balance of its energy budget. Since the various components of environment affect both the inputs and outputs of energy, the level of energy retention may be regarded as an integration of the diverse effects of environment variation. Under extensive grazing, the most important buffer to variations in food supply is the animal's ability to store in its body tissues, nutrients that are ingested in excess of its immediate requirements during times of plenty and to mobilize them in times of scarcity (Fuller, 1976). But, when animals compete for limited amounts of pasture forage, the result is a low level of production per animal.

In many situations, grazing beef cattle suffer from a deficiency of both energy and protein supply which in some instances may be compounded by shortages of minerals, vitamin and other elements. During dry seasons, herbage has a low content of phosphorus and sodium and is almost entirely devoid of carotene, the animal's natural source of vitamin A. Deficiencies of either phosphorus or vitamin A are known to have an adverse effect on fertility. In the growing heifer, the main effect of under-nutrition is to delay the onset of sexual activity.

Lamond (1970) indicates that there is a genetically determined size at which puberty will be reached in each individual. Under-nutrition increases the time taken to reach this weight, and, hence, influence the age of puberty. Joubert (1963) has shown that

there is an inter-relationship between body weight and age of puberty in heifers. Turman, Pope, Watkin, Pinney, McNutt and Stephens (1963) found that when heifers reached puberty they needed to continue to gain weight in order to maintain regular oestrus cycling. Under poor nutritional conditions that are frequently found with extensive grazing, postpartum infertility is a very serious problem.

It has been shown that the physiological response to stress in a cow will be expressed in her metabolic profile (Torrel *et al.*, 1974). The assessment of stressor agents is related to the homeostasis of several physiological mechanisms. This evaluation may involve a number of different measurements including behaviour, blood constituents, body composition and others. Evaluation of stressor agents may be related to performance records which reflect the integrated effect of all the stressful and beneficial environmental influences (Wilson, 1971). Data such as body weight changes, feed intake, fertility of the cows and weaning weight may be used as bioassays to evaluate the effect of stressor agents. Correlating such data to a large number of behavioral, morphological or physiological characteristics, should identify which indices can be used to help formulate supplementation strategies for more efficient beef production under fluctuating range conditions.

1.2. Objectives of the research The hypotheses which were tested in the present study were the following:

- a) There are significant individual differences between animals in the values of the critical parameters relating to intake, conversion efficiencies, and maintenance requirements under seasonally difficult grazing conditions that are reflected in measurable physiological responses, mainly blood characteristics and fat storage, and possibly in morphological features such as body size and in behavioral characteristics.

- b) Such measurable parameters can be related to long-term performance of the cow as reflected by the length of the period between calving and by the weaning weight of the calf.
- c) A reliable and measurable relationship between some parameters and performance in individual cows will facilitate the prediction of performance for selection purposes or the determination of critical nutrient deficiencies (for supplementation purposes). In both cases, efficiency of beef production from the basic pasture resource should be increased.

The scientific and applied objectives of the research were thus:

- a) To investigate the relationship between performance and the physiological and behavioral response of beef cows subjected to seasonal stress under free range conditions.
- b) To determine whether such a relationship could be used to identify nutritional stress in beef cows and help formulate supplementation strategies for more efficient beef production from limited range resources.
- c) To determine whether such a relationship could be used to identify superior animals better able to cope with unavoidable stress.

In order to attain the objectives of this study, a comprehensive set of measurements was carried out on herds of experimental animals, grazing under different levels of stress. These measurements were analysed in terms of various measured criteria related to performance and productivity.

PART 2 - PLAN OF RESEARCH

2.1. Israel

2.1.1. The grazing trial

The trial was carried out on the Karei Deshe experimental range. Over hundred beef cows were allocated to four nutritional stress treatments imposed by heavy stocking rates (1.5-2.0 ha/cow) and low energy supplementary feed treatments. As the main stress period occurs after the heavy rains in autumn, the supplementation was geared to this period. Within each treatment the cows were of similar initial average body weight and condition. In order to ensure that at the beginning of the experiment the cows were in normal reproductive condition, all cows were with calf. The experiment continued for four years, covering three full production years and a fourth year until the end of the calving season.

2.1.2 Experimental site

The Karei Deshe experimental range is situated in the eastern Galilee between Safed and the Jordan River, just north of the Sea of Galilee (Lake Kinneret).

Climate and vegetation (including pasture seasons)

The climate is typically Mediterranean. Rainfall is limited to the winter months between October and April (Fig. 1). The average seasonal precipitation is around 600 mm. The coldest month is January, with minimum and maximum means of 7 and 14 C, respectively. The absolute minimum temperature seldom drops below 0°C. The hottest month is August with minimum and maximum means of 19 and 32°C respectively.

Fig. 1
Average monthly precipitation and average maximum and minimum monthly temperatures at the Kare Deshe Experimental Station.

The soil is a basaltic protogrumosol (Dan and Raz, 1970). Field capacity is about 33% (gravimetric) and wilting point is about 23%. Bulk density is 1.35. The outstanding features of the landscape are the hilly topography, overlain with basaltic rocks which cover about 30% of the surface. Most of the area is inaccessible to vehicles. The slopes are gentle and the cattle can graze most of the range. There is very little erosion from the basaltic protogrumosol (Morin et al. 1976).

The vegetation is classified as Mediterranean transitional batha (Zohary 1973), composed principally of hemipterophytes (Psoralea bituminosa, Echinops viscosus, Hordeum bulbosum). These species form 40-60% of the cover. The other botanical components include over 250 species, mostly therophytes, among which the following are prominent: Annual grasses: Avena sterilis, Hordeum ithaburensis, Bromus spp.; Perennial grasses (traces): Phalaris tuberosa, Dactylis glomerata; Legumes: Medicago polymorpha, Medicago rotata, Trifolium subterraneum, Trifolium pilulare; Forbs: Scabiosa prolifera, Scolymus maculatus, Carthamus glauca, Hirschfeldia incana, Anthemis spp., Linum strictum.

Seasonal development of this vegetation depends almost wholly on the rains. Only Psoralea bituminosa and Echinops viscosus begin to grow in October, before the rainy season starts. After the onset of the first effective rains, usually between mid-October and late November, the annuals germinate and the perennials emerge. The growing period extends until the end of April (or, rarely, until the beginning

of May), when most of the herbaceous vegetation dries up. Psoralea bituminosa stays green till the end of May. During the summer the only green species are Cynodon dactylon and Prosopis farcata. The latter is a thorny dwarf shrub occasionally eaten by the cattle. Some of the similarities and differences between this type of vegetation and the grasslands of California have been discussed by Naveh (1967).

Pasture availability and quality are more than adequate during the relatively short green season. Both the length of the adequate green season and the amount of biomass produced depend on the rainfall and are more variable the lower the annual rainfall.

After the first heavy rains, the residual dry vegetation decomposes quickly. The newly germinated vegetation is generally insufficient to maintain the cattle until 40 to 60 days after emergence or regrowth of perennial species. This period (from November to January) is a difficult transitional season, when supplementary feeding is generally practiced.

The protein content of the vegetation from June to December is low, sometimes as low as 4%. Protein supplements are necessary and poultry litter is used for this purpose.

The annual pasture cycle can be divided into four phases:

- a) The early green season between the first germinating rains and the establishment of a pasture capable of supplying satiation requirements of the grazing animal. In intensive systems a period of grazing deferment is needed to ensure that pasture reaches this level soon after the beginning of the green season.
- b) The effective green season, the period during which pasture availability and quality are normally sufficient to meet all nutritional requirements of the herd.

- c) The early dry season during which the pasture quality is lower than during the green season, but considerably higher than during the rest of the dry season. This period lasts for about half the length of the green season, but also depends on utilization intensity.
- d) The main dry season, which is the period between the end of the early dry season and the first rains, that generally reduce the residual dry feed in the pasture to a very low nutritional value.

2.1.3 Animals and management regime

The treatment herds were composed of about 60% cows of first crosses of Local Arab X European breeds (mainly Simmental) and about 40% backcrosses to Simmental and Charolais (not pure). All allocated cows had a relatively common history of grazing and nutritional management.

At the start of the experiment, the age of the cows was between 2 to 7 years. The breeding season was between November 15th and May 15th, and calves were weaned at the beginning of the dry season in June-July. One bull (Grade-Charolais) was allocated to every 24 cows. The bulls were rotated between the treatment herds, every month.

All the cows were vaccinated against Foot-and-Mouth disease and Rabies, the offspring against Blackleg and Rinderpest (cattle plague) and the heifers (2-7 month of age) against Brucellosis. The cows were also provided with vitamin A, by injection, during the dry season at the rate of 3000,000 IU per season.

2.1.4 Treatments

2.1.4.1. Stocking rate, grazing system and level of supplementation

Four nutritional stress treatments were imposed, three on cows that grazed yearlong, and one on cows in a deferred grazing system.

The nutritional stress levels were achieved by relatively high stocking rates and by various levels of supplementation during the autumn - early winter transitional period, as follows:

- a) High stress (HS) stocking rate, 1.5 ha/cow, yearlong grazing, and a low energy supplementary diet, of about 1.55 Mcal/kg D.M.,

consisting mainly of poultry litter and wheat straw. This treatment was conducted in two paddocks one 25.5 and the other 28.3 ha.

- b) Medium stress with deferment (MD) - stocking rate 1.5 ha/cow, but with grazing deferred from the first rains until pasture was well established (about 800 kg D.M. per ha of green forage). During deferment, cows were confined to a small area (about 0.2 ha/cow), only large enough to allow free movement and prevent stress from climatic influences such as excessive mud. The energy concentration of the supplements averaged 1.8 Mcal/kg D.M.
- c) Medium stress (MS) - stocking rate 1.5 ha/cow, yearlong grazing, and a supplementary diet of about 1.75 Mcal/kg DM. This treatment was conducted on a 27.2 ha area paddock;
- d) Low stress (LS) - stocking rate 2.0 ha/cow, yearlong grazing, and a supplementary diet of 1.8 Mcal/kg DM;

2.1.4.2 Feeding management and feed composition

The supplementary feed treatments were based on poultry litter (PL) for protein supplementation during the dry pasture period and poultry litter, wheat straw and some barley grain during the transitional period.

The early dry summer is generally not a critical period as the cows are not lactating and the pasture is usually sufficient for maintenance. Protein deficiency was corrected by PL supplementation, the commonly used nitrogen supplement for beef herds in Israel. In the experiment, where animals were kept at a high stocking rate, it was necessary to supplement with some roughage (wheat straw) to ensure maintenance. Supplemented feed was given ad libitum at the different energy concentrations, in wagon troughs. Feed was recorded and

consumption was calculated for each experimental herd as average per cow. As poultry wastes vary in crude protein and ash content, PL was analysed weekly during the supplementation period.

Poultry litter (PL) as feed for beef cattle: Recycling of PL by feeding is not sanctioned by the FDA (Food and Drug Administration) in the USA (Kirk, 1967; Taylor, 1971). However, despite these reservations it is widely used in many countries as a protein feed supplement, because of its low price and value as a feed, characteristics which enable higher production of high quality livestock products from extensive feed resources.

PL is an accumulation of poultry excreta, bedding, wasted feed and feathers. Poultry litter has been shown to be a valuable feedstuff for ruminants (Fontenot et al., 1966, 1971). It is usually high in nitrogen (crude protein). The main nitrogenous compound excreted in poultry urine is uric acid. Rumen microorganisms can utilize uric acid as a nitrogen source (Belasco, 1954). Results of investigations on the nutritional value of PL indicate variable digestibility (55-80%) of nitrogen of which about 1/3 to 1/2 is in the form of true protein (Bhattacharya and Fontenot, 1965 and 1966). The energy availability is generally lower (Bhattacharya and Fontenot, 1966, Lowman and Knight, 1970).

When poultry litter was used experimentally in practical beef cattle rations (Noland et al., 1955, Drake et al., 1966, Holzer and Levy, 1976) satisfactory performance was obtained and no serious trouble with animal health was encountered. It is today a common practice in Israel to feed poultry litter as a protein supplement, and in many cases as a sole supplement, during the dry season, when the cows are pregnant.

2.1.6 Feed composition

Monthly samples of pasture and supplement feed were taken for analysis of feed composition. As poultry litter varied, to a rather large extent, as for its ash content, samples were taken weekly. Chemical compositions of poultry litter were tabulated according to ash content (less than 20%, between 20-30%, and more than 30%).

Laboratory evaluation

Chemical analysis of feeds was carried out according to Association of Official Analytical Chemists (1970). Neutral detergent fibre (NDF) and acid-detergent fibre (ADF) and its components were determined by the procedures of Goering and Van Soest (1970). DM digestibility (DMD) in vitro was determined by the method of Tilley and Terry (1963).

Total digestible nutrients (TDN) for poultry litter and wheat straw was calculated using digestibility coefficients obtained in a former experiment (Holzer and Levy, 1976). Metabolizable energy content was obtained by calculation $[TDN (\%) \times 3.616]$.

The chemical composition of the supplement feeds is given in table 2.1 and of the mixed pasture in tables 2.2. and 2.3.

Table 2.1. CHEMICAL COMPOSITION OF THE SUPPLEMENT FEEDS (M±SD)
(ON DRY MATTER BASIS)

COMPONENT	FEED	POULTRY LITER			WHEAT STRAW	BARLEY GRAIN
		Ash content (%)				
		< 20 %	20 - 30 %	> 30 %		
		Percent of analyzed PL samples				
		36 %	52 %	12%		
Dry matter	(%)	82.93±3.53	86.02±3.26	88.54±1.32	89.6 ±1.0	88.63±0.55
Crude protein	(%)	28.0 ±2.25	19.74±3.14	16.23±2.37	3.22±0.48	13.08±0.62
Ether Extract	(%)	2.18±0.31	1.93±0.16	1.92±0.08	1.85±0.17	2.11±0.15
Ash	(%)	17.65±1.62	23.59±2.49	35.51±2.90	8.39±0.84	2.80±0.16
Crude Fiber	(%)	14.90±1.66	14.90±2.27	17.0 ±1.35	40.86±2.15	5.52±0.52
Nitrogen Free Extract	(%)	37.27±3.35	39.84±4.10	29.34±5.16	45.58±2.59	76.49±0.62
NDF (Cell Walls)	(%)	55.6 ±7.25	54.69±7.13	56.61±12.35	77.00±5.87	23.60±2.79
ADF	(%)	25.24±3.49	26.13±2.24	23.12±2.18	55.89±1.42	7.33±0.36
Cellulose	(%)	16.42±2.52	17.31±1.24	14.74±1.95	40.82±1.18	5.08±0.16
Lignin	(%)	7.18±1.29	6.55±1.32	6.10±0.71	12.37±2.19	1.91±0.21
In Vitro DMD	(%)	47.07±6.40	43.8 ±1.41	38.1 ±2.76	37.36±3.38	-
TDN	(%)	46.29±0.90	42.86±1.33	36.25±1.45	40.00±0.40	84.00 [@]
ME(calculated)-Mcal/kgDM ¹		1.67±0.03	1.55±0.05	1.31±0.05	1.45±0.05	3.04 [@]
Calcium	(%)	3.42±0.37	6.67±0.63	7.29±0.90	0.16±0.02	0.064±0.014
Phosphorus	(%)	1.85±0.18	2.34±0.11	2.32±0.10	0.07±0.004	0.37±0.03
Magnesium	(%)	0.54±0.05	0.59±0.06	0.61±0.06	0.13±0.007	0.19±0.02
Potassium	(%)	2.43±0.77	2.65±0.15	2.65±0.13	1.24±0.06	0.5 ±0.07
Sodium	(%)	0.42±0.16	0.55±0.04	0.57±0.06	0.14±0.07	0.035±0.01
Iron	(mg/kg)	1077 ± 301	2324 ± 283	2409 ± 278	179 ± 37	85 ± 51
Manganese	(mg/kg)	387 ± 63	465 ± 59	495 ± 70	33 ± 9.6	19 ± 1.92
Zinc	(mg/kg)	348 ± 41	323.5± 50	340 ± 52	8.48 ± 2.7	21 ± 2.4
Selenium	(mg/kg)	1.72	1.20	0.63	0.34	0.16

1 - ME weighted mean value for poultry litter = 1.56 Mcal/kg DM.

@ - According to NRC - 1984.

Part 3. MEASUREMENT OF FORAGE INTAKE

Introduction

The amount of feed that the grazing cow consumes voluntarily determines to a large extent the degree to which it can satisfy its nutrient requirements. Accurate measurements of pasture intake by grazing ruminants are valuable for evaluating animal performance and planning efficient supplementary feed practice. However, it is difficult to measure directly the feed intake by grazing ruminants. Direct measurements under field conditions are particularly problematic when the food intake of a large number of individual animals is to be determined.

Isotope dilution techniques such as tritiated water (TOH) dilution (Benjamin et al. 1977), may provide a relatively easy and accurate method of measuring feed intake of grazing animals, but may not be sufficiently precise to determine differences between individual animals. In the present study it was important to estimate food intake of the individual experimental cows. Consequently, a study was initiated to compare various methods of intake determination during the green and dry seasons.

3.1. Pasture intake estimation during the green season

3.1.1. Materials and methods

A validation trial was conducted to determine the suitability of three different techniques:

1. Water turnover, calculated from TOH dilution and water content of the pasture. When animals are grazing green pastures of high availability, their water intake from the pasture consumed and metabolized is usually enough to meet their requirements and no free water is drunk. If the water content of the pasture is known

then the dry matter intake for individual cows can be estimated by calculation from their measured water turnover (Benjamin et al., 1975). As under such conditions water turnover is directly related to dry matter intake, it is itself a useful relative measure of intake for comparing the intakes of individual cows.

2. Total fecal collection (TC). Intake can be estimated from the digestibility of pastures grazed by animals and fecal output. Among methods used to estimate intake it would appear that the most reliable data have been obtained where fecal output was determined by total collection and digestibility measured by in vitro analysis of grazed forage samples (Cordova, Wallace and Pieper, 1978).
3. Estimate of fecal output by means of a magnesium ferrite magnetic marker (Neumark et al. 1975).

Ten beef cows (six of them with suckling calves) taken from the experimental herds, were used to estimate green pasture intake, using the three methods.

1. Tritium Dilution Technique

The isotope used was tritiated water (Amersham) that was supplied in capsules with a radio-activity of 5 milli-curies per cc. To enable efficient counting in a Packard Liquid Scintillation counter, after dilution in the animal after up to six days, the tritium dosage were four micro-curies per kg animal liveweight.

As the cows weighed in the average up to 350 kg they were all dosed at a rate of 1400 micro-curies. Dosages per cows were prepared by diluting the tritium with 0.9% saline in isotonic solution to a dilution of 156 micro-curies per cc and than filling 12 cc syringes with 9 cc of the diluted tritium.

The syringes were then inverted and 3cc of air was then sucked in, to enable the flushing of the tritium through the needle at the time of injection. All syringes were then weighed on an analytical balance and sealed to prevent leakage during transport to the field.

Preparation of cows for injection: On the day to be injected cows were corralled at 11⁰⁰ a.m. together with their calves (it was not possible to separate the calves from the cows). After 4 to 5 hours fasting the cows were intramuscularly injected in the rump with tritium and left over night together with their calves in the corral without access to food or water. After injection syringes were resealed to prevent evaporation or spillage and reweighed.

The following morning, approximately 14-16 h after injection, blood samples were taken from the tails of the cows into heparinized test tubes. After bleeding the cows were weighed to the nearest kg. The blood samples were used to estimate TOH space in the cows. After weighing the cows were returned to their respective treatment paddocks. After two, four and six days respectively, at the same hours, the cows were again bled for samples to be used for estimating daily water turnover.

Laboratory

- a. Blood samples were centrifuged at up to 3,000 r.p.m. for 10 minutes and the separated plasma was transferred to clean labelled test tubes and sealed.
- b. About 0.25 cc of plasma was pipetted into a weighed volume of about 5 cc of scintillation cocktail (Instagel Packard). The exact weight of plasma was measured by weight difference on an analytical balance. Blank blood plasma samples from non tritium injected cows were also prepared for blood background counting.
- c. About 0.25 cc of a diluted sample (1:200) of the tritium solution injected was also added to 5 cc of scintillation as in b above and replicated six times.

- d. All samples to be counted for radio-activity were kept overnight in darkness in the scintillation counter before being counted twice each time for ten minutes.
- e. Resulting counts were corrected automatically in the scintillation counter for quench and background counts and manually for plasma DM content. Resulting counts were expressed as counts per minute per 1cc of body water.
- f. Counts from the samples of tritium injected were also corrected for quench, background and dilution and the results expressed as counts per minute per cc of tritium injected into the cows.

Calculation of TOH space in the cow: The determination of tritiated water space relies on the fact that tritiated water freely mixes with water in the body and that after 6-8 hours it has been evenly mixed with water in all the body spaces of the animal injected. In controlled experiments at Karei Deshe it was demonstrated from blood samples taken hourly between 4h and 8h after injection that equilibration in terms of radio-activity of the blood water took place at 6h. Generally blood samples were always taken at least 6h after injection. Calculation of TOH space in the animal is then determined from the dilution of the tritium injected, by dividing the radio-activity (counts per minute) of the tritium injected by the radio-activity of 1 cc of body water taken from the blood, at least 6h after injection. $Y = a \cdot R_1 / R_0$; Y = TOH space of the cow; a = amount of tritium injected, in cc; R_1 = counts/minute/cc of tritium injected; R_0 = counts/minute/cc of body water.

2. Total fecal collection

Because of the tediousness of the method - only four cows were harnessed with fecal collection bags, designed in a manner to enable calves to suck (fig.2). Inside the canvas bags there were plastic sacks which were replaced twice a day after weighing the faeces.

Urine was prevented from entering the collection bag by means of a catheter (Porges) (fig.3). The trial lasted 16 days, 10 days for adaptation and 6 days for data collection. The cows were permitted to graze in a paddock adjacent to the holding corral.

The fecal collection bags were emptied for weighing, twice a day, early morning and late afternoon. Digestibility was estimated in vitro (Tilley and Terry, 1963), from samples collected from an oesophageal fistulated cow. This cow was the only one, out of three fistulated animals, which permitted adequate sample collection. The oesophageal fistulation was carried out according to the method of Little and Takken (1970), modified by Cohen (1979).

Dry matter intake was estimated, from total 24 hours fecal output, according to Theurer (1970): $DMI(kg) = [Fecal\ DM\ output\ (kg) / (100 - \%IVDMD)] \times 100$.

3. Magnesium ferrite

Magnesium ferrite (MF) capsules were introduced twice daily (7⁰⁰ and 15⁰⁰ hours). At the same time, grab samples were taken, throughout the experimental period. The analysis of the faeces were carried out according to Neumark et al. (1975).

3.1.2. Results

Results are given in Table 3.1. Mean deviation from TC of the TOH estimates was 1.0 ± 1.1 kg. DM cow⁻¹ day⁻¹ and of the MF estimates 2.8 ± 2.8 kg. d.m. cow⁻¹ day⁻¹. The correlation between TOH and MF estimate was poor, $r^2 = 0.20$. Correlation between TC and both TOH and MF was not really meaningful with only 4 values of TC for the whole measurement period.

It should be noted that blank, fecal samples, analysed, were found to be high in ferrite. Therefore, MF was not a suitable marker for faecal output estimation at this site. As for the TOH results,

considering that there was no way of knowing the actual digestibility of the consumed forage of each cow, as they were foraging on a large area, the compatibility for three out of four cows between TOH and total faecal collection is acceptable.

Table 3.17 Pasture intake - green season

Cow No.	Live weight Kg.	Intake - Kg DM/24 hours				
		Total * Faecal collection	TOH **	Diff.	Magnesium ferrite ***	Diff.
1	318	9.85	10.40 $\pm$ 0.98	0.5	16.02	6.1
3	284		10.92 $\pm$ 1.58		12.98	
4	335	10.66	10.74 $\pm$ 1.26	0.1	12.99	2.3
7	291		10.09 $\pm$ 1.35		7.71	
673	376		12.30 $\pm$ 2.24		13.16	
35	323	10.29	11.23 $\pm$ 0.98	0.9	9.35	-0.4
200	260		8.02 $\pm$ 0.25		7.23	
226	272		9.24 $\pm$ 0.35		14.25	
246	172		6.25 $\pm$ 1.52		7.77	
55	323		10.20 $\pm$ 1.64		8.06	
111	307	9.64	12.38 $\pm$ 0.75	2.5	12.98	3.1
196	276		9.12 $\pm$ 0.90		10.77	
X ₄ $\pm$ SD		10.16 $\pm$ 0.39	11.19 $\pm$ 0.86	1.0 $\pm$ 1.05	12.96 $\pm$ 2.5	2.8 $\pm$ 2.67
X ₁₂ $\pm$ SD			10.0 $\pm$ 1.8		11.15 $\pm$ 3.0	

* Digestibility 72.6% - Dates of estimate 10/3 - 16/3/83.

** % DM of pasture 16% - Dates of estimate 8/3 - 17/3/83.

*** Digestibility of pasture 72.6% estimate 10/3 - 17/3/83.

Fig. 2 Cows harnessed for total fecal collection

3.2. Pasture intake estimation during the dry season

Introduction

When animals are grazing dry pastures their water turnovers are derived in the main from free water drunk and small amounts of water associated with the pasture and supplemental feed (PL) intake and their metabolism (metabolic water). Here the estimation of feed intake in dry pasture is dependent on a constant relationship between free water drunk and voluntary dry matter intake as found in sheep by Benjamin et al. (1977) and in beef cattle Siebert (1971), McFarlane & Howard (1972) and Hyder et al. (1968).

Intake can also be calculated from Na turnover. In mature animals Na retention is negligible and sodium turnover can be estimated with radioactive ^{22}Na . Green et al. (1978) have shown that the rate of sodium turnover is closely related to the sodium content of the vegetation consumed by herbivores. Consequently intake can be calculated from Na turnover once the concentration of Na in feed and water is known (Williams and Green, 1982). In the present study we compared the tritium dilution Na turnover techniques with actual intake determined on hand fed animals

3.2.1. Material and methods

Six dry cows, grades of Simmental and Hereford on the Local Arab breed were used. Before the experiment they grazed on natural dry summer pasture supplemented with poultry litter. Each cow was penned in a small yard and fed and watered individually. The cows had access to shade. The diet of the cows consisted of poultry litter and wheat straw, which were offered separately in different troughs, ad libitum. The water and the poultry litter troughs were placed in the shade and the wheat straw trough was placed in the open, in order to simulate paddock conditions during the summer.

Animals were given 30 days for adaptation to the experimental conditions, after which the intake of wheat straw, poultry litter, and water was measured daily for 14 days. Feed samples were collected throughout the 14 days and the chemical analysis were carried out according to methods, as described in part 2.

Six hours before the injection of the isotopes, feed and water were withdrawn. Blood samples were taken before injection for background counting. Each cow was injected intramuscularly with 7 ml of saline containing 150 μ ci 22 Na and 1400 μ ci of tritiated water (TOH). The cows were injected at 17⁰⁰h and weighed. The following morning at 7⁰⁰h blood samples were taken from the tail, by venipuncture into heparinized vacutainers, and the cows weighed again and allowed access to feed and water. During the following 10 days blood was taken by the same method once a day at 10⁰⁰h.

Blood plasma was prepared for separate counting of tritiated water and 22 Na activity in a liquid scintillation counter (Packard Tri-carb model 2002) by the procedure described by Williams and Green (1982). Water was squeezed out of the faeces and urine samples were also counted. Sodium concentration in plasma, fecal and urinary samples were determined by atomic absorption spectrometry (Instrumentation Laboratory, Video 22).

Total tritiated water space (TOH space) was calculated by regression analysis and sodium exchangeable pool by extrapolation. Water and sodium turnover rates were calculated by multiplying TOH space and sodium exchangeable pools with the respective constant fractional turnover rates.

Calculation of water turnover

This calculation is based on the work of Black et al. (1964) who demonstrated that following equilibration of tritium in the water (and the determination of TOH spaces) when the animal is allowed to freely graze and drink water, the natural logarithm of the radioactivity of

the body water falls linearly with time. That is: $\ln R_t = \ln R_o - bt$ (1), where $\ln R_t$ = natural logarithm of radioactivity of body water at time t following equilibration ; $\ln R_o$ = natural logarithm of radioactivity of body water at equilibrium time; b = rate of the loss of radio-activity. The rate b is calculated from Black et al. 1964, $b = 0.693/t_{1/2}$ (2). The constant 0.693 is based on equation (1). When $t_{1/2}$ replaces t , and represents the point in time when R_o is twice the radio-activity R_t , thus $\ln 0.5 = -bt_{1/2}$ (3) and $b = 0.693/t_{1/2}$; ($\ln 0.5 = -0.693$).

Water turnover than is the amount of water consumed (water drunk + water associated with feed consumed + metabolic water) to reduce the radio-activity of the body water measured at equilibration time, and can be calculated from the equation $Vt = b.M$ (4), where Vt = volume of water consumed after t days, and b = rate of loss of radioactivity.

Equation (4) is derived as follows $\Delta R/\Delta t = -VtRs$ (a), where $(-VtRs)$ represents the rate of loss of radioactivity of body water. To derive the specific radio-activity divide (a) by M (the amount of water in the body); $\Delta Rs/\Delta t = (-Vt/M)Rs$ (b), or $\Delta Rs/\Delta t = (-Vt/M)dt$, (c). The integrated solution of this equation is $Rs/Rso \int dRs/Rs = -Vt/M \int dt$; $\ln Rs - \ln Rso = (-Vt/M)t$; $\ln Rs = \ln Rso - (Vt/M)t$ (d)

Equation (d) is in fact equation (1) with the only difference that it relates to specific radioactivity. The rate of loss of radio-activity ($b=Vt/M$) in equation (1) is represented by $-Vt/M$ and therefore WTO can be calculated by bM in equation (4).

WTO can be determined more simply by regression analysis of the natural logarithm of the radioactivity of the body water with time, where the slope of the regression line is the rate of WTO and the regression constant is the logarithm of the radioactivity of the body water at equilibrium time. In this way total body water (in fact TOH space) can be calculated independently.

In our experiments WTO was determined by regression analysis using three blood sampling dates: 2, 4 and 6 days after equilibration time. TOH space was also determined from the regression equations and

was generally equal to that determined from tritium dilution. In cases of variation TOH space calculated by regression analysis was used.

Errors that could occur in calculating water turnovers are mainly in the determination of TOH space due to possible losses of tritium at the time of injection and losses of tritiated water in urine, faeces and respiration before equilibration time. For this reason TOH space as determined from regression analysis was used as representing the amount of water to be turnedover.

Estimation of dry matter intake from water turnover (WTO) rates measurement were made as follows:

$$(1) \text{ D.M.I.} = \text{WTO} \times \text{B/C}$$

Where D.M.I. is the dry matter intake, B is the fraction of water intake out of WTO rate and C is the ratio between water intake rate and feed intake.

Excretion of Na in faeces was partitioned into that of feed and endogenous origin by the scheme proposed by Blau et al., (1957) which was reconsidered and reviewed by Hurwitz (1972). They assumed that secretion precedes absorption so that the secreted Ca is absorbed at the same rate as that originating from feed. Calculation will also be true if secretion and absorption occur simultaneously at a relative constant rate along the gut. On the basis of large amounts of saliva, enriched with sodium, secreted to the rumen, it is assumed that the same holds for sodium.

The inflow of sodium into and out of the alimentary tract and its fraction of absorption can be calculated as follows:

$$(2) \text{ Vnet} = \text{VI} - \text{VF}$$

Where VI is the intake rate of Sodium, VF is the excretion rate of Na in faeces and Vnet is the net absorption of Na.

$$(3) \text{ VEn} = \text{NaS.F.} \times \text{VF/NaS.P.}$$

Where VEn is the excretion of endogenous Na in faeces, NaS.F. NaS.P. are the specific activities of sodium in faeces and blood plasma following equilibrium in body pools respectively.

$$(4) \quad V_a = V_{net} - V_{En}$$

Where V_a is the absorption rate of feed sodium.

$$(5) \quad d = V_a / V_i$$

Where d is the fraction of Na absorption.

$$(6) \quad V_{Al} = V / En(1-d)$$

Where V_{Al} is the inflow of Na to the alimentary tract.

Since the absorbance of the sodium is very high, it is assumed that sodium turnover is equal to sodium intake, and since sodium intake from water was found to be negligible in the present case, D.M.I. was calculated by the following equation:

$$(7) \quad D.M.I. = STO / Na_F$$

Where STO is sodium turnover rate and Na_F is sodium concentration in the feed consumed.

The data are reported as means $\pm$ standard errors of the means ($\pm$ SE). Estimation of feed intake by the isotopes dilution techniques were compared to actual feed intake with paired t-test procedure.

Fig. 3 Schematic representation of sodium homeostasis in adult beef cattle

3.2.2. Results

Animal live-weight: The mean body weight (BW) of the experimental cows at normal feeding state was measured 8 times during 6 weeks intervals of 4-7 days: 2 weeks before the experiment, during the experiment, and 2 weeks after the experiment. The respective BW were (n=6):

(1) 358±19, (2) 349±26, (3) 375±23, (4) 355±25, (5) 366±19, (6) 362±21, (7) 356±18, (8) 362±19 Kg. The BW in the six cows following 12 hrs of fast at the beginning of the experiment was 343±20 Kg and after 10 days was 342±21 Kg. The results indicate that there were no gains or losses of body weight during the experiment.

Feed consumption and digestibility: Total dry matter intake amounted to 2.6% of body weight (Table 3.3). On average, 59% of total feed intake was wheat straw and 41% poultry litter. The ratio between poultry litter/wheat straw intake varied between 0.67 - 0.85.

Total Body Water and Water Turnover: Total body water was 304L which was 84% of BW (Table 3.4). WTO Rate was on average 55L/Kg live weight / day and the tritium half life value ($T_{1/2}$) was 3.8 days (Table 3.4). The partition of TWO rate to its components of intake is shown in Table 3.5. Water intake rate accounted for 26.5% of the WTO rate and the rest were contributed by metabolic water production (10.2%) and feed moisture intake (3.2%). There were no significant differences between the measurement of WTO rate from tritiated water dilution and the sum of water measured as input rate (water consumption plus feed moisture plus metabolic water).

Sodium Concentration Total Exchangeable Pool (TES) And Turnover Rate (STO): Plasma sodium concentration was 140.7 mM/L. Total exchangeable sodium was 13185 mM or 159.9 mM/Kg $W^{0.75}$. Sodium turnover rate was 936 mM/day and $T_{1/2}$ of sodium was 9.7 days (Table 3.6).

Role of the alimentary tract in sodium homeostasis: A schematic representation of the role of the alimentary tract in sodium homeostasis is given in Figure 3.

Sodium intake was 101.5% of STO rates. In consequence of the high absorptability (98.5%) of sodium, 95% of the sodium secreted in faeces in concentration of 64 mM/Kg DM is of endogenous origin. Therefore, the amount of sodium secreted into the alimentary tract is 19 times greater than the amount of sodium consumed with feed.

Estimation of Food Intake From Tritium and ^{22}Na Dilution: The ratio between water intake and DMI was 5.33 ± 0.13 and was not affected by different proportions of poultry litter and wheat straw in individual cows. Dry matter intake was calculated therefore as: $\text{WTO} \times (0.865/5.33)$. Intake of dry matter calculated from tritiated water dilution was 97.3% of the actual intake (N.S.). Calculated intake of dry matter from ^{22}Na dilution was 100.8% of the actual intake (N.S., Table 3.7).

3.2.3. Discussion

Tritiated water space measured in this study (84% of W) exceeded typical values recorded in ruminants and other mammal species (Macfarlane and Howard, 1972). Body water pool in cattle may be overestimated with the tritiated water space method by up to 15% (Bird *et al.*, 1978 ; Odwongo *et al.* 1984). A large water space may also result from the trend to increase rumen volume (Odwongo *et al.*, 1984), extracellular and plasma volume (Macfarlane and Howard, 1972) with the increase in WTO rate. An increase in pool size which is associated with greater water flux could have an important physiological significance. The larger pools with their greater capacities can allow the animal to withstand dehydration longer (Shkolnik and Silanikove, 1981).

On a metabolic weight basis, WTO rate in the present experiment was about twice the rate recorded in sheep under semi-desert conditions (Benjamin *et al.*, 1978). Cattle are known to be much less efficient than sheep and goats in preventing water losses through fecal and urinary routes (Siebert and Macfarlane, 1971). Since water

and feed intake are closely related (Macfarlane and Howard, 1972) cattle are much more vulnerable to conditions of water shortage, than sheep and goats. In large paddocks several water sites may be needed in the summer to prevent reduced intake.

The ability to measure accurately individual water intake rate from WTO rate is based on the assumption that there is a constant ratio between the two variables, this is confirmed in Table 3.6. An additional assumption is that there is a constant ratio between dry matter intake and water intake which was reconfirmed in the present experiment in beef cows under simulated grazing conditions. Dry matter intake can be therefore fairly accurately from WTO measurements (Table 3.7). The advantage of the method is that the procedure is simple, relatively cheap and can be applied to a large number of animals. However, since water metabolism can vary considerably with environmental conditions, a control group should be run together with the main field experiment in order to derive a relevant conversion factor from WTO rate to dry matter intake.

Analysis of sodium metabolism (Figure 3) indicates that alimentary tract plays a major role in sodium homeostasis. Secreting a voluminous ammount of saliva rich in sodium requires a very effective absorption from the gut, otherwise sodium would be soon depleted. Assuming that sodium concentration in saliva is abut 180 mM/L (Baily, 1961), about 100L of saliva was produced daily in the present experiment. This value is within the normal range in cows (Baily, 1961) and is needed for normal rumen function.

The size of the Total Exchangeable Sodium (TES) in the cows (Table 3.5) is similar to that found in Buffalo, beef cows, and other mammals (Williams and Green, 1982 and references within, Williams and Dudzinski, 1982).

The close similarity between sodium intake and STO and the fact that the major content of sodium in faeces are of endogenous origin indicates that sodium is absorbed very effectively from the digestive tract. Our results are therefore consistent with those obtained by Williams and Green (1982) on buffalos.

Dry matter intake from pasture can be accurately predicted once the concentration of sodium in pasture is known. The method can be applied to measure pasture intake in both the green and dry season and is independent of environmental conditions.

As the recorded average DMI of the cows was less than 3% higher than the estimation obtained using the TOH dilution technique, it may be concluded that this method is valid and may be used to advantage.

Table 3.2. Composition of poultry litter and wheat straw (% of dry matter)

	Poultry litter	Wheat straw
Dry matter	78.5	90.0
Ash	15.5	10.3
Acid insoluble ash	4.9	3.5
Total nitrogen	4.8	0.67
Ammonia (N)	0.9	-
Ether extract	2.1	-
NDF (cell walls)	43.6	84.4
Hemicellulose	16.0	29.8
Cellulose	19.8	44.1
Lignin (ADL)	3.8	10.5
<u>Minerals</u>		
Sodium	0.45	0.02
Potassium	2.9	1.4
Phosphorus	2.0	0.10
Calcium	3.5	0.17
Magnesium	0.7	0.12
Chlorine	0.8	0.3
In vitro dry matter digestibility	46.0	43.0

Table 3.3. Voluntary intake of poultry litter, and wheat straw

	Poultry litter	Wheat straw	Total
Dry matter			
Kg/day	3.7±0.3	5.3±0.3	9.0±0.3
g/Kg live weight per day	10.6±0.7	15.0±0.8	25.8±1.0
g/kg W ^{0.75} per day	45.7±3.1	65.0±3.5	110.7±4.3
Organic matter	---	---	---
Kg/day	3.1±0.2	4.9±0.3	7.9±0.3
g/Kg live weight per day	8.8±0.6	13.9±0.1	22.7±0.9
g/Kg W ^{0.75} per day	37.9±2.6	60.1±3.1	98.0±3.8

Table 3.4. Total body water, fractional turnover rates and water turnover rates in six beef cows fed poultry litter and wheat straw ad libitum

Unit	Mean $\pm$ S.E.
Total body water (1)	304.4 $\pm$ 10.1
As percentage of BW	84.0 $\pm$ 2.2
Fractional rate	18.2 $\pm$ 0.05
a) as percentage of body pool per day.	
b) $T_{1/2}$ (days)	3.8 $\pm$ 0.1
Water turnover rates:	
a litter per animal per day	54.7 $\pm$ 0.6
b ml/Kg live weight per day	153.2 $\pm$ 1.7
c ml/Kg $W^{0.75}$ per day	668.1 $\pm$ 7.5

Table 3.5. Serum sodium concentration, body pool of exchangeable sodium, fractional turnover rates, and turnover rates in six beef cows fed poultry litter and wheat straw ad libitum

Unit	Mean $\pm$ S.E.
1. Serum sodium (mM/L)	139.7 $\pm$ 0.6
2. Exchangeable sodium	
a. Total millimoles	13185 $\pm$ 1052
b. mM/Kg live weight	36.4 $\pm$ 2.9
c. mM/Kg $W^{0.75}$	158.9 $\pm$ 13
3. Fractional Rate:	
a. as percentage of body pool per day	7.1 $\pm$ 0.5
b. $T_{1/2}$ (days)	9.7 $\pm$ 0.7
4. Turnover Rates:	
a. millimoles per animal	936.2 $\pm$ 61
b. mM/Kg live weight per day	2.59 $\pm$ 0.16
c. mM/kg $W^{0.75}$ per day	11.28 $\pm$ 0.73

Table 3.6. Components of daily rates of water input and water turnover rate calculated from tritium dilution in six beef cows fed poultry litter and wheat straw ad libitum¹ (litter per animal per day).

Cow	Water consumed	Water in feed	Metabolic water ¹	Total water intake	Water turnover rate
1	47	1.8	5.9	55	56
2	46	1.9	5.8	54	54
3	52	1.8	6.1	60	57
4	46	1.7	5.3	53	54
5	53	1.9	5.7	61	55
6	40	1.4	4.6	46	53
M±SE	47.3±4.3	1.75±0.17	5.57±0.5	54.8±4.9	54.7±1.5

1 Metabolic water was calculated assuming 0.7 litter was produced per 1 Kg organic matter consumed.

Table 3.7. Comparison between dry matter intake measured by weighing with estimation of intake from tritium and sodium turnover rates in six beef cows fed poultry litter and wheat straw ad libitum

Cow	Intake Kg/Day		
	Actual intake	Tritium	Sodium
1	9.64	9.67	9.69
2	10.53	9.08	10.72
3	10.24	9.34	10.71
4	9.05	9.45	9.20
5	8.35	8.94	7.68
6	9.35	9.25	9.71
M±S.E.	9.53±0.36	9.29±0.17	9.26±0.50

Part 4: Forage availability and feed supplementation.

4.1 Forage availability

4.1.1 Introduction

Availability of forage in the different experiment paddocks can influence animal performance and should be known when evaluating the influence of experimental treatments. However, measurement of forage availability is complicated by the nature of the site and the vegetation.

The Mediterranean herbaceous vegetation at the Karei Deshe experimental range is strongly seasonal. Three almost distinct phases can be distinguished.

- (a) The transitional period after the first rains and till the growth of the pasture vegetation is well established. As a rule, this period extends from about November through to mid-January.
- (b) The main green season, which extends from mid-January till the end of seed fill at the end of April and sometimes till mid-May.
- (c) The dry season follows with only a small proportion of perennial plants (Prosopis farcata and Cynodon dactylon) that provide a limited amount of green forage.

The experimental site is very heterogenous with varying slopes, rock cover and botanical composition. Consequently, determination of forage availability requires extensive sampling of the vegetation. As it is logistically impractical to clip enough sample quadrats, a double sampling

method is used whereby visual estimates are calibrated against clipped quadrats.

4.1.2 Materials and Methods

The vegetation was sampled along fixed permanent transects that were placed so as to give systematic coverage over the whole experimental area. Quadrats 25 x 25 cm were placed every 10 double paces along the transects and the vegetative biomass in the area bounded by the quadrat was estimated. About 300 estimates were recorded per paddock at each sampling date. Every tenth quadrat was clipped, put in a marked paper bag, oven dried at 80°C and weighed. The calibration regression was then calculated for each set of data and the estimated means were adjusted accordingly. Standard deviations of the mean were calculated by the method described in 'Range Research Methods, 1965'.

Biomass estimates were conducted at the beginning of the green season, at its height and at the end of the dry season. Occasionally, additional estimates were made at intermediate dates.

4.1.3 Results and discussion

The pasture biomass in the treatment paddocks at the height of the green season and at the end of the dry season is given in Table 4.1. The dry matter content rose from around 31% at the height of the green season to 90% during the summer. The amount of pasture biomass in the different treatments was influenced by stocking rate. The high stress and medium deferred treatments were stocked at 1.5 ha per cow, the medium stressed treatment at 1.7 and the low stress treatments at 2.0 ha per cow. As a result, the biomass in the lightly stocked paddock was higher than in the

other treatments in both green and dry seasons. However, the medium stressed paddock had consistently lower pasture biomass in the green season than the heavily stocked paddocks. The pasture production when measured in the green season in the moderately stocked paddock, decreased from year to year and was particularly low in the last year of the experiment. (The effects on animal performance are discussed in a later section). However, there were only small differences in biomass between the moderately and heavily stocked paddocks at the end of the dry season.

The 3-year mean green biomass levels in the two heavily stocked treatments were very similar; the biomass in the continuous treatment was relatively low in the third year of the experiment, while that in the deferred treatment was considerably higher. However, as will be discussed in a later section, animal performance was better in the continuous treatment compared to the deferred. Part of the reason may lie in the fact that the pasture availability was low during the deferment period (Table 4.2). Even though the animals in the deferment treatment were given more supplementary feed (see below), it apparently did not compensate for the small amount of high quality pasture that was available at the beginning of the season.

The early season growth in the moderately stocked paddock was not much better than in the continuously grazed, heavily stocked paddock (Table 4.2). As will be shown later, animal performance was better in the heavily stocked treatment.

The pasture biomass in the lightly stocked paddocks was perceptibly higher than in the other treatments already in the early part of the season. Forage availability was highest in this treatment and the animal performance responded accordingly (see part 5.1.2 below).

4.1.4 Conclusion

The vegetative biomass that was measured in the grazed paddocks was determined not only by stocking rate and grazing management, but also by inherent differences between the paddocks. Thus, the pasture vegetation in the moderately grazed paddocks appeared to be less vigorous than in the other paddocks. On the other hand, the pasture vegetation in the heavily stocked, continuously grazed paddock appeared to be particularly vigorous and had higher biomass levels even than in the heavily stocked treatment where grazing was deferred. These differences in pasture productivity can have an overriding effect on the experiment treatments.

4.2. Feed supplementation

As the protein content of the vegetation from June to December is less than 4%, protein supplementation is necessary. Poultry litter (PL) was given, ad libitum, to all experimental cows mainly as a nitrogen supplement. During the transitional period, the cows were supplemented with diets that differed in energy concentration according to treatment specifications. The amounts and composition of the various supplementary feeds that were given to the experimental herds during the study period are summarized in tables 4.3, 4.4 and 4.5.

The higher intake of PL during the transitional period is most probably a result of declining availability and quality of the dry vegetation. Under such conditions, a shortage of available energy is very probable and cows may use supplemented protein as an energy source and so remain short of protein (Clayton and Zimmerman, 1970).

In the first experimental year, supplementation began with the start of the experiment (21st October 1982), and lasted the 69 days of the transitional season. For a similar DM intake, the HS treated cows consumed 16% less metabolizable energy than the LS animals. The MD cows consumed double the amount of supplemented metabolizable energy consumed by the HS cows. The consumption of supplemented energy by the MS cows was slightly above that of the HS animals.

In the subsequent experimental years and in all the treatments, supplementary feed consumption increased yearly in both the dry and transitional seasons.

As the third experimental year was completed on October 1985, only PL was fed up to that time. Intake of PL was inversely related to stocking rate.

A special comment should be made on the extensive use of PL. This is a very common practice in Israel, because it is relatively cheap and easy to transport store, and distribute. Experimental data (Tagari et al. 1976) indicate that its digestibility declines rapidly as its proportion in the diet increases. No detrimental effects were observed on the experimental cows. However, in farms in which intake reached very high levels owing to shortage of other feed, detrimental effects, including mortality were observed.

of the dry season (Dry).

Year	Sampling date	D.M. content %	Biomass g m ⁻² (d.m.)									
			High stress	Medium deferred	Medium	Low stress						
	Green	Dry	Green	Dry	Green	Dry	Green	Dry	Green	Dry		
1982	-	17 Nov	-	89	-	.89	-	70	-	90	-	99
1983	24 Mar	15 Nov	25	91	145	102	148	106	146	102	238	182
1984	9 Apr	19 Nov	41	89	159	76	130	67	124	68	162	120
1985	2 Apr	8 Sep	27	90	146	93	164	105	118	108	182	142
Mean	-	-	31	90	150	90	147	93	129	93	194	148
SD	-	-	3.0	1.0	2.8	3.6	4.1	4.7	3.8	4.6	6.3	5.6

Table 4.2. Early season biomass in treatment paddocks

Year	Sampling date	DM content %	High stress	Biomass g m^{-2} (d.m.)		
				Medium deferred *	Medium	Low stress
1983	5 Jan	16	20	15	22	35
1984	22 Dec '83	18	41	14	56	70
1985	17 Jan	17	62	28	58	87
Mean		17	41	19	45	64
S.D.		1	4.6	2.8	4.5	5.1

* Biomass in the confinement paddock where the cows grazed during the deferment periods.

Table 4.3. Average supplementary feed consumption during each year of the experiment period (kg as fed/cow/day).

Treatment	Season Year	DRY			TRANSITIONAL			
		No. of days ⁽¹⁾	Poultry litter	Wheat straw	No. of days	Poultry litter	Wheat straw	Barley grain
HIGH STRESS	82/83	-	-	-	69	4.0	1.26	-
	83/84	101	3.8	-	77	5.2	0.56	
	84/85	112	4.1	0.93	78	6.1	1.62	
	1985	130	6.8	-	-	-	-	-
	Average		5.03	0.30		5.14	1.14	
MEDIUM DEFERRED	82/83	-	-	-	69	6.1	1.76	1.53
	83/84	101	4.8	-	77	8.6	2.03	1.97
	84/85	112	5.3	1.37	78	9.3	2.32	2.10
	1985	130	6.4	-	-	-	-	-
	Average		5.57	0.45		8.07	2.05	1.88
MEDIUM STRESS	82/83	-	-	-	69	2.7	1.31	0.70
	83/84	101	3.4	-	77	3.7	-	0.93
	84/85	112	4.2	0.50	78	7.6	1.04	0.92
	1985	130	5.2	-	-	-	-	-
	Average		4.34	0.16		4.75	0.76	0.85
LOW STRESS	82/83	-	-	-	69	2.9	1.60	0.92
	83/84	101	3.6	-	77	5.5	-	1.00
	84/85	112	5.1	0.2	78	6.4	1.50	1.47
	1985	130	4.4	-	-	-	-	-
	Average		4.39	0.06		5.01	1.01	1.14

(1) No. of supplement days during the dry season - until the 14th October.

Table 4.4. Average consumption of the supplementary feed during the entire experiment. Dry matter (DM) and organic matter (OM) kg/cow/day. Metabolizable energy (ME) concentration of the ration.

Pasture season Treatment	DRY			TRANSITIONAL		
	DM kg	OM kg	ME Mcal/kg	DM kg	OM kg	ME Mcal/kg
High stress	4.55	3.55	1.55	5.40	4.31	1.54
Medium deferred	5.15	4.03	1.55	10.39	8.61	1.78
Medium stress	3.84	2.98	1.56	5.48	4.47	1.75
Low stress	3.79	2.93	1.56	6.18	5.10	1.79

Table 4.5. SUPPLEMENTARY FEED INTAKE, PER COW, DURING
THE EXPERIMENTAL YEAR

Treatment			High Stress		Medium Defer.		Medium Stress		Low Stress	
Feed - suppl.	Period	Days	Kg/day	Kg/period	Kg/day	Kg/period	Kg/day	Kg/period	Kg/day	Kg/period
<u>1982 / 83</u>										
Poultry Litter -	21/10-29/12/82	69	4.05	279.4	6.10	420.9	2.74	189.1	2.89	199.5
Wheat Straw -	21/10-29/12/82	69	1.26	86.9	1.76	121.4	1.31	90.4	1.60	110.4
Barley grain -	21/10-29/12/82	69	-	-	1.53	105.6	0.70	48.3	0.92	63.5
Total DM Intake - Kg			4.57	315.5	8.13	561.0	4.11	283.6	4.71	325.0
Total ME Intake - Mcal			7.0	483.5	14.52	100.9	7.20	496.6	8.39	579.2
<u>1983 / 84</u>										
Poultry Litter -	5/7 -30/12/83	178	4.41	785.0	6.44	1147.0	3.53	629.0	4.0	784.1
Wheat Straw -	9/11-22/12/83	43	1.00	43.0	3.65	156.9	-	-	-	-
Barley grain -	3/11-30/12/83	57	-	-	2.66	151.7	1.26	71.8	1.35	77.0
Total DM Intake - Kg				706.1		1252.4		599.6		736.4
Total ME Intake - Mcal				1097.3		1237.2		1029.6		1250.0
<u>1984/85</u>										
Poultry Litter -	24/6 -31/12/84	190	4.91	933.0	6.93	1316.0	5.59	1063.0	5.62	1067.8
Wheat Straw -	9/8 - 2/1/85	146	1.58	231.0	2.29	335.0	0.94	137.2	0.95	138.5
Barley grain -	14/10-31/12/84	78	-	-	2.10	163.8	0.92	71.8	1.47	114.7
Total DM Intake - Kg				1000.4		1566.7		1090.5		1135.6
Total ME Intake - Mcal				1537.8		2625.9		1781.9		1908.4
<u>1985</u>										
Poultry Litter -	7/6 -25/10/85	140	6.82	955.0	6.36	890.4	5.2	728.0	4.38	614.0
Total DM Intake - Kg			5.80	812.1	5.41	757.2	4.2	856.1	3.72	522.1
Total ME Intake - Mcal				1266.9		1181.2		1335.4		814.5

Part 5: ANIMAL RESPONSES TO TREATMENT

5.1 Cow and calf performance

5.1.1 Materials and methods

Animal Weights: Animals were weighed at the start of the experiment and at monthly intervals until the experiment was terminated. Before each weighing the cows were held in the corrals over night (approx. 16-17 hours) without food or water (Baker and Guilbert, 1942; Bass and Duganzich, 1980).

Body measurements: The cows were measured at the start and the end of the experiment. Measurements were taken with the animals standing as naturally as possible in a squeeze chute. The following measurements were taken at the start of the experiment: height at withers, heart girth circumference, width at hips, length from withers to pin-bone, and round measurement (taken horizontally at the height of the patella). At the end of the experiment only height at withers was measured .

In addition , two indices were calculated. The round measurement is determined largely by muscle, and the ratio of round to height ($RM/H \times 100$) is considered a muscle: skeletal index and, therefore, an index of conformation (Guilbert and Gregory, 1952). The dimension: weight index (Yapp, 1924) is also an expression of conformation. Dimension : weight index = $[W.1047/H^2]L \times 100$, where H is height at withers, W is body weight, L is length of body, and 1047 is the volume of 1 Kg of the body, in cm^3 .

Body condition was expressed by the live weight at weaning adjusted for pregnancy/height at withers ratio. A visual appraisal (scoring) for body condition, was also made at weaning, on a 1-4 scale

(1-bad; 2-satisfactory; 3-good; 4- very good). Adjustment for pregnancy of live weight was made according to A.R.C.-(1980).

Cow efficiency was calculated as percent of calf weight at weaning from the cows weight at weaning, adjusted for pregnancy.

Calving interval was calculated as the number of days between the last and second-to-last calvings.

5.1.2. Results and discussion

At the start of the experiment they were no significant differences in the live-weight and conformation (as shown by the muscle: skeletal and dimension : weight indexes) of the experimental cows of the different treatments (Table 5.1). Live weight at weaning (LWW), body condition and cow efficiency of the experimental cows, which were permanent in the trial, are presented in Table 5.2.

Changes in body weight adjusted for pregnancy, during the experimental years, are presented in Fig. 5. It appears that all experimental cows followed the same trend of body weight changes, from green season to dry season during the early part of the experiment. During the last transitional season, the bodyweight of the cows in the deferred treatment increased more than in the other treatments, apparently because of the greater amount of supplementary feed, including barley grain that they consumed (Table 4.5).

In the first and second experimental years there were no significant differences between the different treatments in LWW. In the third year the LWW of the MS cows decreased significantly, as compared with the other treatments. In the same way, body condition of the MS cows was lower than that of the HS and MD treated animals. This was observed also by visual appraisal. Due to the young age of the cows, 4-5 years in average, the LWW increased every year. As result of

the lower liveweight, the cow efficiency was highest at the MS cows. The lowest cow efficiency was found at the MD cows.

The reproductive performance of the experimental cows is presented in table 5.3. Calving percentage increased from year to year in all treatments, except in the MD one. This may be due to the maturing of the cows, and in part to adaptation to nutritional stress conditions. Calving percentage in any year was reflected in the average date of birth in the subsequent year. Dry cows, in a given year generally calved early the following year. There were no consistent differences in calving interval according to treatment. However, the calving interval was shortest on the LS treatment. The long calving interval in the MS treatment may be explained by the lower body condition in that treatment, for which we have no explanation. Ward, 1968, and others, have shown that low body weights or large weight losses were closely associated with poor conception rates.

The differences in weaning weight (Table 5.4.) were derived from differences in age at weaning. There were no significant differences between treatments in weaning weight adjusted to 220 days. Weaning weight produced per cow and per ha are given in table 5.5. Weaning weight per cow was highest and per ha was lowest on the LS treatment. There were no other consistent differences among the other treatments.

Table 5.1. Body Measurements of the Experimental Cows

Treatment	Live	Height at withers		Heart	Width	Body	Round	Muscle	Dimension:
	weight			girth	at	length	measure		
	21.10.1982	21.10.82	15.4.86	circumference	hips		ment	skeletal	weight
		-cm-	-cm-	-cm-	-cm-	-cm-	-cm-	index	index
HIGH STRESS	324	118.03	120.55	166.33	42.79	122.56	69.79	59.06	29.3
MEDIUM-DEFERRED	308	116.83	119.50	166.33	43.13	119.93	71.58	59.00	30.5
MEDIUM STRESS	298	117.92	119.46	162.92	42.08	118.92	68.67	60.65	32.8
LOW STRESS	315	117.84	119.94	163.87	43.96	122.36	68.92	57.90	31.0
SEM	10.5	1.20	1.11	1.82	0.76	1.33	1.16	0.95	1.30

Table 5.2. LIVE WEIGHT AT WEANING (LWW), BODY CONDITION AND COW EFFICIENCY OF THE EXPERIMENTAL COWS

TREATMENT	Year of Experiment	No. of permanent cows	LWW -kg	BODY CONDITION ¹		Cow Efficiency ³
				LWWP/HW	Scoring ²	
HIGH STRESS	1982/83	29	344	3.03	3.38	56.9
	1983/84		355	2.89 ^a	3.22 ^{ab}	46.3 ^{bc}
	1984/85		376	3.12 ^a	3.62 ^{ab}	47.2 ^{bc}
	Average		358	3.02 ^a	3.41 ^{ab}	50.1 ^{ab}
MEDIUM DEFERRED	1982/83	18	333	3.10	3.40	57.1
	1983/84		352	2.90 ^a	3.38	46.7
	1984/85		396 ^a	3.19 ^a	3.87 ^a	39.9 ^c
	Average		361 ^a	3.06 ^a	3.55 ^a	48.0 ^a
MEDIUM STRESS	1982/83	13	307	2.85 ^b	3.16	59.6
	1983/84		340 ^b	2.44 ^b	3.17 ^b	47.9
	1984/85		336 ^b	2.82 ^b	3.46 ^b	60.3 ^a
	Average		328 ^b	2.70 ^b	3.26 ^b	56.0 ^b
LOW STRESS	1982/83	32	331	2.90	3.24	58.9
	1983/84		343 ^{ab}	2.67 ^{ab}	3.31 ^{ab}	49.3 ^b
	1984/85		370	3.19 ^a	3.73 ^{ab}	51.6 ^b
	Average		348 ^{ab}	2.92 ^{ab}	3.43 ^{ab}	53.3 ^{ab}
SEM - and level of significant	1982/83		11.78	0.09 [*]	0.15	2.50
	1983/84		13.41 [*]	0.10 [*]	0.13 [*]	3.24 [*]
	1984/85		11.97 [*]	0.09 [*]	0.09 [*]	2.59 [*]
	Average		7.23 [*]	0.06 [*]	0.10 [*]	1.59 [*]

* P < 0.05; ** P < 0.01

a,b,c - Means of the same year not sharing a common letter are significantly different.

1 - Body condition expressed by: the live weight at weaning adjusted for pregnancy(LWWP)/height at withers (HW) ratio;

2 - scoring = visual appraisal on a 1-4 scale (1-bad, 2-satisfactory, 3-good, 4-very good.

3 - Cow efficiency = $\frac{\text{Calf weight at weiging}}{\text{LWWP}} \times 100$

Table 5.3. REPRODUCTIVE PERFORMANCE OF THE EXPERIMENTAL COWS

TREATMENT	Year of Experiment	Calving Percentage	Average calving date	Calving interval days
HIGH STRESS	1982/83	-	4.01.83	-
	1983/84	79.4	23.01.84	384.7 ^b
	1984/85	84.8	15.12.84	422.8 ^b
	1985/86	90.6	11.01.86	415.9 ^{ab}
	Average	85.0		407.8 ^a
MEDIUM DEFERRED	1982/83	-	20.01.83	-
	1983/84	63.1	22.01.84	385.9
	1984/85	73.7	27.02.85	570.3 ^a
	1985/86	72.2	8.12.85	449.4 ^a
	Average	69.7		468.5 ^b
MEDIUM STRESS	1982/83	-	21.12.82	-
	1983/84	46.7	3.01.84	387.4
	1984/85	73.3	15.11.84	546.7 ^a
	1985/86	88.2	5.12.85	477.4 ^a
	Average	69.4		470.5 ^b
LOW STRESS	1982/83	-	1.01.83	-
	1983/84	84.8	21.01.84	359.9 ^b
	1984/85	90.9	19.12.84	387.5 ^b
	1985/86	93.7	29.11.85	341.3 ^b
	Average	89.8		362.9 ^a
SEM - AND LEVEL OF SIGNIFICANCE	1982/83			
	1983/84			20.85 [*]
	1984/85			36.62 [*]
	1985/86			31.23 [*]
	Average			17.98 [*]

* P < 0.05; **P < 0.01

a,b,c - Means of the same year not sharing a common letter are significantly different.

Table 5.4. WEANING DATA

TREATMENT	Year of Experiment	Weaning %	Age at Weaning days	Weaning weight - kg	Adjusted 220 days weaning weight-kg	Birth to Weaning gain gr/d	males g/d	females g/d
HIGH STRESS	1982/83	67.6	224 ^{ab}	184.7	182.3	701	719	691
	1983/84	67.6	195 ^{ab}	155.2	170.3	647	675	622
	1984/85	87.9	204 ^{ab}	173.9 ^b	188.1	728	785	671
	Average	74.4	208 ^a	173.1 ^{ab}	180.2	692	726	661
MEDIUM DEFERRED	1982/83	73.7	209 ^a	176.2	184.6	712	765	538
	1983/84	63.2	200 ^c	158.2 ^c	172.1	655	725	571
	1984/85	73.7	145 ^c	142.8 ^c	201.6	789	853	734
	Average	70.2	184 ^b	159.1 ^a	186.1	719	781	614
MEDIUM STRESS	1982/83	86.7	239 ^b	183.2	172.1	655	679	556
	1983/84	46.7	204 ^a	156.0	167.5	634	720	505
	1984/85	66.7	222 ^a	202.8 ^a	199.5	780	833	654
	Average	66.7	222 ^c	180.7 ^b	179.7	690	744	572
LOW STRESS	1982/83	93.9	240 ^b	191.5	177.4	679	680	664
	1983/84	72.7	196 ^b	150.4 ^{ab}	161.8	608	647	552
	1984/85	78.8	196 ^b	188.4 ^{ab}	207.5	816	871	786
	Average	81.8	211 ^a	176.8 ^b	182.2	701	733	667
SEM - and level of significance	1982/83		6.92*	8.43	6.70	30.0		
	1983/84		6.73	10.76	9.40	40.1		
	1984/85		7.03*	8.68*	7.12	30.0		
	Average		4.25*	5.14*	4.15	0.91		

* P < 0.05; **P < 0.01

a,b,c - Means of the same year not sharing a common letter are significantly different.

Table 5.5. WEANING WEIGHT PRODUCED PER COW AND PER HA

TREATMENT	Year of Experiment	Weaning Weight Per Cow - kg -	Weaning Weight Per ha - kg -
HIGH STRESS	1982/83	124.9	83.3
	1983/84	105.0	70.0
	1984/85	152.8	101.8
	Average	127.6	85.0
MEDIUM DEFERRED	1982/83	129.8	86.5
	1983/84	99.9	66.6
	1984/85	105.2	70.1
	Average	111.6	74.4
MEDIUM STRESS	1982/83	158.8	105.8
	1983/84	72.8	48.5
	1984/85	135.2	90.1
	Average	122.3	81.5
LOW STRESS	1982/83	179.9	89.9
	1983/84	109.4	54.7
	1984/85	148.4	74.2
	Average	145.9	72.9

FLUCTUATIONS OF EMPTY BODYWEIGHT OF COWS BY TREATMENTS

PLOT OF EBWT*DATE SYMBOL IS VALUE OF TRT

67

NOTE: 6 OBS HIDDEN

Fig. 5 Changes in mean body weight (adjusted for pregnancy) during the experiment

5.2. MILK PRODUCTION

5.2.1. Materials and Methods

Milk yield of the experimental cows was estimated for each treatment for two consecutive years on eight occasions each year. The daily milk yield of cows was determined by the weigh-suckle-weigh method. Calves were separated from their dams for 12-14 hours during the night and then weighed before and after suckling in the morning. The values obtained were multiplied proportionally in order to obtain an estimate of daily, 24h milk yield.

Statistical analysis: The method of least - squares for unequal subclass numbers using the GLM (SAS, 1985) was used for all analyses. The basic model included class effects (breed and age of cow, sex of calves, season of milk sampling and treatments) and continuous effects (interval from calving to milk sampling) and interactions with treatments.

5.2.2. Results and discussion

Milk production data that were measured during the 1982/83 main lactation period are given in Table 5.2.1. Grand average daily milk production was 6.3 kg/cow/day. Age of cow, breed and sex of calves had no significant effects, but season and treatment effects were significant. Spring milk production was higher than winter milk production and cows in the high and medium stress treatments had significantly less milk than in the other treatments. In the medium deferred treatment the cows gave the highest milk production, significantly higher than in the high and medium stress treatments, but not significantly higher than in the low stress treatment.

Milk production data for 1983/84 are given in Table 5.2.4. Grand average milk production was 5.76 Kg/cow/day. As in the previous year, age of cow, breed and sex did not have a significant effect. The low stress treatment cows gave significantly higher milk production than the cows in the high and medium deferred treatments. Although there were significant differences in milk production between treatments, no significant differences were found in the daily gain of calves during their preweaning growth. This is in accordance with the findings of Melton et al (1967), Gifford (1953) and Neville (1962) who found a declining relationship between milk production and calf gain as lactation progressed.

Table 5.2.1. Least squares means and standard errors of daily milk yields (1982/83)

Class	No. of cows	Milk yield (kg/day)	
		Mean	Standard error of means
GRAND TOTAL	79	6.26	0.46
<u>Age of dam</u>			
2	28	5.60	0.53
4	6	5.72	0.94
mature (5,6,7)	45	6.34	0.42
<u>BREED</u>			
First cross	43	6.05	0.52
Back cross	36	5.55	0.47
<u>SEX OF CALVES</u>			
Males	32	5.84	0.39
Females	47	5.77	0.37
<u>SEASON</u>			
Winter	31	4.64 a	0.41
Spring	48	6.97 b	0.36
<u>TREATMENT (stress)</u>			
High stress	23	5.13 a	0.84
Medium deferred	15	6.78 b	0.50
Medium stress	13	5.28 a	0.60
Low stress	28	6.02 b	0.82

Table 5.2.2. Analyses of variance of daily milk yields

Source	d.f.	Mean Squares	
Age of dam	2	8.29	ns
Breed	1	1.45	ns
Sex	1	1.35	ns
Season	1	90.55	**
Treatment	4	31.60	*

* $P < 0.05$ ** $P < 0.01$ Season

Winter: 1 Oct. - 15 Jan.,

Spring: 16 Jan. - April.

Table 5.2.3. Least squares means and standard errors of daily gains of calves (1982/83)

Treatment (stress	No. of calves	Mean	St. error of means
High Stress	23	0.806	0.047
Medium deferred	15	0.772	0.036
Medium stress	13	0.802	0.043
Low Stress	28	0.824	0.042

Table 5.2.4 - Least squares means and standard errors of daily milk yields (1983/84)

	No. of cows	Milk Yields (kg/day)	
		Mean	Standard error of means
GRAND TOTAL	73	5.76	0.106
<u>AGE OF DAM</u>			
4	22	5.01	0.316
mature (6,7,8,9)	51	6.16	0.256
<u>BREED</u>			
First cross	48	6.11	0.272
Back cross	25	5.07	0.275
<u>SEX OF CALVES</u>			
Males	38	5.74	0.166
Females	35	5.43	0.175
<u>TREATMENT (STRESS)</u>			
1. High Stress	26	4.88 ^a	0.190
2. Medium deferred	12	5.28 ^{ab}	0.267
3. Medium stress	9	5.96 ^{bc}	0.267
4. Low Stress	26	6.22 ^c	0.153

Table 5.2.5. Simple (Pearson) correlation coefficients between milk yield and preweaning daily live-weight gain of the offspring (1983/84)

Treatment	Production criteria		Corr. Coef.
	Milk yield -kg-	Preweaning daily live- weight gain (g)	
High stress	4.88	539	.276
Medium deferred	5.28	638	.481
Medium stress	5.96	643	.151
Low stress	6.22	611	.241

5.3 Energy requirements for measured performance

5.3.1 Introduction

The energy balance of the experimental animals can be used as an indicator of the degree of nutritional stress. However, the direct measurement of the energy balance of free ranging animals is generally impractical with available instrumentation. Estimates of some terms of the energy balance are possible. Thus in the USA part of the project, energy expenditure was studied in detail (Part 9.) while in the Israeli part, body composition was determined by TOH space measurements and used to calculate total body energy. Water turnover was used to calculate dry matter intake (section 5.5.2). However, energy requirements for the maintenance and production of the cows in the experiment could only be derived from normative tables (NRC, 1984). These energy values, however, are no more than a summary of the total normative requirements of the animals and are of interest mainly as a check on the intake measurements.

5.3.2 Method

a. Metabolizable energy requirement. Net energy requirements for maintenance and gain is calculated from appropriate formulae in the NRC (1984) publication (Table 5.3.1). The maintenance term includes both requirements for lactation and pregnancy. Lactation requirements are based on 6 kg milk per lactation day. Pregnancy requirements are standard NRC (1984). Net energy is converted to metabolizable energy requirements for green and dry pasture by multiplication with the ratio between

metabolizable and net energy for maintenance and gain for either green or dry pasture. As temperatures in the experimental range are relatively moderate (see Part 2) and extreme temperatures are rare, maintenance requirements have not been corrected for temperature (Mount, 1974). Net pasture requirements for the average cow in the herd is then calculated by deducting the metabolizable energy intake from supplementary feed.

b. Dry matter intake. The pasture intake is calculated from the total metabolizable energy requirements after correcting for grazing activity on the assumption that grazing activity increases maintenance requirements by 60% over and above maintenance requirements for penned cows (Young, 1970; Wallace, 1956; Havstad and Malachuk, 1982; also Part 9 in this report).

c. Total herd energy requirements. The requirements were calculated for each cow, for each period between weighing dates and summed up for the herd by green and dry seasons separately. As some cows were removed and some replaced during the three years of the experiment, the average number of cows in a herd was calculated by totalling the grazing days and dividing by number of days between the first weighing of the year and the last. Mean yearly requirements were then determined by correcting to 365 days.

5.3.3 Results and discussion

The duration of the green and dry seasons varied over the years, and only 1983 and 1984 were relatively full years (Table 5.3.2). The 1982 dry season included only the latter part of the summer dry season and the transitional season while the 1985 dry season ended before the subsequent transitional season. The three green seasons, 1983, 1984 and 1985 were full green seasons of more or less similar duration. The end of the green season included the first month of the dry season, when relatively high quality pasture was still abundant and could be selected by the experimental herds.

The mean seasonal energy requirements were calculated according to the schedule in Table 5.3.2. Daily metabolizable energy requirements of the cows (including maintenance, lactation, pregnancy, empty bodyweight change and grazing activity) are summarized in Table 5.3.3. Mean green season requirements varied between 23 and 27 Mcal/cow/day when mean metabolizable energy concentration of the green pasture was taken as 2.3 Mcal/kg, d.m. The dry season requirements that were supplied by pasture in the two years when the whole of the dry and transitional seasons were covered by the data, varied between 11 and 15 Mcals/cow/day in the continuously grazed pasture and from 7 to 13 Mcals/cow/day in the deferred treatment where dry season supplementation was highest. In the low stress treatment energy requirements that were met from pasture were somewhat higher. Mean metabolizable energy concentration of the dry pasture was taken as 1.6 Mcals/kg, d.m.

As most of the metabolizable energy requirements for calves were met by milk from the nursing cows, only a small part was supplied by pasture (Table 5.3.4). This pasture contribution only exceeded 3.5 kg/calf/day in

the green season in the low stress treatment where the available pasture area per animal was highest. In energy terms, the intake of dry pasture by calves was not much lower than the green pasture intake. A more detailed summary of fluctuations in energy utilization is given in Fig. 5.5.

The normative pasture requirements in terms of dry matter are simply the metabolizable energy requirements divided by the ME concentration of the green and dry pasture respectively (Tables 5.3.5 and 5.3.6). These values should provide an estimate of normative pasture dry matter intake. The mean green season value of cow DM intake was 11.3 ± 0.80 kg/day. This compares with 13.5 ± 0.51 that was estimated by TOH turnover (section 5.5). The underestimate of the normative values may indicate that the energy expenditure for grazing and exposure was higher than the 60% of maintenance that was assumed in these calculations. The energy expenditures measured in the USA component of this project (Part 9) indeed included values more than double the maintenance requirement.

The dry season net pasture DM intake of cows after correcting for supplementary feeding was more variable. Mean dry season daily intake varied between 4.2 and 9.6 kg/cow/day. On the whole, the lowest intake was calculated for the deferred treatment (MD), a logical consequence of heavy supplementary feeding. The highest dry season pasture intake was estimated for the low stress treatment where pasture allocation per cow was highest. While these are logical results, the variation between years is so high that it is not possible to determine a characteristic dry season intake for a specific treatment. As a mean, dry matter pasture intake under the supplementary feeding regime practiced, is estimated at 8.2 ± 1.25 kg/cow/day. The total intake (including supplementary feed) estimated from water turnover (section 5.5), is somewhat higher at 8.9 ± 0.3 kg/day.

The utilization of primary pasture dry matter production in kg/ha is given in Tables 5.3.7, 5.3.8 and 5.3.9. Green season utilization of pasture by the cows was highest in the deferred treatment (MD) and lowest in the more lightly stocked pasture (LS). The slightly lower utilization in the medium stress treatment (MS) compared to the high stress treatment (HS) is consistent with the results on performance of the respective herds. Green season utilization is remarkably consistent between years in the various treatments as reflected by the standard deviation (Table 5.3.7). Dry season pasture utilization is almost the same as green season utilization but lowest in the deferred treatment and highest in the medium stress treatment. As a result, overall animal utilization (corrected to 365 days per year) is around 2000 kg/ha in the heavily stocked pastures and about 1700 kg/ha in the lightly stocked ones. Calf pasture DM utilization (Table 5.3.8) adds between 250 to 320 kg/ha.

5.3.4 Conclusion

The intake of the cows, based on energy balance calculations is somewhat lower than the intake estimated from water turnover. The green season underestimate may be caused by neglecting to account for cool winter temperatures or by using too low a grazing activity factor. The dry season underestimate is within the experimental error. As both the green and dry season intake estimates are fairly close to each other in both methods used, they give a fairly reliable indication of the range of values that can be expected. However it is doubtful whether either approach could give accurate estimates for intake on individual cows.

The overall dry matter utilization of the pasture was around 2300 kg/ha. Residual litter at the end of the dry season was between 1000 and

1500 kg/ha. Total primary production is thus similar to values that have been recorded at the Karei Deshe Experiment Ranch over the past 20 years (Gutman and Seligman, 1985).

Table 5.3.1 Equations and constants used to calculate energy requirements and normative dry matter intake.

a. Energy concentration of pasture and supplementary feeds (Mcal/kg d.m)

	Metabolizable energy	Net	Energy
	CME	CME _m (maint.)	CNE _g (gain)
Pasture- green	2.3	1.43	0.84
" dry	1.6	0.76	0.23
Poultry litter (PL)	1.56		
Straw (ST)	1.45		
Barley grain (BR)	3.04		

Energy expenditure factor for grazing (GRZ) = 1.6

b. Daily energy requirements and pasture intake (Mcal or kg/cow/day)

-from NRC (1984).

Cows (W = wt of cow; G = daily gain, EBW)

$$NE_m = 0.077 W^{.75} * GRZ \quad (NE \text{ for maintenance})$$

$$NE_g = G * 6.25 \quad (NE \text{ for gain})$$

$$ME_g = NE_g * CME / CNE_g \quad (ME \text{ for gain})$$

$$DMI = (ME_m - SUP_m) / CME + (ME_g - SUP_g) / CME \quad (DM \text{ intake/cow/day})$$

$$SUP_m = PLI + SII \quad (\text{daily ME intake from PL and ST})$$

$$SUP_g = BRI \quad (\text{daily ME intake from BR})$$

Milk production = 6 kg/day (=2.45 Mcal NE)

Pregnancy = .028 (0.0149-0.0000407t)e (0.05883t-0.0000804t²)

t = days after onset of conception

Calves - (W = wt of calf; G = daily gain)

NWm = 0.077 W^{.75} * GRZ

NEg (males) = .0493W^{.75} .G^{1.097}

NEg (females) = .0686W^{.75} .G^{1.119}

Table 5.3.2 Duration of green and dry seasons during the experiment

Year	Green			Dry		
	From	To	Duration (days)	From	To	Duration (days)
1982	-	-	-	21/10/82	1/2/83	103
1983	2/2/83	16/6/83	135	17/6/83	10/1/84	208
1984	11/1/84	30/5/84	141	31/5/84	17/1/85	232
1985	18/1/85	31/5/85	134	1/6/85	21/10/85	143

Table 5.3.3 Daily metabolizable energy requirements from pasture of cows in the experimental treatments for maintenance (including lactation and pregnancy) and gain (Mcal/cow/day).

Treatment	Season	Year			
		1982	1983	1984	1985
HS (1,3)	Green	-	27.4	26.2	26.5
	Dry	10.2	12.3	14.2	12.1
MD (4)	Green	-	27.1	25.1	27.0
	Dry	8.6	6.7	12.7	11.6
MS (6)	Green	-	27.1	22.7	23.9
	Dry	9.3	15.0	11.3	15.4
LS (2,5)	Green	-	26.8	25.0	25.9
	Dry	8.4	14.6	15.4	15.0

Table 5.3.4. Normative metabolizable energy requirements from pasture of calves over and above normative milk ration from nursing cows (Mcal/calf/day).

Treatment	Season	Year			
		1982	1983	1984	1985
HS (1,3)	Green	-	2.4	1.9	3.2
	Dry	0.3	1.7	0.9	2.2
MD (4)	Green	-	3.5	1.8	1.5
	Dry	0.6	2.3	0.9	2.0
MS (6)	Green	-	2.6	1.3	3.4
	Dry	0.2	2.1	0.8	1.7
LS (2,5)	Green	-	3.7	1.9	3.6
	Dry	0.5	2.9	1.1	2.3

Table 5.3.5 Normative pasture requirements of cows in green and dry seasons (kg/cow/day).

Treatment	Season	Year			
		1982	1983	1984	1985
HS (1,3)	Green	-	11.9	11.4	11.5
	Dry	6.4	7.7	8.9	7.6
MD (4)	Green	-	11.8	10.9	11.8
	Dry	5.4	4.2	7.9	7.3
MS (6)	Green	-	11.8	9.9	10.4
	Dry	5.8	9.4	7.1	9.6
LS (2,5)	Green	-	11.7	10.9	11.3
	Dry	5.2	9.1	9.6	9.4

Table 5.3.6 Normative pasture requirements of calves in green and dry seasons over and above normative milk ration from nursing cows (kg/calf/day).

Treatment	Season	Year			
		1982	1983	1984	1985
HS (1,3)	Green	-	1.1	0.8	1.4
	Dry	0.2	1.1	0.6	1.4
MD (4)	Green	-	1.5	0.8	0.6
	Dry	0.4	1.4	0.5	1.3
MS (6)	Green	-	1.1	0.8	1.4
	Dry	0.1	1.3	0.5	1.1
LS (2,5)	Green	-	1.6	0.8	1.6
	Dry	0.3	1.8	0.7	1.4

Table 5.3.7 Pasture utilization by cows (kg/ha, d.m.)

Treatment	Season	Year				
		1982	1983	1984	1985	Mean*
HS (1,3)	Green	-	1004	1019	947	990 $\pm$ 6.2
	Dry	427	999	1302	663	988 $\pm$ 17.9
	Total	-	2003	2321	1610	1978 $\pm$ 18.9
MD (4)	Green	-	1094	1073	1133	1100 $\pm$ 5.5
	Dry	358	594	1289	748	877 $\pm$ 19.1
	Total	-	1688	2362	1881	1977 $\pm$ 18.6
MS (6)	Green	-	976	916	971	954 $\pm$ 5.8
	Dry	399	1194	1076	960	1077 $\pm$ 10.8
	Total	-	2170	1992	1931	2031 $\pm$ 11.1
LS (2.5)	Green	-	787	778	790	785 $\pm$ 2.5
	Dry	293	944	1131	704	926 $\pm$ 14.6
	Total	-	1731	1909	1494	1711 $\pm$ 14.4

* excluding 1982.

Table 5.3.8 Pasture utilization by calves (kg/ha, d.m.)

Treatment	Season	Year			
		1982	1983	1984	1985
HS (1.3)	Green	-	110	90	145
	Dry	17	174	100	153
	Total	-	284	190	298
MD (4)	Green	-	157	82	64
	Dry	30	227	95	138
	Total	-	384	177	202
MS (6)	Green	-	151	77	195
	Dry	14	269	117	150
	Total	-	420	194	345
LS (2.5)	Green	-	145	79	142
	Dry	22	258	109	137
	Total	-	403	188	279

Table 5.3.9 Pasture utilization by herd (kg/ha, d.m.)

Treatment	Season	Year			
		1982	1983	1984	1985
HS (1.3)	Cows	(427)	2003	2321	1610
	Calves	(17)	284	190	298
	Total	(444)	2287	2511	1908
MD(4)	Cows	(358)	1688	2362	1881
	Calves	(30)	384	177	202
	Total	(388)	2072	2539	2083
MS(6)	Cows	(399)	2170	1992	1951
	Calves	(14)	420	194	345
	Total	(413)	2590	1986	2296
LS(45)	Cows	(293)	1731	1909	1494
	Calves	(22)	403	188	279
	Total	(315)	2134	2097	1773

() partial dry season utilization only.

5.4. GRAZING BEHAVIOUR

5.4.1. Introduction

Knowledge of cattle behaviour under nutritionally harsh conditions is important for understanding animal response to stress and to supplementary feed utilization. Grazing time can give an indication on the adaptability of cattle to a particular environment (Payne et al. 1951). Many investigations have shown a tendency for animals to extend their grazing time in response to a decline in the amount of herbage available (Hodgson, 1933; Hancock and McMeekan, 1955). However, when animals are provided with adequate herbage the amount of dry matter consumed is often closely related to the time devoted to grazing (Brumby, 1959; Fernando and Carter, 1970). Also, more recent studies (Hodgson et al. 1977) have established that, in conditions where herbage quantity per unit area or per animal is not limiting, the herbage intake of grazing cattle is related primarily to the digestibility of the herbage consumed. However, in most practical situations, as in the conditions of our experiment, the quantity of herbage to which animals have access is limited to some degree so that animals must adjust their grazing behavior in response to changes in sward conditions. The degree to which grazing animals succeed in maintaining adequate levels of herbage intake depends, to a large degree, on their ability to adapt to changes in pasture availability.

The objective of the present study was to determine the effect of pasture availability and quality and supplements on offer, on the activities and grazing time of beef during the difficult transitional early green season phase and during the dry season.

5.4.2. Materials and methods

Herd behaviour observations were carried out during the transitional period on the 12th December 1982 for 24 hours and 22nd

December 1983 for 13 hours, from sunrise to sunset. These observations were carried out on two groups of beef cows, one of them on deferred and the other on continuous grazing. The cows on deferment were confined to a small area (0.2 ha/cow, near to supplementary feed and water troughs). It was assumed that on the observation dates, the forage availability in all the continuous grazing paddocks was similar.

From the beginning of May through to the 20th of June 1983 (dry season), observations of 24 hours a week for 7 weeks, were carried out on two groups of beef cows. During these observations, because of visibility problems, night time recordings were not reliable.

Cattle activities were determined by herd observations made at 10 minutes intervals. Gary et al. 1970, have shown that such intervals accurately reflect the amount and distribution of grazing time. Observations were made with binoculars from higher vantage points. During the hours of darkness a 12-v spot lamp was used to lighten the observed area. Grazing was recorded when an animal was seen with his head close to the sward. Activities recorded were: grazing, eating supplements (poultry litter, wheat straw), drinking, standing, lying, walking and fighting.

Grazing time: In addition to the visual observations, two cows from each stress treatment, were rotationally equipped with a vibracorder to record grazing time. The vibracorders used (Zeeb, 1972) were developed for logging truck operating times and are manufactured by Kienzle, Villingen, W. Germany. They were successfully used for continuous recording of grazing time on cattle by Stobbs, 1970. The instruments were attached to the necks of the cows by means of a wide band of canvas which was secured by adjustable straps round the neck. The vibracorder was kept in a pocket tightly stropped to the band, so that the axis of the recorder was vertical when the head of the animal was in a grazing position. The vibracorder transfers movements by

means of a stylus attached to a freely oscillating pendulum to a waxed chart which is rotated by a clock mechanism. We used an eight day instrument (TFW 3/8), so that the chart recorded the grazing pattern continuously and had to be replaced only once a week (Fig. 4).

Individual cow behaviour observation trial;

In a trial carried out in the summer of 1985, eight cows, four of which were good performers and the other four poor performers (expressed by number of calvings and by weaning weight during the experimental years) were individually observed during three days for 15 hours (from sunrise to sunset). The objective of this trial was to determine whether differences in performance under stress were reflected in different behaviour patterns.

Activities recorded were: grazing time, feeding a supplements (poultry litter), drinking, standing and lying.

Biting rates: Five measurements of biting rates were made on three different occasions, after the behaviour observation trial. Observations were made on each of the eight cows of the experiment. A stop watch was used to measure the time taken for animals to make 20 bites (Jamieson and Hodgson, 1979). From these records, biting rates (bites per min.) were calculated. A record was discarded if an animal raised its head from the sward before it had completed 20 bites.

5.4.3. Results and discussion

During the December (transitional period) observations, cattle generally rose before daylight and started grazing while calves nursed. After 3-4 hours of intense grazing the herd would move toward water. After watering most cows rested, for 4-5 hours. During this period they would alternately rest and ruminate whilst standing or lying. Approximately 25 % of the cows grazed during this rest period. In addition they watered and ate supplement intermittently and calves

suckled once or twice. Movement after dark was minimal and walking was only associated with grazing. Most of the cows grazed during the night between 21⁰⁰ and 24⁰⁰ h.

The results of the herd behaviour observations are presented in Tables 5.4.1. and 5.4.2. It appears that in spite of being confined to a small area (0.2 ha/cow) and although highly supplemented, the cows in the deferred treatment spent for almost the same number of day light hours (only 4% less) grazing as the cows in continuous grazing herd spent. During the 24 hours observation, the continuously grazing spent an additional 2.45 hours for grazing, mainly during the night. The fact that the cows in the deferred paddock spent almost as much time foraging as did the cows in continuous grazing treatment, has important implications to management of deferred grazing systems. The deferred cows were more vigilant. The lay around less and even fought.

In the observations carried out during the dry season (May - June), most of the grazing observed was concentrated in the late afternoon, in the evening through to 1⁰⁰ a.m. and in the morning after sunrise. Other than this, little consistency of grazing pattern was observed.

Meteorological and dry matter content of pasture showed a progressive increase in percent dry matter content of the herbage in the field, and a general rise in temperature (Table 5.4.5). No association was found between average time spent grazing per cow and between percent dry matter content of the pasture and temperature changes. Even though recording of night grazing was handicapped by poor visibility it was observed grazing activity increased during the night as temperature increased.

Mean grazing time, during the green season, as recorded by vibracorders is presented in Table 5.4.3. The differences in stocking

rates between the treatments, did not significantly affect the grazing time of the cows during the green season, but a trend to spend more time grazing was recorded in the high stress treatment. The cows spent on average of 10.7 hours grazing during the green season.

The results of the individual cow behaviour observations are presented in Table 5.4.4. The good performing cows spent 19% more time grazing, 25% more time for drinking, and less time idling (as expressed by times spent for standing and lying), than the poor performing cows. There were no differences in biting rate between the good and poor performing cows.

Table 5.4.1. Time distribution and hour/activity spent by cows on different activities (12th December 1982)

Obs. time	2 4 h o u r s			
Padock No. Grazing Syst.	4 deferred		1 continuos	
Activity	Time distrib %	h/Acti- vity	Time distrib %	h/Acti- vity
Grazing	39.54	9.49	49.76	11.94
Supplementing				
Poultry litter	5.88	1.41	0.80	0.19
Wheat straw	20.68	4.96	2.60	0.62
Drinking	1.98	0.47	0.54	0.13
Other activities on pasture	31.92	7.66	46.29	11.11
Total	100	24.0	100	24.0

Table 5.4.2. Percentage time and hour/activity spent by cows on different activities (22nd December 1983)

Obs. time	Sunrise - Sunset			
Padock No. Grazing Syst.	4 deferred		5 continuos	
Activity	Daytime %	h/Acti- vity	Daytime %	h/Acti- vity
Grazing	41.43	5.38	42.95	5.58
Supplementing				
Poultry litter	6.71	0.92	--	--
Wheat straw	13.35	1.73	--	--
Drinking	1.93	0.25	--	--
Standing	22.94	2.98	31.52	4.10
Lying	6.15	0.80	17.73	2.31
Walking	6.71	0.92	7.80	1.01
Fighting	0.78	0.10	--	--
Total	100	13.0	100	13.0

Table 5.4.3. Mean grazing time during the green season, as recorded by vibracorders

Treatment	Nr. of recordings ¹	Mean grazing time (min. $\pm$ SD)		
		Day-time (5 ⁰⁰ -19 ⁰⁰ h)	Night (19 ⁰⁰ -5 ⁰⁰ h)	Total
High stress	14	524 $\pm$ 36	157 $\pm$ 56	681 $\pm$ 26
Medium deferred	14	490 $\pm$ 24	135 $\pm$ 32	625 $\pm$ 28
Medium stress	14	463 $\pm$ 56	142 $\pm$ 40	605 $\pm$ 68
Low stress	12	531 $\pm$ 16	123 $\pm$ 23	655 $\pm$ 37
Mean $\pm$ SEM		502 $\pm$ 8.9	139 $\pm$ 3.9	641 $\pm$ 9.2

1- Nr. of recordings = nr. of cows x nr. of days.

Table 5.4.4. Percentage time and hour/activity spent by good and poor performing cows on different activities (July 1985)

Obs. time	Sunrise - Sunset			
	Good performing cows		Poor performing cows	
Activity	Daytime %	h/Activity	Daytime %	h/Activity
Grazing	28.70	4.30	24.13	3.62
Supplementing Poultry litter	3.30	0.49	3.31	0.50
Drinking	4.28	0.64	3.39	0.51
Standing	40.63	6.09	48.05	7.21
Lying	23.09	3.46	21.12	3.17
Total	100	15.0	100	15.0
Rate of biting	52.0 $\pm$ 3.4		51.8 $\pm$ 7.2	

Table 5.4.5. Dry matter content of the pasture and max. temperature data as tabulated against daily grazing

Observation	1	2	3	4	5	6	7
	1/2	15/16	22/23	29/30	5/6	13/14	19/20
Date	May 83	May 83	May 83	May 83	June 83	June 83	June 83
Dry matter content of pasture (%)	46	55	60	69	78	82	90
Max. temperature C°	31	30	27	34	30	36	31
Average observed grazing time (h/cow/day)	8.28	9.82	6.38	8.13	7.82	8.05	7.60

Fig. 4 Vibracorder charts showing grazing patterns of cows on the experiment

5.5. PHYSIOLOGICAL RESPONSES

5.5.1 Blood profile

(The effects of nutritional stress treatments, pasture condition and physiological state of the cow on its blood profile).

5.5.1.1 Introduction

Clinical biochemistry in veterinary medicine has expanded considerably in the last decade. Many enzymes, proteins, metabolites, hormones and minerals are known to have a significant relationship to specific disorders, diseases and nutritional deficiencies. The term "enzyme and metabolic profile" refers to the activities and levels of enzymes, metabolites and minerals in the blood or serum.

In recent years there has been an increasing concern about nutritionally related animal health problems that may result from a combination of high production and the stress imposed by modern intensive systems of forage production, nutrition and management. In extensive systems, nutritional stress situations occur when relatively high nutritional demands occur during periods of poor feed (pasture) availability. Under such conditions, there may also be environmental stresses that are related to hot and cold weather and also to the exertion required for mobility in difficult terrain.

One tool that has been advocated to help in diagnosis of some nutritionally related health problems is blood profiling. Practical applications of such profiles have been developed by scientists in England (Blowey, 1975; Payne et al., 1970, 1973; Rowlands, et al., 1974; Manston et

al., 1973) who combined tests of the more commonly used clinical blood analyses into a single system and based the identification of abnormalities upon statistical deviations from the population mean. Similar studies have been conducted in other countries (Arthaud et al., 1959; Boots et al., 1970; Blowey et al., 1973; Shultze, 1955).

In Israel, the levels of various blood parameters have been studied in dairy cows and in beef herds under various nutritional management conditions. Several parameters have been suggested as indicators of the nutritional-metabolic status of the animals in the presence and absence of metabolic disorders and during the absence or presence of clinical symptoms (Bogin et al., 1974, 1975, 1976). It is suggested that total fat in the serum, for example, could be a useful indicator of rates of fat depletion or fat accretion during critical grazing periods.

The relationship between blood profile and performance of beef cows, is complicated by the fact that the blood profile is also sensitive to changes in nutrition (both pasture condition and supplementary feeding) and to the physiological status of the cow. It is therefore useful to first study the separate effects of the overall nutritional environment as represented by the experimental treatments as well as the overall effects of pregnancy and lactation on the various blood profile parameters. The nutritional and environmental effects will be analyzed in terms of the treatments (as defined in part 2) for the different pasture seasons. The physiological states are defined as: Dry empty cows (DEC); dry low pregnancy (DLP); dry medium pregnancy (DMP); dry high pregnancy (DHP); early phase of lactation (HLC); and late lactation phase (LLC). In defining these states, lactation takes precedence over pregnancy, so that cows defined as lactating, may or may not be pregnant.

5.5.1.2 Materials and Methods

Blood parameters

These were divided into the following categories:

- Serum proteins (total protein, albumin and globulin)
- Electrolytes (Inorganic phosphorus, Ca, Mg)
- Metabolites (total lipids, glucose, urea)
- Enzymes (aspartate amino transferase, lactic dehydrogenase and alkaline phosphatase)
- Carotene and vitamin A.

Blood sampling

Blood sampling was carried out throughout the annual cycle. The dry season began in early summer and continued till early autumn, when cows started calving. The transitional season began soon after the first heavy rains and continued till mid-winter (about mid January). During this period, most cows were in the early lactation phase. The green season extended from mid-winter till the end of spring.

Blood samples were taken early in the morning from animals that were confined since the previous afternoon. Soon after bleeding, the animals were returned to pasture. Handling stress may have influenced the blood profile. Blood was taken from the jugular vein, inactivated immediately after withdrawal, allowed to clot and transported to the laboratory in an insulated cool container. For the determination of blood inorganic phosphorus and glucose, whole blood was used. For the determination of phosphorus, 1.0 ml of whole blood was added to a tube containing 4.0 ml of 10% trichloroacetic acid (TCA) and for glucose, 0.2 ml blood was added to a tube containing 1.8 ml 4% TCA. Sera were kept in the laboratory at 10°C until analysis.

Proteins, metabolites and electrolites

Total protein was determined by the method of Gornall et al. (1949); albumin by the method of Doumas et al. (1971); and total lipids with the phosphovanilin method as described by Frings et al. (1972). Glucose was determined by the enzymatic, colorimetric method of Boehringer Mannheim (1979), and urea according to the method of Gutman (1974). Globulin levels were obtained by subtracting albumin levels from total protein levels. Inorganic phosphorus (Pi) in serum was determined colorimetrically according to Gilford Diagnostics (1979). Ca was determined according to Gilford Diagnostics (1981), and magnesium (Mg) according to Bohuon (1962). The total lipid/glucose ratio (TL/G), Ca/Pi and albumin/globulin ratios were calculated from the separate values of each cow.

Enzymes

Serum aspartate amino transferase (AST), lactic dehydrogenase (LDH) and alkaline phosphatase (ALP) were run within 48 hours from the time of the blood withdrawal. The enzymes were run on an autoanalyzer (GILFORD-203S). AST was determined according to Bergmeyer (1978); LDH according to Bergmeyer (1974) and ALP according to Boehringer Mannheim Diagnostica (1979).

Carotene and Vitamin A

These were determined according to Carr and Price (1926).

5.5.1.3 Results

A. Statistical analysis

The effects of season, physiological state of the cow and experimental treatment on the values of the blood profile parameters were analysed by means of the GLM procedure (SAS, 1984). The significance of the

effects and of their interactions are given as the null hypothesis probability ($Pr > F$) for the type III sum of squares (Table 5.5.4.1). This analysis determines the marginal significance of an effect when all other listed effects are taken into account. Accordingly, the analysis results are invariant with regard to the order of the listed effects.

Over all blood profile parameters, season effects and effects of physiological state of the cow are, as a rule, highly significant, whereas experimental treatment effects are seldom significant. The outstanding exceptions to this rule are:

- serum total protein which is not significantly affected by physiological state;
- alkaline phosphatase (ALP) which is not significantly affected by physiological state when interactions are taken into account, but is significantly effected when they are not;
- serum globulin, albumin, aspartate amino transferase, which are significantly affected by treatment ($P < 0.05$) when interactions are taken into account;
- blood glucose and lactic dehydrogenase which are significantly affected by treatment ($P < 0.05$) when interactions are not taken into account;
- alkaline phosphatase which is highly significantly affected by treatment.

Interactions between season and physiological state were significant only in the case of calcium.

All effects, including interactions accounted for 17%-41% of the variance in the different parameters; the lowest R^2 values were registered for total lipids and calcium, and the highest, for lactic dehydrogenase (LDH) and aspartate amino transferase (AST). Variation around the mean due

(LDH) and aspartate amino transferase (AST). Variation around the mean due to unaccounted for individual differences between animals and measurement error was highly variable between parameters. Thus coefficient of variation (CV %) was 4.15% for total serum protein and 48.74% for alkaline phosphatase. All models, even those without interactions (R^2 varying from 0.07 to 0.33 were highly significant ($Pr > F = 0.0001$)).

In summary, the weight of season and physiological state effects is far greater than treatment effects in all cases except in alkaline phosphatase where treatment effects are much greater than season or physiological state effects. In addition, interactions between season and physiological state are highly significant as a rule. With this general background we can now turn to the specific influence of the various effects on the different blood profile parameters.

B. Treatment and seasonal interactions

Blood serum proteins: While there were significant differences between treatments and between seasons, no clear pattern emerged (Table 5.5.1.2). Total proteins were relatively high in the medium stress treatment in the green season and also in the low stress treatment in the dry season; nevertheless, it cannot be concluded that high total protein levels are associated with low to medium stress, because as indicated in Table 5.5.1.2 this is not always so. The albumin and globulin levels are roughly inversely related, as both make up the total serum protein which does not vary much. Albumin is thus highest and globulin is lowest in the low stress/green season treatment. Also where albumin is relatively low, as in the medium stress/green and medium deferred/transitional treatments globulin is relatively high.

Over all treatments, total proteins were highest in the green season, albumin during the dry season and globulin in the green and transitional seasons. From this, one can conclude that protein and globulin levels tend to be high when nutrition is adequate, as it is in the green season.

Electrolytes: The data for the electrolytes are given in table 5.5.1.3. Here too it is difficult to discern a distinct pattern, but some regularities do occur. During the green season, in the medium deferred treatment, all three electrolytes, inorganic phosphorus, calcium and magnesium, were low, whereas in the medium stress treatment, electrolyte levels were relatively high. This observation is difficult to interpret, as during the green season no supplements were given to either herd. Stocking rate was higher in the medium deferred treatment, but also in the high stress herds.

During the dry season, only magnesium was significantly higher, again in the medium stress treatment. The only notable result in the transitional season was that the phosphorus and calcium levels were highest in the medium deferred treatment in contrast to the green season, when they were the lowest among the experimental herds.

Over all the treatments, phosphorus was highest in the dry season, calcium in the transitional season and magnesium in the green season! Whereas phosphorus and calcium could be related to poultry litter supplementation, magnesium appears to depend more on availability in the green pasture.

Metabolites: No significant differences in total lipid levels were detected between treatments even though, they tended to be lowest in the

low stress herds (Table 5.5.1.4). The medium deferred and low stress treated cows had significantly higher levels of total lipids in the transitional period. Differences in glucose levels were significant only in the transitional season when the levels were highest in the medium deferred herd and lowest in the high stress herd.

Differences in urea level were also significant only in the transitional season (when poultry litter intake was high). However, the highest urea levels were detected in the medium stressed herd while the lowest were in the medium deferred herd which received a considerable amount of barley grain with the poultry litter (see part 4.2.).

Over all treatments, glucose levels dropped from green to dry to transitional seasons; total lipids tended to be higher while urea levels were highest in the transitional season. It appears that whenever nutritional stress increases, blood glucose goes down and total blood lipids go up as a result of the mobilization of energy reserves.

Blood enzymes: In the green season, all three blood enzymes that were monitored, were highest in the medium stressed treatment, and generally low in the medium deferred treatment (Table 5.5.1.5). In the dry season there are no significant differences between treatments but during the transitional season, both AST and ALP levels were highest in the medium deferred treatment.

Over all treatments, season effects were strong, most enzyme levels being significantly higher during the green season, possibly due to more intensive physiological activity in lactating cows.

Carotene and Vitamin A: Treatment effects are significant only with regard to carotene in the green season when the levels were highest in the medium deferred treatment and lowest in high stress herds (Table 5.5.1.6). Both carotene and vitamin A levels were consistently lowest in the high stress treatment, but not always significantly so. However, the overall seasonal effects were much more emphasized. Carotene levels were very low in the dry season, as would be expected, but were highest not in the green but in the transitional season. Vitamin A levels were also low during the dry season, but relatively less so than the carotene. During the green season, vitamin A was, as expected, higher than in the transitional season. The vitamin A is stored in the liver while the carotene level is more directly influenced by the carotene content of the feed. The vitamin A reflects the storage and buffering effect of the liver : replenishment during the transitional and green seasons and release during the dry season.

C. Treatment and physiological status interactions

Blood serum protein: Total protein levels are only slightly affected by physiological status and tend to be somewhat higher in lactating cows (Table 5.5.1.7) . The albumin and globulin levels however are more clearly related to physiological status. Albumin levels were, as a rule, highest during late lactation and lowest in dry cows, either empty or at an early stage of pregnancy. The opposite was noted in the case of globulin, albeit with exceptions, especially in the medium stressed and medium deferred treatments. Globulin appears to be higher, as a rule, in non-lactating cows.

Electrolytes: Inorganic phosphorus and magnesium in the blood serum have a fairly clear but opposite relationship to physiological status (Table 5.5.1.8) Phosphorus is high in dry, empty cows and low in the early phase of lactation whereas magnesium is low in dry, empty cows but high in the early phase of lactation. This pattern could be related to the composition of the feed - phosphorus in poultry litter given in the dry season to non-lactating cows; magnesium in the green feed of lactating cows. With regard to calcium there appears to be an interaction between treatment and physiological status. In the high and low stress treatments, the calcium level is high in lactating cows and low in dry cows at an early stage of pregnancy, whereas in the medium stress and medium deferred treatments it is low during lactation and highest during mid-pregnancy in dry cows. The reasons for this result are not clear.

Metabolites: Lipid levels were high in lactating cows and low in dry cows, with little difference between the different stages of pregnancy (Table 5.5.1.9). Glucose levels were less clearly related to physiological status. They were higher in dry cows at low pregnancy in all treatments except in the high stress treatment where they were highest during the later phase of lactation. Dry cows in mid-pregnancy generally had the lowest glucose levels. Urea levels exhibited a pattern similar to that of the serum lipids: high during lactation and low in dry cows.

Enzymes: Aspartate amino transferase (AST) levels tended to be high in dry cows that were empty or at a low stage of pregnancy and lowest in dry cows during mid-pregnancy and also in cows during the late lactation phase (Table 5.5.1.10). Lactic dehydrogenase (LDH) levels were also high in

dry empty cows, but generally lowest during the later stages of pregnancy. Alkaline phosphatase (ALP) was generally highest in dry, empty cows, but also during the late lactation phase. It tended to be lowest during mid-pregnancy in dry cows. The overall pattern that emerges for all three enzymes is that their levels tend to be higher in dry, empty cows (or dry cows during early pregnancy) and low during mid or late pregnancy. Whereas AST tends to be low during the late lactation phase, LDH and ALP tend to be higher during lactation.

Carotene and Vitamin A: These were usually high in lactating cows and low in dry cows (Table 5.5.1.11). An exception is carotene in the medium deferred treatment, where it was highest in dry cows during mid pregnancy. In the low stress treatment carotene is very low during high pregnancy in dry cows, but this is not statistically significant. As pointed out earlier, carotene levels are closely related to carotene availability in the green feed intake. As most cows were lactating during the green season, higher carotene intake would coincide with lactation. Vitamin A levels were generally high in lactating and low in dry cows.

5.5.1.4 Discussion

The values for the different blood profile parameters are those of a healthy herd of cows managed relatively extensively on seasonal range. Some of the values are different from those of dairy cows (Avidar et al., 1981) but similar to those of beef cows (Collins et al., 1982). We will therefore discuss the effects of the environmental and nutritional stresses as well as the effects of physiological state on the blood profile parameters in the context of a normal herd without attempting to identify or define

pathological levels for any of the parameters. The aim of the analysis is thus to identify the homeostatic sensitivity of the various parameters to changes in environmental, nutritional and physiological conditions.

Blood serum proteins: Total proteins reflect the overall nutritional level and tend to be higher as the forage conditions improve. Thus levels are higher during the green season than during other seasons. Response to physiological state per se is not consistent. Globulin is also related to nutritional level, but also to the physiological state of the animal. When the physiological requirements are high, as they are during lactation, the globulin levels tend to fall. Conversely, the globulin level in the serum tends to rise when physiological activity is less intense, as in dry cows. It appears, therefore, that globulin levels are related to the ratio 'nutritional level/physiological activity'. In other words, it would appear that globulin tends to increase when the energy balance is positive and decrease when it is negative. Albumin, which is the complement of globulin in total blood protein, tends to be higher in lactating cows and during the dry season, but low in dry cows. More generally, albumin levels appear to be inversely related to the energy balance.

Electrolytes: Seasonal effects of pasture quality appear to override physiological effects on the serum electrolyte levels. Phosphorus and calcium levels, are highest during the dry season, when poultry litter is available ad lib, mainly as a nitrogen supplement. Magnesium levels, on the other hand, are highest during the green season. As the main lactation period generally coincides with the green season, the low phosphorus and calcium and the high magnesium levels in lactating cows could well be

related to the availability of electrolytes in the feeds. Magnesium levels, especially in hypomagnesemia, are dominated by environmental conditions (Beenson, 1959; Bould, 1964), but the levels recorded in this experiment do not indicate magnesium deficiency. The observation that all electrolyte levels were lowest in the medium stress deferred treatment during the green season is puzzling. It would suggest that the high mineral content of the young green herbage that was not available to the cows during the deferment period in the deferred treatment, was important in determining the electrolyte levels for the whole green season. No poultry litter or other supplement was fed during the green season, so that the electrolyte levels could only have reflected the grazing regime of the treatments.

Metabolites: Lipid levels rise when fatty acids are mobilized from adipose tissue; glucose levels are more directly dependent on nutritional level. Both are influenced by the energy requirements of the cow. Where these are high (e.g. during lactation), both lipid and glucose levels tend to be high. Where feed is restricted (e.g. during the transitional pasture phase) lipid levels tend to rise. Where feed is generally adequate (as in the low stress, low stocking rate herds), the lipid and glucose levels tend to be lower.

Urea levels depend on nitrogen supply in the feed and probably on the availability of digestible energy too. It is the main end product of protein metabolism and appears in the blood before being excreted by the kidney (Hewetts 1974). When poultry litter is fed ad lib., the urea levels tend to increase (during the dry and transitional pasture phases), especially when intake of poultry litter increases as available roughage decreases. Where digestible energy supply is increased (as in the medium

stress deferred herd during the transitional pasture phase), urea levels in the blood serum tend to be lower. However, not only poultry litter is a source of nitrogen. During the green season, nitrogen content of the pasture is high and the protein content of the ingesta is generally even higher than the mean level in the pasture because of selective grazing (Table 2.3.2). Consequently, urea levels during this phase are high, not as high as during the transitional phase, but higher than during the dry phase, when poultry litter is available but consumption is relatively low. As the lactation phase generally coincides with the green pasture phase (and the transitional phase), urea levels tend to be high in lactating cows.

Enzymes: Aspartate amino transferase (AST) is found in all body cells and serves as a catalyst for the transfer of amino groups from amino acids to keto acids. It is released into the blood stream as a result of tissue turnover and has been used as an indicator of tissue damage (Coles, 1969). Lactic dehydrogenase (LDH) is also widely distributed in the body, with different isozymes concentrated in different organs (Schmidt and Schmidt, 1983). It tends to increase in the blood serum as a result of increased activity that involves strenuous exertion. Alkaline phosphatase (ALP) is involved in the hydrolysis of phosphoric esters that liberate organic phosphorus. As phosphorus is involved in all energy related metabolic reactions, it is possible that during intensified metabolic conditions, phosphorus requirements are high and little is released into the blood stream whereas when metabolic activity is less intense, surplus phosphorus and ALP is released into the blood.

Generally, the relationship between enzyme levels and treatment, pasture condition and physiological state is rather complex. LDH is consistently high in the medium stressed herd; AST and ALP also tend to be high in this treatment, especially in the green season. All of which would indicate that, despite the fact that the treatment was designated as 'medium stress' on the basis of stocking rate and supplementation level, it was, in fact, highly stressed, possibly because of poorer productivity of the range vegetation. There is some indication that it could indeed have been so (see part. 4). On the other hand, as the enzyme levels were lowest in the 'high stress' herds, especially in the dry season, it could be concluded that conditions were better in the 'high stress' paddocks so that, in fact, stress was lower in the 'high stress' treatment!

The response of the enzyme levels to physiological state varied with the different enzymes. AST was lowest in lactating cows during the later phase of lactation and in dry cows in mid-pregnancy; it was highest in dry empty cows and dry cows at an early stage of pregnancy. LDH was low in dry cows during late pregnancy; and high in dry, empty cows and also in lactating cows during the late lactation phase. ALP, like AST, was lowest in dry cows during mid-pregnancy and tended to be high in dry, empty cows, and fairly high in lactating cows. The most consistent observation was that all enzyme levels were generally high in the dry, empty cows. This would indicate that, as a rule, - dry, empty cows were most highly stressed, and that could be related to the fact that they did not conceive. It is not clear what the cause of the stress could be, - subclinical pathological events or poorer ability to cope with the cyclic stresses imposed on the animals. Whatever the reason, these physiological parameters were the only ones that gave a consistent response over all treatments.

Enzyme levels tended to be lowest in dry, pregnant cows during mid and late pregnancy. This could reflect a generally more quiescent state where activity is considerably reduced. However, during this phase, major metabolic changes are under way and one would expect an elevation of enzyme response. But that is not what was observed and so it can be concluded that mid and late pregnancy are periods when cows are not subjected to severe physiological stress.

Carotene and vitamin A: The outstanding observation regarding carotene is its overriding dependence on pasture phase and the remarkable fact that it is highest during the transitional season, when even though young green pasture is rich in carotene, it is available only in small amounts. It would appear that despite the low availability of the green vegetation it is effectively gathered even by cows. Observations with a fistulated cow on the experimental paddocks indicated that selection for green feed is so strong that within a few days of germination, the forage grazed was predominantly green even though the seedlings were less than 3 cm high (N. Silanicove, personal communication). The possibility that the poultry litter contained significant amounts of carotene, is not likely as the carotene levels during the dry season, when poultry litter was available ad lib, was lower than in the other seasons by more than an order of magnitude.

Both carotene and vitamin A levels were lowest in the high stress treatment, where stocking rate was highest. It would appear that with strong selection pressure on young green vegetation, the supply must have been lower than in the other treatments. This would indicate that both

carotene and vitamin A levels in the serum are strongly influenced by high stocking density.

The effect of physiological state on carotene and vitamin A levels in the blood is much less dramatic than the effect of pasture condition, and is probably confounded with pasture condition. No clear relationship between either carotene or vitamin A and physiological state emerges. In general, both levels are high in cows during the early phase of lactation and low in dry cows.

5.5.1.5 Conclusion

Many blood profile parameters fluctuate widely as a result of pasture conditions, supplementation regime and physiological state of the animal. Some can be clearly related to environmental, nutritional or physiological factors. However, even after all these have been taken into account, there is still a major part of the variance in the data that is unaccounted for. A large part of this residual variance is due to the individual animal characteristics. The relationship between the individual cow performance and its relation to the blood profile will be analysed in a later section.

Table 5.5.1.1 Statistical analysis of effects of season(S), physiological state (P) treatment (T) and interactions on the values of blood profile parameters.
1) with interactions; 2) without interactions (BARD TRT EFF)

Parameter	Significance of effects (Pr > F, Type III SS)						Model statistics					
	S	T	P	S x T	S x P	T x P	Mean	R ²	Pr > F	CV(%)		
PROT	(1)	.0001	.37	.15	.016	.0001	.16	.14	7.60	.21	.0001	4.15
	(2)	.0001	.058	.46					"	.07	.0001	4.35
GLOB	(1)	.0001	.038	.0001	.78	.0001	.22	.11	4.04	.33	.0001	11.09
	(2)	.0001	.044	.0001					"	.22	.0001	11.53
ALB	(1)	.0009	.039	.0001	.026	.0001	.009	.099	3.57	.37	.0001	11.01
	(2)	.0001	.40	.0001					"	.20	.0001	11.98
TL	(1)	.0010	.106	.0001	.61	.73	.99	.71	532.3	.19	.0001	26.59
	(2)	.0001	.062	.0001					"	.13	.0001	26.37
SUG	(1)	.0028	.57	.0055	.012	.0001	.104	.36	62.16	.26	.0001	32.64
	(2)	.0271	.039	.0001					"	.13	.0001	34.09
UR	(1)	.0001	.072	.0001	.034	.0001	.63	.83	37.7	.30	.0001	30.26
	(2)	.0001	.065	.0001					"	.15	.0001	32.34
PI	(1)	.0001	.088	.0001	.028	.0001	.80	.091	6.02	.31	.0001	26.85
	(2)	.0001	.24	.0001					"	.20	.0001	27.90
CAL	(1)	.0001	.41	.0012	.0092	.0028	.0020	.029	9.58	.17	.0001	15.14
	(2)	.0001	.104	.0001					"	.08	.0001	15.39
MAG	(1)	.0001	.059	.0001	.67	.0001	.41	.90	2.56	.36	.0001	12.27
	(2)	.0001	.0107	.0001					"	.28	.0001	12.64
AST	(1)	.0001	.049	.0001	.67	.0001	.88	.11	75.2	.40	.0001	31.27
	(2)	.0001	.0124	.0001					"	.30	.0001	32.44
LDH	(1)	.0001	.15	.0001	.26	.0009	.16	.50	21.50	.41	.0001	16.64
	(2)	.0001	.032	.0001					"	.33	.0001	17.00
ALP	(1)	.0043	.0001	.22	.92	.67	.86	.33	117.1	.23	.0001	48.74
	(2)	.0001	.0001	.0009					"	.17	.0001	48.45

Table 5.5.1.2

Protein levels in the blood of the experimental beef cows
during the different grazing seasons

Treatment	Total proteins - (g/100 ml)				Albumin - (g/100 ml)				Globulin - (g/100 ml)			
Season	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM
High stress	ab	a			ab		a				a	
	7.71	7.46	7.53	7.56	3.50	3.67	3.57	3.58	4.21	3.82	3.96	4.0
	x	y	y	±0.028	x	y	xy	±0.042	x	y	y	±0.05
Medium deferred	b	a			ab		b				b	
	7.54	7.56	7.48	7.53	3.41	3.76	3.30	3.49	4.22	3.82	4.13	4.06
				±0.056	x	y	x	±0.044	x	y	x	±0.05
Medium stress	a	a			a		a				a	
	7.84	7.50	7.46	7.60	3.35	3.68	3.52	3.52	4.48	3.83	3.95	4.09
	x	y	y	±0.06	x	y	xy	±0.097	x	y	y	±0.095
Low stress	ab	b			b		a				a	
	7.64	7.66	7.47	7.59	3.56	3.86	3.57	3.66	4.12	3.81	3.92	3.95
	x	x	y	±0.04	x	y	x	±0.05	x	y	xy	±0.06
Mean±SEM	7.68	7.55	7.49	7.57	3.48	3.75	3.52	3.57	4.23	3.82	3.97	4.016
	±0.054	±0.032	±0.038	±0.043	±0.052	±0.065	±0.054	±0.058	±0.068	±0.066	±0.053	±0.062

a,b,c - Means within a column (season) not sharing a common letter are significantly different;

x,y,z - Means within a row (treatment) not sharing a common letter are significantly different.

SEM - Standard error of the mean.

Table 5.5.1.3.

Inorganic Phosphorus (Pi) Calcium (Ca) and Magnesium (Mg)
levels in the blood of the experimental beef cows during the different grazing seasons

Treatment	Pi (mg/100 ml)				Ca - (mg/100 ml)				Mg - (mg/100 ml)			
Season	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM
High stress	a		a		ab				ab	a	a	
	5.59	6.60	5.89	6.03	9.40	9.21	10.02	9.54	2.79	2.38	2.53	2.57
	x	y	xy	±0.21	x	x	y	±0.16	x	y	z	±0.038
Medium deferred	b		b		a				b	a	b	
	4.92	7.17	7.03	6.37	9.27	9.16	10.49	9.64	2.66	2.35	2.34	2.45
	x	y	y	±0.24	x	x	y	±0.16	x	y	y	±0.03
Medium stress	a		a		b				a	b	a	
	5.36	7.14	6.06	6.19	9.79	9.45	10.33	9.86	2.84	2.54	2.47	2.62
	x	y	x	±0.29	xy	x	y	±0.25	x	y	y	±0.07
Low stress	a		a		ab				ab	a	a	
	5.53	6.68	5.96	6.06	9.48	9.24	10.06	9.59	2.72	2.32	2.53	2.52
	x	y	xy	±0.21	x	x	y	±0.161	x	y	z	±0.038
Mean±SEM	5.41	6.83	6.14	6.14	9.47	9.26	10.18	9.65	2.75	2.39	2.49	2.54
	±0.127	±0.301	±0.234	±0.23	±0.155	±0.177	±0.181	±0.18	±0.037	±0.058	±0.043	±0.044

a,b,c - Means within a column (season) not sharing a common letter are significantly different.

x,y,z - Means within a row (treatment) not sharing a common letter are significantly different.

SEM - Standard error of the mean.

Table 5.5.1.4.

Total Lipids, Glucose and Urea levels in the
blood of the experimental beef cows during the different
grazing seasons

Treatment	Total Lipids - (mg/100ml)				Glucose (mg/100 ml)				Urea - (mg/100 ml)			
Season	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM
High stress	550.9	498.1	553.7	534.23 ±19.47	70.88 x	61.38 y	51.03 z	61.10 ±2.80	39.04 x	31.37 y	43.26 z	37.89 ±1.17
Medium deferred	539.5 xy	513.3 x	591.7 y	548.17 ±25.23	70.41	61.98	64.92 b	65.77 ±3.51	37.54 x	31.63 x	34.03 xy	34.40 ±1.27
Medium stress	535.9	502.4	599.7	546.0 ±35.52	71.06	59.85	57.57 ab	62.83 ±5.19	37.98 x	35.32 x	49.90 y	41.07 ±2.38
Low stress	508.9 xy	482.5 x	555.5 y	515.63 ±16.63	64.98 x	58.06 xy	54.83 y	59.29 ±2.75	37.36 x	30.47 y	46.25 z	38.03 ±1.24
Mean±SEM	532.9 ±18.27	496.7 ±21.31	569.5 ±28.21	534.52 ±23.40	68.97 ±2.287	60.12 ±4.129	55.72 ±3.500	61.93 ±3.43	38.05 ±0.98	31.93 ±1.60	43.93 ±1.754	37.91 ±1.48

a,b,c - Means within a column (season) not sharing a common letter are significantly different.

x,y,z - Means within a row (treatment) not sharing a common letter are significantly different.

SEM - Standard error of the mean.

Table 5.5.1.5.

Aspartate amino transferase (AST), Lactic Dehydrogenase (LDH)
and alkaline phosphatase (ALP) levels in the blood of the experimental beef cows
during the different grazing seasons

Treatment	AST - (mU/ml)				LDH - (mU/ml)				ALP - (mU/ml)			
Season	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM
High stress	ab		a		ab				a		a	
	92.02	53.31	68.64	71.32	2351.3	1850.9	1928.7	2043.6	107.83	92.07	91.38	97.09
	x	y	z	±2.74	x	y	y	±53.67				±6.02
Medium deferred	a		b		b				ab		b	
	81.04	54.21	79.18	71.48	2273.7	1989.9	2016.9	2093.5	126.05	130.29	125.89	127.41
	x	y	x	±5.87	x	y	y	±73.73				±17.78
Medium stress	b		a		a				b		b	
	96.72	55.44	68.52	73.48	2527.6	2072.3	2072.4	2224.1	154.62	96.56	124.74	125.31
	x	y	z	±4.60	x	y	y	±99.88				±10.51
Low stress	ab		a		ab				ab		a	
	90.25	59.87	68.92	73.01	2342.5	1906.6	1959.5	2069.5	127.65	94.90	95.75	106.1
	x	y	z	±2.63	x	y	y	±53.26	x	y	xy	±8.42
Mean±SEM	90.33	55.99	70.49	72.31	2365.0	1928.7	1980.5	2099.6	125.72	101.45	105.14	112.38
	±3.37	±3.48	±2.89	±3.60	±67.96	±69.16	±58.11	±67.61	±9.27	±12.97	±9.45	±10.62

a,b,c - Means within a column (season) not sharing a common letter are significantly different.

x,y,z - Means within a row (treatment) not sharing a common letter are significantly different.

SEM - Standard error of the mean.

Table 5.5.1.6.

Carotene and Vitamin A levels in the
blood of the experimental beef cows during the different
grazing seasons

Treatment	Carotene				Vitamin A				
	Season	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM
High stress		a							
		517.50	50.75	993.27	520.51	50.75	16.85	43.36	36.99
		x	y	z	±48.03	x	y	z	±5.43
Medium deferred		b							
		1012.0	66.94	1001.00	693.31	61.60	28.50	44.89	45.0
		x	y	x	±54.22	x	y	xy	±6.99
Medium stress		ab							
		734.6	66.0	1165.0	655.2	65.75	20.17	46.63	44.18
		x	y	z	±99.64	x	y	z	±10.28
Low stress		ab							
		718.64	74.94	1206.3	666.63	69.36	24.44	48.96	47.59
		x	y	z	±63.05	x	y	z	±6.58
Mean±SEM									
		745.69	64.66	1091.39	633.91	61.87	22.49	45.96	43.44
		±103.9	±8.08	±86.78	±66.24	±12.82	±4.87	±6.57	±7.71

a,b,c - Means within a column (season) not sharing a common letter are significantly different;
x,y,z - Means within a row (treatment) not sharing a common letter are significantly different.
SEM - Standard error of the mean.

Table 5.5.1.7.

Protein levels in the blood of the experimental beef cows,
according to their physiological state

Treatment	Total proteins - (g/100ml)					Albumin - (g/100ml)					Globulin - (g/100ml)				
Phys. state	HS	MD	MS	LS	Mean $\pm$ SEM	HS	MD	MS	LS	Mean $\pm$ SEM	HS	MD	MS	LS	Mean $\pm$ SEM
DEC	7.60	7.55	7.77	7.55	7.62 xy $\pm$ 0.09	3.35	3.19	3.53	3.44	3.38 x $\pm$ 0.076	4.25	4.37	4.24	4.11	4.24 xy $\pm$ 0.08
DLP	7.64	7.40	7.77	7.66	7.62 xy $\pm$ 0.06	3.35	3.37	3.17	3.38	3.32 x $\pm$ 0.087	4.33	4.03	4.61	4.28	4.31 x $\pm$ 0.06
DMP	7.52	7.53	7.54	7.50	7.52 x $\pm$ 0.049	3.57	3.50	3.81	3.56	3.61 xy $\pm$ 0.096	3.95	4.03	3.73	3.94	3.91 yz $\pm$ 0.089
DHP	7.55	7.35	7.59	7.61	7.53 xy $\pm$ 0.060	3.67	3.79	3.74	3.76	3.74 yz $\pm$ 0.069	3.88	3.75	3.85	3.85	3.79 z $\pm$ 0.083
HLC	7.60	7.81	7.53	7.57	7.63 xy $\pm$ 0.05	3.52	3.62	3.45	3.55	3.54 xy $\pm$ 0.067	4.08	4.22	4.07	4.03	4.10 yz $\pm$ 0.08
LLC	7.59	7.60	7.83	7.68	7.68 y $\pm$ 0.05	3.75	3.78	3.81	3.92	3.82 z $\pm$ 0.10	3.86	3.88	4.07	3.78	3.90 z $\pm$ 0.105
Mean $\pm$ SEM	7.58 $\pm$ 0.05	7.54 $\pm$ 0.065	7.67 $\pm$ 0.085	7.60 $\pm$ 0.05	7.60 $\pm$ 0.06	3.54 $\pm$ 0.070	3.54 $\pm$ 0.079	3.59 $\pm$ 0.135	3.60 $\pm$ 0.076	3.66 $\pm$ 0.086	4.06 $\pm$ 0.080	4.02 $\pm$ 0.088	4.10 $\pm$ 0.12	4.00 $\pm$ 0.075	4.04 $\pm$ 0.086

1- Physiological State: DEC - dry empty cows, DLP - dry low pregnancy, DMP - dry medium pregnancy, DHP - dry high pregnancy, HLC - high lactating, LLC - low lactating cows.

SEM - Standard error of the mean.

a,b,c - means within a row (physiological state) not sharing a common letter are significantly different;

x,y,z,w - means within a column (treatment) not sharing a common letter are significantly different.

Table 5.5.1.8.

Inorganic Phosphorus (Pi), Calcium (Ca) and Magnesium (Mg)
levels in the blood of the experimental beef cows, according to their physiological state

Treatment	Pi (mg/100ml)					Ca (mg/100ml)					Mg (mg/100ml)				
Phys. state	HS	MD	MS	LS	Mean±SEM	HS	MD	MS	LS	Mean ±SEM	HS	MD	MS	LS	Mean ±SEM
DEC	a	ab	ab	b		a	a	b	a		a	b	ab	ab	
	8.15	7.06	7.97	6.68	7.47±0.44	9.27	9.04	10.40	9.14	9.46±0.30	2.13	2.39	2.25	2.28	2.26±0.07
	x	x	x	xy		xy	xz				x	x	x	x	
DLP											a	a	b	a	
	7.20	6.99	6.35	7.06	6.9 ±0.43	9.01	9.35	10.00	9.10	9.37±0.324	2.46	2.42	2.82	2.40	2.53±0.058
	xy	x	xy	x		x	xz				y	x	z	xy	
DMP															
	6.23	6.61	6.48	6.39	6.43±0.49	9.73	10.56	10.75	9.78	10.21	2.53	2.39	2.58	2.48	2.50±0.094
	yz	xy	xy	xy		xy	y			±0.333	yz	x	yz	xyz	
DHP															
	5.59	5.28	6.20	5.86	5.73	9.27	9.99	9.42	9.48	9.54±0.32	2.61	2.41	2.40	2.53	2.49±0.066
	z	z	xy	xy	±0.375	xy	yz				yzz	x	xy	yz	
HLC															
	5.56	5.16	5.10	5.45	5.32±0.20	9.51	9.63	9.34	9.89	9.59±0.22	2.74	2.72	2.82	2.69	2.74±0.05
	z	z	y	y		xy	yz				z	y	z	z	
LLC						ab	c	a	bc		ab	a	ab	ab	
	5.82	5.50	5.88	5.81	5.75±0.30	9.87	8.85	10.53	9.50	9.69±0.306	2.58	2.39	2.71	2.49	2.54±0.08
	z	yz	y	y		y	x				yz	x	yz	yz	
Mean ± SEM	6.43	6.10	6.33	6.21	6.27	9.44	9.57	10.07	9.48	9.64	2.51	2.45	2.60	2.48	2.51
	±0.36	±0.37	±0.50	±0.30	±0.37	±0.23	±0.30	±0.50	±0.25	±0.31	±0.065	±0.067	±0.105	±0.06	±0.072

1- Physiological State: DEC - dry empty cows, DLP - dry low pregnancy, DMP - dry medium pregnancy, DHP - dry high pregnancy, HLC - high lactating, LLC - low lactating cows.

SEM - Standard error of the mean.

a,b,c - means within a row (physiological state) not sharing a common letter are significantly different;

x,y,z - means within a column (treatment) not sharing a common letter are significantly different.

Table 5.5.1.9.

Total lipids, glucose and urea levels in the blood of the experimental beef cows,
according to their physiological state

Treatment	Total lipids - (g/100ml)					Glucose - (g/100ml)					Urea - (g/100ml)				
Phys. state	HS	MD	MS	LS	Mean $\pm$ SEM	HS	MD	MS	LS	Mean $\pm$ SEM	HS	MD	MS	LS	Mean $\pm$ SEM
DEC	508.0	479.7	490.7	425.7	476.03	51.5	69.6	39.9	61.2	55.55	34.01	33.02	35.11	36.74	34.72
	x			x	± 55.87	x	xy	x		± 8.06	xy	xy	x	xy	± 2.82
DLP	509.8	517.4	467.7	474.5	492.35	70.0	76.7	73.9	65.2	71.45	37.61	28.19	36.72	28.74	32.82
	x			x	± 27.10	yz	z	y		± 5.29	xyz	x	xy	x	± 2.23
DMP	507.2	549.5	525.6	491.0	518.33	51.1	52.8	43.70	57.8	51.35	32.38	32.53	38.17	38.71	35.45
	x			x	± 35.49	x	y	x		± 5.19	x	xy	y	y	± 2.70
DHP	502.0	527.4	458.6	465.3	488.33	53.2	61.2	52.3	51.8	54.63	39.87	40.45	40.86	36.5	39.42
	x			x	± 21.51	xy	xy	xy		± 4.13	yz	y	xy	xy	± 2.72
HLC	575.2	543.2	589.7	571.2	569.83	70.4	67.7	63.9	64.3	66.58	40.75	37.11	45.25	40.78	40.97
	xy			y	± 29.27	yz	xy	xy		± 2.48	z	xy	y	y	± 2.01
LLC	609.4	583.4	602.9	563.5	589.8	83.0	71.6	71.9	64.2	72.68	39.44	41.07	37.10	40.2	39.45
	y			y	± 25.27	z	xy	y		± 4.81	yz	y	xy	y	± 1.48
Mean $\pm$ SEM	535.2	533.4	522.5	498.5	522.44	63.2	66.6	57.6	60.75	62.04	37.34	35.40	38.87	36.94	37.14
	± 26.5	± 35.7	± 47.9	± 21.7	± 32.71	± 4.75	± 4.75	± 6.33	± 4.11	± 4.93	± 2.05	± 2.27	± 2.85	± 2.23	± 2.37

1- Physiological State: DEC - dry empty cows, DLP - dry low pregnancy, DMP - dry medium pregnancy, DHP - dry high pregnancy, HLC - high lactating, LLC - low lactating cows.

SEM - Standard error of the mean.

a,b,c - means within a row (physiological state) not sharing a common letter are significantly different;

x,y,z - means within a column (treatment) not sharing a common letter are significantly different.

Table 5.5.1.10.

Aspartate amino transferase (AST), lactic dehydrogenase (LDH) and alkaline phosphatase (ALP)
levels in the blood of the experimental beef cows, according to their physiological state

Treatment	AST - I.U. (mU/ml)					LDH - I.U.					ALP - I.U.				
Phys. state	HS	MD	MS	LS	Mean $\pm$ SEM	HS	MD	MS	LS	Mean $\pm$ SEM	HS	MD	MS	LS	Mean $\pm$ SEM
DEC	85.28	91.58	85.52	80.99	85.84 x $\pm$ 4.60	2225.0	2331.5	2436.8	2211.5	2301.2 x $\pm$ 109.79	127.5	161.3	134.8	106.5	132.53 $\pm$ 15.75
DLP	82.91	77.21	108.86	87.55	89.13 x $\pm$ 5.34	2174.4	2090.0	2433.7	2375.7	2268.45 x $\pm$ 114.43	124.6	137.0	141.6	131.0	133.55 $\pm$ 16.16
DMP	61.95	69.55	56.26	71.85	64.90 z $\pm$ 4.68	1801.1	2036.8	2143.0	1864.9	1961.45 y $\pm$ 92.02	71.5	118.3	81.1	102.9	93.45 $\pm$ 15.36
DHP	68.83	64.80	63.14	72.44	67.30 yz $\pm$ 5.05	1822.8	1878.1	1821.7	1827.6	1837.55 y $\pm$ 80.75	96.5	147.5	100.4	98.0	110.6 $\pm$ 14.90
HLC	77.84	79.00	72.57	83.58	78.25 xy $\pm$ 4.19	2191.9	2271.9	2116.2	2277.9	2214.48 x $\pm$ 90.16	89.4	130.5	141.1	117.1	119.53 $\pm$ 15.12
LLC	63.92	52.06	68.57	64.75	62.33 z $\pm$ 5.03	2107.6	2264.2	2361.6	2447.0	2295.1 x $\pm$ 103.83	90.6	173.1	110.5	131.5	126.43 $\pm$ 16.96
Mean $\pm$ SEM	73.46 $\pm$ 4.07	72.37 $\pm$ 5.66	75.82 $\pm$ 6.92	76.86 $\pm$ 3.97	74.63 $\pm$ 5.01	2053.8 $\pm$ 82.81	2145.4 $\pm$ 104.4	2218.8 $\pm$ 149.7	2167.4 $\pm$ 85.64	2146.3 $\pm$ 102.07	100.01 $\pm$ 8.30	144.62 $\pm$ 22.85	118.25 $\pm$ 19.06	114.5 $\pm$ 13.17	119.35 $\pm$ 15.70

1- Physiological State: DEC - dry empty cows, DLP - dry low pregnancy, DMP - dry medium pregnancy, DHP - dry high pregnancy, HLC - high lactating, LLC - low lactating cows.

SEM - Standard error of the mean.

a,b,c - means within a row (physiological state) not sharing a common letter are significantly different;

x,y,z - means within a column (treatment) not sharing a common letter are significantly different.

Table 5.5.1.11.

Carotene and Vitamin A levels in the blood of the
experimental beef cows, according to their physiological state

Treatment	CAROTENE					VITAMIN A				
Phys. state	HS	MD	MS	LS	Mean $\pm$ SEM	HS	MD	MS	LS	Mean $\pm$ SEM
DEC	221.7 x	257.4 x	422.0	874.0 	443.78 $\pm$ 319.5	15.00	37.40 x	34.00	62.50 	37.23 $\pm$ 19.68
DLP	143.7 x	333.6 x	606.0	408.4 	372.93 $\pm$ 141.00	20.00	32.89 x	36.00	42.67 	32.89 $\pm$ 8.80
DMP	161.1 x	1180.8 y	555.0	753.0 	662.48 $\pm$ 174.5	27.25	48.00 xy	22.50	32.14 	32.47 $\pm$ 8.28
DHP	638.6 xy	800.0 xy	524.5	326.1 	572.3 $\pm$ 186.7	34.33	55.0 xy	32.50	36.78 	39.65 $\pm$ 9.98
HLC	973.3 y	972.5 y	1121.4	1098.0 	1041.3 $\pm$ 170.3	30.33	74.50 y	54.20	63.47 	55.63 $\pm$ 11.71
LLC	476.8 xy	600.0 xy	716.7	768.2 	640.43 $\pm$ 161.5	42.80	60.00 xy	66.67	54.40 	55.97 $\pm$ 15.46
Mean $\pm$ SEM	435.8 $\pm$ 166.4	690.7 $\pm$ 139.7	657.6 $\pm$ 268.3	704.6 $\pm$ 177.7	622.20 $\pm$ 190.17	28.29 $\pm$ 9.65	51.30 $\pm$ 8.54	40.98 $\pm$ 16.76	48.66 $\pm$ 11.27	42.31 $\pm$ 11.94

1- Physiological State: DEC - dry empty cows, DLP - dry low pregnancy,
DMP - dry medium pregnancy, DHP - dry high pregnancy, HLC - high lactating,
LLC - low lactating cows.

x,y - means within a column (treatment) not sharing a common letter are significantly different;

SEM - Standard error of the mean.

Total Lipids (TL)/Glucose, albumin/globulin and Ca/Pi ratios in the
blood of the experimental beef cows during the different
grazing seasons

Treatment	TL / Glucose				Albumin / globulin				Ca / Pi			
Season	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM
High stress	8.01 x	9.31 y	9.02 xy	8.78 ±0.42	ab 0.868 x	0.984 y	0.917 xy	0.923 ±0.026	a 1.73	1.58	1.70	1.67 ±0.06
Medium deferred	8.06	9.39	8.67	8.71 ±0.07	ab 0.828 x	1.015 y	0.806 x	0.88 ±0.026	c 1.96 x	1.42 y	1.60 y	1.66 ±0.07
Medium stress	8.25	10.06	8.91	9.07 ±0.86	a 0.762 x	1.015 y	0.788 xy	0.86 ±0.08	bc 1.90 x	1.45 y	1.69 xy	1.68 ±0.09
Low stress	7.69	8.99	8.77	8.48 ±0.48	b 0.921	1.043	0.930	0.96 ±0.042	ab 1.76 xy	1.56 x	1.82 y	1.71 ±0.07
Mean±SEM	7.96 ± 0.358	9.36 ±0.750	8.86 ±0.530	8.74 ±0.503	0.858 ±0.047	1.014 ±0.036	0.877 ±0.050	0.91 ±0.044	1.81 ±0.047	1.52 ±0.087	1.72 ±0.075	1.68 ±0.07

a,b,c - Means within a column not sharing a common letter are significantly different.

x,y,z - Means within a row not sharing a common letter are significantly different.

SEM - Standard error of the mean.

5.5.2 Body composition and feed intake

5.5.2.1 Introduction

The use of the tritium dilution technique for estimating TOH space and water turnover has an additional advantage in that TOH space closely approximates the total body water (TBW) of the animals under study (Pace et al., 1947; Paneretto 1963; Peneretto and Till 1963; Little and Macfarlane 1968; Little and Morris, 1972; Foot et al., 1979; Little and Mclean, 1981). These researchers have estimated body composition in the live animal by relating total body water, body fat, protein and ash to TOH space by regression analysis.

Estimation of body composition, however, involves calibration by slaughtering animals which is tedious and expensive and is not always possible where experimental animals are not expendable. Despite this disadvantage it is possible to calculate TOH space as a percentage of shrunk body weight (liveweight after 16 h without food and water) and use this parameter as a relative indicator of body condition and composition. Animals with a fractionally high TOH space obviously have a low body solid content. Furthermore, mature animals have a constant protein and ash content in their bodies except in extreme cases of undernutrition, (Little and Mclean, 1981) so that it is mainly their fat content (energy reserves) that varies with changing body water content. Thus, on the assumption of constant mean protein and ash content in the bodies of the population being studied, it is possible to estimate the fat content of individual animals from the TOH space.

In preliminary experiments, at this site, immediately prior to this project, protein and ash contents were found to be relatively constant at 16.2 and 6.2% respectively, regardless of the cow's physiological state (Table 5.5.2.1).

Table 5.5.2.1 Mean estimated body composition of 46 cows in different physiological states, March 29, 1982.

	Fasted	Percent of total body weight			
	Liveweight(kg)	Water	Fat	Protein	Ash
Mean	296	69.4	7.9	16.2	6.5
S.D.	± 46	8.0	7.95	0.14	0.28
CV %	15.5	11.5	10.0	0.9	4.3

5.5.2.2. Materials and Methods

In each of the seasonal periods, green, dry and transitional as defined in part 2 body composition and feed intake were estimated for all the cows in each treatment by the tritium dilution technique as described in part 3. This was repeated in each year of the project.

5.5.2.3. Results and Discussion

Mean results over 3 years for water turnover , tritiated water space and body solids in each treatment are presented in Table 5.5.2.4.

Water turnover is expressed as liters/day/kg shrunk liveweight to enable relative comparison between treatments and seasons. Within seasons there was no significant difference between treatments indicating that during this time cows in all treatments were probably able to achieve mean satiated organic matter intakes (OMI) of approximately 3.5% of thwe shrunk liveweight (SLW) (Table 5.5.2.6.). This result should probably be expected in all years as the green season corresponds to a time when maximum pasture biomass production takes place and stocking rates in all treatments were imposed such that biomass production would be greater than the cow consumption rate to enable some grazing intake during the following dry and possibly the transitional period. Only in poor rainfall years, when pasture biomass production rates are low, could differen ces between stocking rate treatments be expected . The stocking rate in the high stress treatment was in fact similar to that in the medium stress treatments (approximately 1.5 ha/cow) so that again no significant differences in intake could be expected.

Significant differences (at the 5% level of significance) occurred during the dry season between the medium deferred and the other treatments during the dry season. This result was unexpected as the treatment was imposed in order to improve pasture availability

during the dry season by delaying grazing initiation at the beginning of the green season. In fact, pasture availability was not improved compared to the other treatments but no explanation could be given for the lower intake. The water turnover during the dry period represents mainly water drunk, and assuming a constant positive relationship between OMI and water drunk, any difference between turnover rates also would indicate differences between OMI. However, any shortfalls in pasture availability could be made up by ad libitum poultry litter intake so that differences in total OMI between treatments were not to be expected during the dry season.

Differences between treatments were also recorded during the transitional season. The lowest water turnover was again in the medium deferred treatment. This was to be expected as in the other treatments cows were grazing lush green pastures and their water intake included water associated with their pasture intake (only up to 10% DM content). Differences between the other treatments were not significant and again were not to be expected as only in the low stress treatment was there a difference in stocking rate.

Within treatments highest turnovers were always in the green season followed by the dry and transitional season. However differences between the dry and transitional season were not significant except for the medium deferred treatment. Again, this was to be expected as pasture intake shortfall could be made up for by supplementary intake (Table 5.5.2.6).

Influence of physiological state within and between treatments are presented in Table 5.5.2.5. Within treatments, cows in high and low lactation invariably had the highest water turnovers and were significantly different from dry highly pregnant cows, whereas there was no significant difference between cows in the other physiological states. Cows in lactation have the highest metabolic rate and dry highly pregnant cows not only have a lower metabolic rate but also lower intakes due to lower physical activity induced by the pregnant

state, especially for dry feeds of low digestibility and low passage rate in the alimentary tract.

Between treatments, the cows in the medium deferred treatment had a tendency to have lower water turnovers when compared to the other stress treatments, but differences were rarely significant and any differences were mainly a result of their low water turnovers during the transitional period.

Body Composition, TOH space and Body solids

No significant differences were recorded between cows within or between treatments and season of grazing (Table 5.5.2.6). This would indicate that at least in terms of body composition there were no overall treatment effects and that body composition, achieved as a result of high OMI during the green season, were maintained during the dry and transitional season, despite any changes in liveweight (5.5.2.6). Possibly this is due to the uniformly low relative fat content of 5-10% of the cows in all treatments calculated from the estimated protein and ash content of the cow bodies which together accounted for approximately 22.5% of the shrunk liveweight. The constant of 22.5% corresponds to the 27% of the fat free bodyweight given by Reid et al., 1955, and Garrett and Hinman, 1969. Our estimate is lower only because it is a percentage of total liveweight including fat. The mean estimate of TOH space of 71.5% of the shrunk liveweight is equivalent to 76% of the fat free liveweight, 3% higher than the figure given by Reid et al., and Garrett and Hinman. However, our estimate of body water (TOH space) is for cows, whereas the above researchers included steers in their population sample. Mean fat content of the cow bodies was therefore rarely more than 6% of liveweight, which is rather low, and indicates that cows were always under stress conditions, relative to the expected body condition of cows grazing at stocking rates lower than 2.0 ha/cow and given optimal supplementation according to NR.C. (1984).

Physiological state within treatments had some significant effect on body condition. Dry cows, in most cases, having lower TOH spaces than lactating cows. Possibly this was because lactating cows during the transitional period and early green season were using body reserves for milk production, as the feed supplementation during these periods, in all treatments, were restricted to impose stress conditions, as described in Part 2. This explanation however is not supported by the TOH spaces recorded for lactating cows in the medium deferred treatment, where supplementation was highest during the transitional season (Table 5.5.2.6) but where there are no differences between it and the other treatments. Strangely, differences, although small and barely significant, are between dry cows.

Shrunk liveweight

The mean shrunk liveweight in all treatments during the three seasons are shown in Table 5.5.2.6. Within treatments, with the exception of the medium deferred treatment, cows had significantly lower liveweight during the transitional than in the other seasons. This is mainly because cows calved during that season. Differences between treatments are confounded with initial differences at the beginning of the experiments. Cows in the medium stress treatment had initially lower weights and remained lower in all seasons. Weight losses between the mean for three transitional periods and the mean initial weight were lowest for the medium deferred (+ 10 kg) and highest for the medium period. However these differences are too small to be significant. On the other hand, weight losses recorded between the green and transitional period were highest in the low and medium deferred treatments but again these differences are too small to have significance.

Organic Matter intake (Table 5.5.2.6)

This was highest in all treatments in the green season, but no differences were recorded between the dry and transitional periods. However the results presented for the transitional period are not accurate. The medium deferred treatment, although highly supplemented during that period, gave the lowest intake figures. During this period water turnover was lowest relative to the dry period because of the large mean daily ambient temperature difference. Also, the DM content of the pasture consumed was lower. However the OMI for this season was calculated on the assumption that the ratio of dry OMI to water intake was the same as that for the dry season, an unsupportable assumption.

There were significant differences between treatments for intake in the green season between the high and medium stress treatments but there is no apparent reason for this as in all treatments could achieve satiated intakes. Similarly, it is difficult to explain the significant intake difference during the dry season between the medium deferred (lower intake) and the other treatments. Short falls in pasture intake could and were made up by a higher intake of poultry litter in the high stress treatment but for unknown reasons not in the medium deferred treatment.

Influence of cow physiological state (Table 5.5.2.7)

Cows in a high state of lactation, in all treatments, had the highest intakes and between treatments were highest in the HS treatment. This probably caused the higher intake recorded in the HS treatment during the green season, but again cannot be explained.

The lower intakes in the medium deferred treatment for the dry low and medium pregnant cows caused the generally low intake performance of cows in this treatment (Table 5.5.2.7.).

Conclusions

1. The tritium dilution technique was not accurate enough during the transitional season for estimating either absolute values or for relative values for comparing cow performance between and within treatments.
2. Differences in intake were not obviously apparent between the treatments with the exception of the medium deferred treatment which was generally lowest.
3. Deferred grazing during the green season does not appear to have been justified because it could not be shown that intakes were improved during the dry season by greater availability of phytomass for grazing cows.
4. Any differences in intake between treatments were not large enough to have influenced any significant differences in liveweight or body composition changes during the experiment.²
5. Stress differences between treatments, caused by intake, could have been possible during the transitional period because of the low pasture availability during this season, but could not be quantified by the intake technique used. Pasture dry matter availability during the dry season, although limited, was compensated for by ad libitum availability of poultry litter.
6. Differences in quality of intake could not be distinguished between treatments by the intake technique used.

Table 5.5.2.4. Mean cow water turnover, TOH space and total body solids according to season for all years in each stress treatment.

Season	Water turnover liters/day/kg liveweight				TOH space % of shrunk liveweight				Total body solids % of shrunk liveweight			
	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM	Green	Dry	Trans.	Mean±SEM
Treatment	0.210 ^a	0.153 ^b	0.129 ^b	0.007	72	72	72	0.009	29	29	29	0.009
High stress	0.189 ^x	0.138 ^x	0.113 ^{xy}	0.029	71	70	69	0.011	29	30	31	0.011
Medium deferred	0.182 ^y	0.158 ^y	0.152 ^y	0.011	71	71	75	0.015	29	29	25	0.015
Medium stress	0.190 ^y	0.155 ^x	0.137 ^x	0.007	72	72	70	0.011	29	29	30	0.011
Low stress	0.193 ^{xy}	0.151 ^x	0.133 ^{xy}		71.500	71.250	71.500		29 ±	29 ±	29 ±	
Mean±SD	0.012	0.009	0.016		±0.577	±0.957	±2.646		0.577	0.957	2.646	

a,b,c, Means within a row not sharing a common letter are significantly different ($P < 0.05$).

x,y, - Means within a column not sharing a common letter are significantly different ($P < 0.05$).

Table 5.5.2.5. Mean cow water turnover, TOH space and total body solids according to season for all years in each stress treatment

Treatment	Water turnover (liters/day/kg liveweight)				TOH space (% shrunk liveweight)				Body solids (% of shrunk liveweight)			
	HS	MD	MS	LS	HS	MD	MS	LS	HS	MD	MS	LS
Physiol. state												
DEC	0.167 ^b	0.150 ^{ab}	0.142 ^b	0.168 ^a	72 ^{ab}	69 ^{ab}	72	74 ^a	28 ^{ab}	31 ^{ab}	28	26 ^a
DLP	0.168 ^b	0.140 ^b	0.166 ^{ab}	0.163 ^a	70 ^b	69 ^x	69 ^y	69 ^b	30 ^b	31 ^{ab}	31	31 ^b
DMP	0.152 ^{bc}	0.111 ^b	0.167 ^{ab}	0.154 ^{ab}	72 ^y	68 ^x	71 ^y	71 ^y	28 ^{ab}	32 ^b	29	29 ^{ab}
DHP	0.131 ^c	0.116 ^b	0.137 ^b	0.130 ^b	72 ^y	68 ^x	72 ^y	70 ^{xy}	28 ^{ab}	32 ^b	28	30 ^{ab}
LCL	0.172 ^b	0.184 ^a	0.168 ^{ab}	0.180 ^a	75 ^a	74 ^a	75	72 ^{ab}	25 ^a	26 ^a	25	28 ^{ab}
HLC	0.213 ^a	0.190 ^a	0.196 ^a	0.187 ^a	73 ^{ab}	73 ^a	73	73 ^{ab}	27 ^{ab}	27 ^a	27	27 ^{ab}
MEAN±SEM	0.158±	0.156±	0.163±	0.164±	72 ±	69 ±	71 ±	71 ±	29 ±	29 ±	29 ±	29 ±
	0.01	0.012	0.015	0.01	0.013	0.016	0.022	0.012	0.013	0.016	0.022	0.012

a,b,c, - Means within a column not sharing a common letter are significantly different ($P < 0.05$).

x,y, - Means within a row not sharing a common letter are significantly different ($P < 0.05$).

Table 5.5.2.6. Mean cow shrunk liveweight, total organic matter intake and supplement organic matter intake according to season for all years in each stress treatment.

	Initial weight	Shrunk liveweight(kg/cow)				Organic matter intake(kg/kg shrunk liveweight)				Suppl. OM intake (kg/kg shrunk liveweight)	
Season	21.10.82	Green	Dry	Trans.	Mean±SE	Green	Dry	Trans.	Mean±SE	Dry	Trans.
Treatment											
High stress	324	332 ^{ab}	348 ^a	322 ^b	343±5.7	0.0405 ^a	0.0237 ^b	0.0200 ^b	0.0282±	0.0102	0.0134
Medium deferred	318	351	350	328	343±8.7	0.0355 ^a	0.0214 ^b	0.0175 ^b	0.0239±	0.0115	0.0262
Medium stress	298	306 ^b	332 ^a	288 ^b	309±7.7	0.0350 ^a	0.0246 ^b	0.0244 ^b	0.0280±	0.009	0.0155
Low stress	315	340 ^a	343 ^a	316 ^b	333±6.8	0.0364 ^a	0.0241 ^b	0.0213 ^b	0.0266±	0.008	0.0161
Mean±SEM	314	332 ± 6.3	343 ± 7.2	313 ± 6.9	330	0.0368 ± 0.0014	0.0234 ± 0.0008	0.0208 ± 0.0017	0.0267 ± 0.0008		

a,b,c, Means within a row not sharing a common letter are significantly different ($P < 0.05$).

x,y, - Means within a column not sharing a common letter are significantly different ($P < 0.05$).

Table 5.5.2.7 Mean cow shrunk liveweight and total organic matter intake according to physiological state for all years in each stress treatment.

	Shrunk liveweight(kg/cow)				Mean ± SEM	Total organic matter(kg/kg liveweight)				Mean ± SEM
Treatment	HS	MD	MS	LS		HS	MD	MS	LS	
Physiol. state										
DEC	313 ^b	327 ^b	290 ^b	379 ^a	327±14	0.0284 ^b	0.0253 ^{ab}	0.0242 ^{bc}	0.0287 ^{ab}	0.0265 ^b
DLP	354 ^y	359 ^{ab}	334 ^a	342 ^{bc}	347±9	0.0274 ^b	0.0235 ^{ab}	0.0318 ^{ab}	0.0265 ^{ab}	0.0263 ^b
DMP	350 ^a	344 ^{ab}	331 ^a	333 ^{bc}	339±11	0.0236 ^b	0.0172 ^b	0.0259 ^{abc}	0.0240 ^b	0.0226 ^c
DHP	343 ^a	367 ^a	325 ^a	354 ^{ab}	347±10	0.0223 ^b	0.0216 ^{ab}	0.0213 ^c	0.0222 ^b	0.0220 ^c
LCL	333 ^{xy}	340 ^{ab}	308 ^{ab}	325 ^{bc}	326±8	0.0238 ^b	0.0242 ^{ab}	0.0231 ^{bc}	0.0271 ^{ab}	0.0252 ^{bc}
HLC	313 ^b	323 ^b	279 ^b	313 ^c	307±9	0.0393 ^a	0.0310 ^a	0.0340 ^a	0.0339 ^a	0.0351 ^a
MEAN±SEM	334 ± 8	343 ± 12	311 ± 11	341 ± 10	332	0.0275	0.0238	0.0267	0.0271	0.0263 ± 0.01

a,b,c, - Means within a column not sharing a common letter are significantly different ($P < 0.05$).

x,y, - Means within a row not sharing a common letter are significantly different ($P < 0.05$).

5.5.3 VOLATILE FATTY ACID AND AMMONIA LEVELS IN THE RUMEN

(The effect of feed supplementation treatments on volatile fatty acid and ammonia levels in the rumen of beef cows grazing seasonal mediterranean range)

5.5.3.1 Introduction

Total volatile fatty acids (VFA) and individual VFA proportions and ammonia concentrations in the rumen liquor of cows are influenced by the amount and type of feed consumed. In order to determine the effects of the nutritional stress treatments on these parameters, rumen liquor was sampled from all treatments, during the dry and transitional periods, and from one group of cows (M-def.) during the green season when no supplements were fed. The main aim of the study was to monitor the effects of seasonal changes in pasture availability and of supplementation, especially with poultry litter, on rumen functioning. No differences were expected between treatment groups when no supplementation was given during the green season. Therefore, only one group of cows was sampled for the analyses of VFA and ammonia.

5.5.3.2 Materials and Methods

Rumen liquor sampling: Rumen liquor (RL) was sampled for analysis of VFA and ammonia during the second experimental year. Cows were gathered into a central corral and RL samples were taken by means of a stomach tube, starting at 7.00 a.m. Samples were taken from forty cows, ten from every treatment. The sampling was conducted at the end of August for the dry season, the end of November for the transitional season and the end of March for the green season.

Analytical Methods

VFA were determined according to the method of Cottyn and Boucque (1968). Ammonia concentration in the rumen liquor was assayed according to the method of Clare and Stevenson (1964) with a Technicon Auto-Analyzer.

Table 5.5.3.1 Ruminal Volatile Fatty Acids (VFA)
and Ammonia in Experimental Cows During the Dry Season

Treatment	High Stress	Medium Deferred	Medium Stress	Low Stress	SE of Means
Total VFA mmol/1RL	81.36 ^a	72.33 ^{ab}	67.04 ^b	80.90 ^a	3.944 *

Individual VFA (molar %)

Acetic	73.00	74.54	72.60	73.23	0.527
Propionic	16.96	16.59	16.94	16.43	0.268
Butyric	8.14 ^{ab}	7.35 ^b	8.15 ^{ab}	8.49 ^a	0.329*
Iso-valeric	1.19 ^{ab}	0.90 ^b	1.46 ^a	1.14 ^{ab}	0.128*
Valeric	0.71	0.62	0.95	0.71	0.080
C2/C3	4.30	4.49	4.29	4.46	0.093
Ammonia mg/100ml RL	15.85 ^a	13.89 ^{ab}	13.68 ^{ab}	11.66 ^b	1.555 *

* $P < 0.05$

** $P < 0.01$

a,b = Means within a row not sharing different superscripts are significantly different.

5.5.3.3 Results

The ruminal VFA and ammonia concentrations of the experimental cows, during the dry season are presented in Table 5.5.3.1. The total VFA concentration of the Medium-stressed cows was significantly lower ($P < 0.05$) than that of the High and Low stressed animals. Butyric and Iso-valeric acids were significantly ($P < 0.05$) lower in the RL of the medium-deferred treated animals in comparison to that of the cows of the other treatments. There were no significant differences in the C_2/C_3 ratio between the different treatments. Ammonia concentration in RL was significantly lower in the Low stressed animals compared to the high stressed group.

The VFA and ammonia concentrations in RL during the transitional season are given in Table 5.5.3.2. Total VFA concentration was, this time, higher ($P < 0.01$) in the RL of the Medium and Medium - deferred treated cows, as compared to that of the cows of the other treatments. Propionic acid concentration was higher, and as result, the C_2/C_3 ratio lower ($P < 0.01$) in the RL of the Medium - deferred treated cows than in these of the other treatments. Butyric acid was lower in the RL of the High stress treated cows and differed significantly from the medium stressed animals. Iso - valeric acid concentration was lower in the Medium deferred and higher in the Medium stressed animals ($P < 0.01$). The valeric acid concentration was highest in the Med.-stressed animals and so was the ammonia concentration.

The concentration of VFA and ammonia in RL of cows from the Medium deferred treatment during the different grazing seasons given in table 5.5.3.3. Total VFA and propionic acid concentration were higher in the transitional season. The proportion of acetic acid was higher and of butyric, iso-valeric and valeric acids was lower in the dry season. Ammonia concentration in RL was higher in the transitional season and differed significantly ($P < 0.05$) from that in the green season.

5.5.3.4 Discussion

Ruminal VFA, which provide some 64% of metabolizable energy (Gray et al. 1967) and ruminal ammonia, which is related to nitrogen intake (Weston & Hogan, 1968), provide information on the efficiency of diet utilization. The volatile fatty acid composition of the rumen contents is determined primarily by the type of microflora which inhabit the rumen contents. This in turn is influenced by the amount of food consumed and the composition of the diet. An outstanding characteristic of the supplementary feed given to the animals in this experiment is the fact that it was composed of poultry litter (PL) during the dry season and PL, some wheat shaw and some barely grain (Table 4.3) during the transitional period. The effect of PL in the diet on VFA in beef cows has, to our knowledge, not been studied. In the present study concentrations of rumen metabolites were sensitive to poultry litter intake and pasture availability, as can be seen from the differences between the different stress treatments.

The rumen fermentation of the experimental cows was characterized, during all seasons, by high levels of acetic acid and low levels propionic and butyric acid. The only exception occurred with cows in the medium-deferred treatment, during the deferment (or transitional) period. Such levels are typical of those found in animals fed low-quality roughage diets (Ulyatt, 1965, Annison, 1954), or in animals on dry season pasture (Playne et al. 1976). Higher acetic: propionic acid ratios are also found at lower levels of feeding (Williams & Christian, 1956) and in animals fed high fibre diets (Elliot & Loosli, 1959).

However, the importance of different proportions of VFA is not clear. Concepts of the efficiency with which individual acids are used as energy sources for maintenance and for fattening have been questioned (Raymond, 1969). The classic series of experiments by Armstrong and Blaxter (1957, 1958) demonstrated that acetic acid is

utilized with low efficiency for fat synthesis in mature sheep. A number of later studies (as described by Tyrell et al. 1976) have not confirmed the calorimetric findings. However, Faichney (1974) suggested that ruminal fermentations with high acetic: propionic acid ratios results in ammonia being used less efficiently, and Hume (1970) found that a high proportion of acetic acid was related to low rates of microbial synthesis. In our results there is no clear association between rumen metabolite concentrations and performance, because of fluctuations in feed availability and quality during the year.

The diet of the Medium - def. treated cows during the transitional period, consisted mainly of the supplementary feed. Compared to that found in the other treatments, this was a grain-rich diet as reflected by the higher propionic acid concentration, and lower C₂/C₃ ratio. The low propionic acid concentration and high C₂/C₃ ratio found in the green season samples is unexpected as the range forage is then abundant and relatively nutritious and both cows and calves put on weight. The high C₂/C₃ ratios in the rumen liquor of the experimental cows suggest that nutritional stress occurred during the dry, transitional and late green seasons. It is clear that the relationship between diet, performance and composition of VFA is not simple.

The high levels of propionic acid and ammonia in the Medium deferred cows during the transitional season probably stems from the high level of poultry litter intake during the deferment period. Poultry litter in Israel contains monensin in concentrations (40-50mg/kg DM) that can affect the fermentation of anaerobic methanogenic fermentors (Dosoretz et al. 1986). Monensin promotes "propionic acid like fermentation" by inhibition of methanogenesis. As an ionophore, its mode of action appears to be due to its effects on the transport of ions across membranes (Upton, 1985). Whale and Livesey, 1985, found that monensin also increased the ammonia concentration in rumen liquor. A positive association can be observed

between iso-valeric acid and rumen ammonia, especially during the transitional season. This agrees with the findings of El Shazly (1952) with sheep and Playne (1976), with cattle, who found a positive relationship between branched - chain VFA and ammonia in rumen. The same pattern was followed by valeric acid, and this is similar to the findings of Playne et. al., 1976, who reported significant correlations between bolus N content and molar proportions of iso-valeric and valeric acids. Iso-valeric acid, a branched chain VFA, is derived mainly from deamination of food amino acids entering the rumen (El Shazly, 1952) and provides carbon skeletons for microbial synthesis of protein (Allison et al., 1962; Hensley & Moir, 1963).

The level of ammonia in rumen liquor is of particular nutritional significance as many types of rumen microorganisms utilize ammonia as a source of nitrogen (Hungate 1966). On low nitrogen, low organic matter diet, such as wheat straw, virtually no ammonia can be detected in the RL of beef cattle (Pritchard and Males, 1985). The higher level of ammonia during the dry and transitional periods, when the content on N in pasture is low, reflect the intake of NPN from supplementation. Similarly, ammonia content during the green season reflects the increased level of protein (about 18%) during that season.

Once microbial requirement for N is met, there should be no further increase in the rate of fermentation (Mehrez et al, 1977). However, estimates of minimal rumen ammonia concentrations in the literature for maximal rate of microbial protein synthesis, vary over a wide range. Hendericks, 1976, reviewing 7 studies proposed a requirement of 10mg/100ml. However, other values have also been found: 5 mg/100 ml (Satter and Slyter, 1974); 8.18-13.3 mg/100 ml (Hume et al. 1970); and 23.5 mg/mmol (Mehrez et al., 1977). Based on these estimations, and considering the usually good body condition of the experimental cows during the green season, we can regard the ammonia concentration during that season (11mg/100ml) as a reference value. Accordingly, during the dry period ammonia concentration was at

optimal range or marginally above, except that of the High stressed cows which was significantly higher ($P < 0.05$) as they consumed more poultry litter as compared with the Low-stressed ones which grazed at a lower stocking rate.

During the transitional period feed intake was based mainly on supplementation, mainly poultry litter. Consequently, ammonia concentration in the RL was considerably higher than any of the various published optimal levels for microbial protein synthesis. In many cases a direct relationship between ruminal ammonia level and plasma urea concentration can be seen (Harmeyer and Martens, 1980). This would indicate that excess ammonia which is not captured by microorganisms is absorbed into the blood stream and converted into urea in the liver. In the present experiment blood urea concentration measured during the transitional period was considerably higher than during the dry period (see part 5.5.1). In addition, during the transitional period, differences between treatments in ammonia concentration in the rumen were reflected by direct ranking of plasma urea concentration. The results on urea concentration in the blood plasma, support the conclusion that ammonia levels in the rumen, during the transitional season were considerably above the required optimum. This would suggest that during the transitional period the cows were subjected to a metabolic burden as result of excess N from higher PL intake. This extra energy requirement would lead to a lower efficiency of rumen fermentation.

**Table 5.5.3.2 Ruminal Volatile Fatty Acids (VFA)
and Ammonia in Experimental Cows During the Transitional season**

Treatment	High Stress	Medium Deferred	Medium Stress	Low Stress	SE of Means
Total VFA mmol/lRL	83.30 ^a	102.36 ^b	102.25 ^b	86.49 ^a	5.510**

Individual VFA (molar %)

Acetic	71.27 ^a	66.45 ^c	68.51 ^{bc}	70.89 ^{ab}	0.655**
Propionic	16.20 ^a	19.98 ^b	15.98 ^a	15.65 ^a	0.320**
Butyric	9.48 ^a	10.85 ^{ab}	11.13 ^b	10.41 ^{ab}	0.470*
Iso-valeric	2.24 ^a	1.49 ^c	3.02 ^b	2.13 ^a	0.123**
Valeric	0.81 ^a	1.05 ^a	1.36 ^b	0.92 ^a	0.064**
C2/C3	4.40 ^a	3.32 ^b	4.29 ^a	4.53 ^a	0.108**
Ammonia mg/100ml RL	26.87 ^a	21.35 ^a	38.21 ^b	26.55 ^a	2.264**

* P < 0.05

** P < 0.01

a,b,c = Means within a row not sharing different superscripts are significantly different.

Table 5.5.3.3 Ruminal VFA and Ammonia, of one group of experimental cows (M-def.), as compared between seasons

Season	Transitional	Green	Dry	SE of Means
Total VFA mmol/1RL	102.36 ^a	86.51 ^{ab}	72.33 ^b	8.656 *

Individual VFA (molar %)

Acetic	66.45 ^a	71.01 ^b	74.54 ^b	1.058 **
Propionic	19.98 ^a	16.51 ^b	16.59 ^b	0.656 **
Butyric	10.85 ^a	10.02 ^a	7.35 ^b	0.683 *
Iso-valeric	1.49 ^a	1.63 ^a	0.90 ^b	0.165 *
Valeric	1.05 ^a	0.83 ^{ab}	0.62 ^b	0.077 **
C2/C3	3.32 ^a	4.30 ^b	4.50 ^b	0.199 **
Ammonia mg/100ml RL	21.35 ^a	11.29 ^b	13.89 ^{ab}	2.487 *

* $P < 0.05$

** $P < 0.01$

a,b = Means within a row not sharing different superscripts are significantly different.

5.6. FACTORS THAT INFLUENCE CONCEPTION

5.6.1 Introduction

A fundamental aspect of cow performance in a beef herd with a regular breeding season, is conception within three months after calving. In order to conceive, cows need to be in satisfactory body condition. Prepartum and postpartum energy intake may interact to affect postpartum reproductive phenomena. Levels of energy intake before, as well as after calving were generally found to be inversely related to the time interval from calving to 1st oestrus, and directly related to percent oestrus and conception rate (Wiltbank et al., 1962; Bellows and Short, 1978). However, it appears that the effect of prepartum weight changes on postpartum reproductive functions depends on the body condition of the cow at parturition (Dunn & Kaltenbach, 1980). Further, Kilkenny (1978) reported a close relationship between body condition score at mating and subsequent calving interval. Body condition is related to the amount of fat deposited in the body (NRC, 1984) and should be reflected by the ratio of water to total body weight. Thus TOH space should be an equivalent measure of body conditions and could be related to conception.

In our data, however, the correlation between TOH space and body condition is weak and not significant (Table 5.6.1). This is partly due in the fact that 'body condition' is defined here as the ratio between shrunk body weight and height at withers. 'Body condition' is more commonly related to fat deposition. As the nutritional state of the animal is

related to the feed intake, a measure of intake could indicate whether the animal is eating efficiently to maintain condition or not. Food intake is related to water turnover (Macfarlane and Howard, 1972; Siebert, 1971) and so TOH turnover could be a measure of nutritional status of the cow. Finally, cow condition is partially determined by the level of milk production, especially during the early stages of the lactation cycle. As calf liveweight during the first three months after birth is mainly dependent on milk intake (Melton et al. 1967; Neville, 1962) daily liveweight increase could be an indication of milk production and of the feeding stress imposed on the animal.

5.6.2 Analysis of Data

The relationship between conception and these factors (body condition, TOH space, TOH turnover and calf liveweight increase), has been investigated in the following manner. All cows that calved were divided into groups according to whether they calved within 60 days, 90 days or 120 days after calving. The mean value for each of the above mentioned factors was determined with regard to each group for the relevant period after calving and compared to the cows that did not conceive during the equivalent period. The sample of cows that conceived within 90 and within 120 days after calving, did not include those that conceived earlier. The significance of the relationship was analyzed by means of the GLM procedure (SAS, 1985). The marginal effect of the relationship between the factors and conception was separated from the relationship between years and treatments (Type III SS); the F value of each factor, and the significance of the relationship ($Pr < F$) are presented. Interactions between factors and conception rate were also examined.

5.6.3 Body condition and conception

Body condition is defined as the relationship between shrunk body weight (corrected for pregnancy) and the height at withers. The height was measured at the beginning and end of the experiment and intermediate dates were interpolated with a saturation function dependent on the age of the cow. The relationship between body condition and conception is given in Table 5.6.2. Body condition of nursing cows that became pregnant within 60 days was significantly higher than that of empty nursing cows. The body condition index of the pregnant cows was 2.8 while that of the empty cows was around 2.5. Between treatments, body condition was significantly lower only in treatment MS and between years, it was significantly lower in 1983 (Table 5.6.3). There were no significant interactions between conception and either treatments or years. There was no clear distinction in the body condition between pregnant and empty cows in treatment MS, where condition was uniformly low for both classes with an index of around 2.4. In this treatment, conception was generally poor, especially during the first 60 days after parturition. Body condition was highest in treatment MD where the index for empty cows was above 2.6 up till 90 days after calving.

In conclusion, it appears that for conception rates to be high within 60 days after calving, the body condition index should be above 2.75. After day 60, conception was less clearly related to body condition, possibly because as time went by, there were simply more oestrus cycles and increasing probability of conception.

5.6.4 TOH space and conception

TOH space is presented here as a ratio between TOH space in kg water and shrunk body weight (corrected for pregnancy) of the cow. On the whole, the relationship between TOH space and conception was not significant. If anything there is an indication that TOH space was slightly higher among cows that conceived within 60 days, indicating that those cows were slightly leaner. This is significantly so in 1985 (Tables 5.6.4 and 5.6.5). But the picture changes from year to year: In 1983 cows that conceived had lower TOH spaces than empty cows and in 1984 the difference between the two classes was small. On the other hand body condition was significantly higher in 1985 than in 1983 (Table 5.6.3). It can be concluded that when body condition is high (1985), the leaner cows tend to conceive earlier, whereas when body condition is low (1983), cow that conceive tend to be somewhat fatter. As the correlation between these two indices is low (Table 5.6.1), it must be concluded that they reflect different characteristics of the animal, especially as 'body condition' in our definition is not a measure of fat cover but of the ratio between weight and height. It appears that cows in high 'body condition' are in fact cows that are heavier but leaner, indicating that they must have replaced fat by a greater weight equivalent of water. If this is so, then our definition of body condition has no relationship to the energy reserves of the cow. There is a weak non significant positive correlation between 'body condition' and TOH space (Table 5.6.1). If 'body condition' reflected fat reserves, then the relationship, if anything, should have been negative. It appears that liveweight of cows when shrunk and corrected for both foetal weight, and height of animals, is related to rapid conception, but the mechanism is not

5.6.5 Water turnover and conception

Like TOH space, water turnover (strictly TOH turnover) is presented as a ratio between kg water turnover per cow and shrunk body weight. Like TOH space, the relationship with conception is not significant (Table 5.6.6 and 5.6.7), mainly because of the large variation in the results.

One can conclude that either there is no simple relationship between water turnover and conception, or that the water turnover values (and the TOH values) were confounded by artefacts introduced during the monitoring process. As the process is rather complex, this is a possibility that cannot be discounted, but also cannot be traced. So, we are left with a frustratingly inconclusive result.

5.6.6 Calf liveweight gain and conception

Calf liveweight gain (CLWG) is here defined as the daily liveweight increase between birth and the first available subsequent calf liveweight at least 40 days after birth but not more than 130 days after birth. Most of the data are derived from weights measured within 90 days after birth.

CLWG is related to conception in all three classes but significantly so only in the class that conceived within 90 days. CLWG in the pregnant cows was generally higher than in non-pregnant cows (Table 5.6.8). Year and treatment effects were also significant (Tables 5.6.8 and 5.6.9) and interactions between conception and treatment were significant in the two conception classes, 60 and 90 days after calving (Table 5.6.8). The conception x treatment interaction is due mainly to the MD treatment. In the 60 day class, the CLWG of pregnant cows in this treatment was lower than that of empty cows. As the number of animals in this case was very small (Table 5.6.8), this result is not reliable.

Overall treatment effects indicated highest CLWG values in treatment HS and lowest values in treatment MS (Table 5.6.9); values were lowest in 1983 and highest in 1985.

We can conclude that even though CLWG (and associated milk production of the cows) is higher, conception rates are nevertheless also higher. This is an expression of the greater efficiency of superior cows that favours both milk production and conception. This result is supported by the observation that TOH space in the pregnant cows with calf would indicate that, if anything, they were leaner, rather than fatter than the empty cows, possibly because the feed intake was being used for milk production instead of fat deposition. Therefore, it can be concluded that cows that tend to conceive early, also tend to have a relatively higher milk production and produce calves with higher CLWG. Such cows appear to be able to maintain better body condition (as defined above) than cows that do not conceive, either by having better appetite, higher intake rates or more efficient constitutions. These are desirable characteristics in a beef cow managed extensively on range and selection for such cows should improve the overall performance of the herd. As calf liveweight increase is an indication of the milk production and mothering ability of the cow during the early growth stages of the calf, it would be desirable to monitor CLWG during the first three months after calving. As this is seldom done, it would involve a change in beef herd management practice. However, such a change could be well worth the trouble, especially when herd performance needs to be improved.

Table 5.6.1 Partial correlation matrix (Pearson correlation) between variables related to conception rate of cows in the experimental herd.

		TURN60	TURN90	TOH60	TOH90	BCON60	BCON90
DLWI	r	.20	.17			.37	.40
	Pr>r	.0917	.1010			.0001	.0001
	n	70	97			145	147
TURN60	r			.31		-.04	
	Pr>r			.0038		.7283	
	n			84		84	
TURN90	r				.19		-.04
	Pr>r				.0474		.6397
	n				115		115
TOH60	r					.14	
	Pr>r					.1677	
	n					100	
TOH90	r						.11
	Pr>r						.2084
	n						129

Note: DLWI - daily livewt. increase of calves between day 40 and day 130 after calving.

TURNi, TOHi, BCONi- relative water turnover, TOH space and ratio of livewt/height at withers, 60 and 90 days after parturition.

Table 5.6.2: Body condition in relation to time elapsed between calving and subsequent conception

Data	Conceptn status	Body condition			No. of observations		
		days 60	after 90	calving 120	days 60	after 90	calving 120
All	Pregn	2.80	2.60	2.55	58	51	40
	Empty	2.51	2.50	2.52	125	74	34
<u>Treatments</u>							
HS	Pregn	2.79	2.73	2.53	20	20	8
	Empty	2.56	2.47	2.48	43	23	15
MD	Pregn	3.06	2.75	2.76	6	7	6
	Empty	2.61	2.62	2.45	19	12	6
MS	Pregn	2.37	2.34	2.41	3	6	4
	Empty	2.33	2.43	2.48	15	9	5
LS	Pregn	2.79	2.49	2.53	29	18	22
	Empty	2.48	2.50	2.60	48	30	8
<u>Year</u>							
1983	Pregn	2.60	2.43	2.46	11	17	19
	Empty	2.39	2.40	2.39	52	35	16
1984	Pregn	2.86	2.61	2.61	22	12	13
	Empty	2.53	2.59	2.71	29	17	4
1985	Pregn	2.84	2.73	2.67	25	22	8
	Empty	2.64	2.60	2.62	44	22	14

Statistical analysis of factors that influence body condition (Type III SS)

Component	d.f.	60 d after calving		90 d. after calving		120 d. after calving	
		F value	Pr>F	F value	Pr>F	F value	Pr >F
Treatment	3	5.4	.0015	3.5	.189	1.2	.3111
Year	2	6.7	.0016	8.6	.0003	5.7	.0054
Conception	1	9.6	.0023	0.1	.8106	0.0	.8424
CON x treat	3	1.3	.2906	2.2	.0978	1.2	.3066
CON x yr	2	1.9	.1485	0.3	.7433	0.7	.5072

Table 5.6.3 Effect of treatment and year on body condition at different times after calving

Factor	Body condition days after calving			No. of observations days after calving		
	60	90	120	60	90	120
<u>Treatment</u>						
HS	2.64 A	2.59 AB	2.50	63	43	23
MD	2.72 A	2.67 A	2.65	25	19	12
MS	2.34 B	2.39 B	2.45	18	15	9
LS	2.60 A	2.50 AB	2.55	77	48	30
<u>Year</u>						
1983	2.43 B	2.41 B	2.43 B	63	52	35
1984	2.67 A	2.60 A	2.64 A	51	29	17
1985	2.71 A	2.67 A	2.64 A	69	44	22

Letters indicate significant differences within factors and within columns by Duncan multiple range test, $P < 0.05$ for type I SS. For significance of factors in Type III SS, see Table 5.6.2.

Table 5.6.4 TOH space in relation to time elapsed between calving and subsequent conception

Data	Concepn status	TOH Space			No. of observations		
		days 60	after 90	calving 120	days 60	after 90	calving 120
All	Pregn	.734	.728	.734	38	33	27
	Empty	.717	.726	.724	62	49	27
<u>Treatments</u>							
HS	Pregn	.722	.711	.755	14	12	6
	Empty	.712	.723	.718	21	15	12
MD	Pregn	.763	.786	.739	2	4	6
	Empty	.705	.720	.708	9	11	5
MS	Pregn	.693	.739	.750	3	6	3
	Empty	.717	.720	.766	11	7	4
LS	Pregn	.747	.719	.717	19	11	12
	Empty	.726	.734	.769	21	16	6
<u>Year</u>							
1983	Pregn	.688	.684	.730	7	12	14
	Empty	.707	.726	.730	31	25	13
1984	Pregn	.722	.718	.727	17	10	12
	Empty	.700	.717	.720	13	14	3
1985	Pregn	.773	.785	.879	14	11	1
	Empty	.745	.737	.718	18	10	11

Statistical analysis of factors that influence TOH space (Type III SS)

Component	d.f.	60 d. after calving		90 d. after calving		120 d. after calving	
		F value	Pr>F	F value	Pr>F	F value	Pr >F
Treatment	3	0.8	.4979	0.5	.7193	.1	.9662
Year	2	4.9	.0092	4.2	.0195	.2	.8463
Conception	1	0.12	.7337	0.0	.8852	.5	.4775
CON x TRT	3		NS		NS		NS
CON x Yr	2		NS	(4.47	.0130)	(7.2	.0010)

Table 5.6.5: Effect of treatment and year on TOH space at different times after calving.

Factor	TOH space days after calving			No. of observations days after calving		
	60	90	120	60	90	120
<u>Treatment</u>						
HS	.716	.719	.730	35	27	18
MD	.716	.737	.725	11	15	11
MS	.712	.729	.719	14	13	7
LS	.736	.728	.735	40	27	18
<u>Year</u>						
1983	.704 B	.712 B	.730	38	37	27
1984	.713 B	.718 B	.726	30	24	15
1985	.757 A	.762 A	.732	32	21	12

Letters indicate significant differences within factors and within columns by Duncan multiple range test, $P < 0.05$ for Type I SS. For significance of factors in Type III SS, see Table 5.6.4.

Table 5.6.6 TOH turnover in relation to time elapsed between calving and subsequent conception [BARD TURN]

Data	Concept status	TOH Turnover			No. of observations		
		days 60	after 90	calving 120	days 60	after 90	calving 120
All	Pregn	.197	.209	.194	32	31	27
	Empty	.197	.192	.192	52	42	19
<u>Treatments</u>							
HS	Pregn	.230	.206	.212	10	12	6
	Empty	.201	.203	.188	16	11	6
MS	Pregn	.090	.361	.216	2	2	6
	Empty	.217	.183	.166	8	11	5
M6	Pregn	.235	.206	.162	3	6	3
	Empty	.212	.194	.267	10	6	3
LS	Pregn	.184	.186	.182	17	11	12
	Empty	.177	.189	.202	18	14	5
<u>Year</u>							
1983	Pregn	.169	.158	.156	7	12	14
	Empty	.154	.150	.141	23	19	8
1984	Pregn	.225	.244	.250	15	10	12
	Empty	.229	.240	.225	13	14	3
1985	Pregn	.175	.238	.045	10	9	1
	Empty	.234	.206	.231	16	9	8

Statistical analysis of factors that influence TOH turnover (Type III SS)

Component	d.f.	60 d after calving		90 d. after calving		120 d. after calving	
		F value	Pr>F	F value	Pr>F	F value	Pr >F
Treatment	3	0.9	.4242	0.5	.6581	0.4	.7800
Year	2	8.4	.0005	15.0	.0001	18.3	.0001
Conception	1	0.8	.3622	1.1	.3001	0.1	.7967
CON x TRT			NS		NS		NS
CON x YR			NS		NS		NS

Table 5.6.7 : Effect of treatment and year on TOH turnover at different times after calving.

Factor	TOH turnover days after calving			No. of observations days after calving		
	60	90	120	60	90	120
Treatment						
HS	.212	.205	.200	26	23	12
MD	.191	.211	.193	10	13	11
MS	.217	.200	.194	13	12	6
LS	.181	.188	.188	35	25	17
Year						
1983	.157 B	.153 B	.151 B	30	31	22
1984	.227 A	.222 A	.211 A	28	18	9
1985	.211 A	.242 A	.245 A	26	24	15

Letters indicate significant differences within factors and within columns by Duncan multiple range test, $P < 0.05$ for type I SS. For significance of factors in Type III SS, see Table 5.6.6.

Table 5.6.8 Calf liveweight gain (g d^{-1}) in relation to time elapsed between calving and subsequent conception [BARD CLWI]

Data	Concepn status	Calf liveweight gain			No. of observations		
		days 60	after 90	calving 120	days 60	after 90	calving 120
All	Pregn	981	1027	757	38	41	35
	Empty	892	811	868	110	69	34
Treatments							
HS	Pregn	1112	1148	850	15	18	7
	Empty	1004	886	903	40	22	15
MD	Pregn	636	1579	972	1	2	6
	Empty	977	877	782	14	12	6
MS	Pregn	1091	750	336	3	6	4
	Empty	713	688	969	15	9	5
LS	Pregn	878	918	742	19	15	18
	Empty	818	760	803	41	26	8
Year							
1983	Pregn	886	874	714	9	15	18
	Empty	778	736	762	49	34	16
1984	Pregn	932	978	889	19	12	13
	Empty	910	863	779	29	17	4
1985	Pregn	1158	1232	520	10	14	4
	Empty	1048	905	1014	32	18	14

Statistical analysis of factors that influence calf LWG (Type III SS)

Component	d.f.	60 d after calving		90 d. after calving		120 d. after calving	
		F value	Pr>F	F value	Pr>F	F value	Pr >F
Treatment	3	5.2	.0021	11.2	.0001	2.2	.1020
Year	2	10.6	.0001	12.7	.0001	0.6	.5762
Conception	1	1.1	.3002	13.4	.0004	3.5	.0675
CON x TRT	3	3.2	.0243	2.9	.0401	2.1	.1116
CON x YR	2	0.5	.5837	2.0	.1353	2.4	.0972

Table 5.6.9 Effect of treatment and year on calf liveweight gain (g d^{-1}) at different times after calving.

Factor	Calf liveweight gain days after calving			No. of observations days after calving		
	60	90	120	60	90	120
<u>Treatment</u>						
HS	1033 A	1004 A	886	55	40	22
MD	954 AB	977 AB	877	15	14	12
MS	776 C	712 C	688	18	15	9
LS	837 BC	818 BC	761	60	41	26

(1) Letters indicate significant differences within factors and within columns by Duncan multiple range test $P < 0.05$ for Type I SS. For significance of factors in Type III SS, see Table 5.6.8.

(2) Liveweight gain calculated for data between d 40 and d 130 after calving. Only one value available for each calving, calculated from the earliest available weight of calf after d 40 but not later than d 130. Occasional exceptional values above 2.0 kg LWG/d were deleted.

(3) No. of observations 90 & 120 days after calving, do not include cows that conceived in a previous period.

Part 6. THE RELATIONSHIP BETWEEN ANIMAL PERFORMANCE AND PHYSIOLOGICAL
PARAMETERS.

(Metabolic characteristics of the productive beef cow under
environmental and nutritional stress).

6.1 Performance and mean 3-year physiological parameters.

6.1.1 Introduction

Beef cows that spend most of the year on seasonal range are subjected to environmental and nutritional stress as the availability and quality of the forage changes with the change of season. Some cows adapt well to these fluctuating conditions and when properly managed, regularly produce a vigorous calf. Others are less successful. The purpose of the present study is to investigate the feasibility of identifying superior animals under such stress conditions by analysing the relationship between a set of measurable parameters and long term performance. The study is preliminary, or exploratory, in the sense that it aims to establish whether such a connection can be established at all. The doubt arises from the fact that on the one hand, most metabolic parameters vary with changing physiological, nutritive and environmental conditions and on the other hand, it is difficult to determine long-term performance in a relatively short-term study. If a connection can be discerned, it may be possible, by concentrating on the more promising relationships, to develop a criterion

(or set of criteria) that will make it easier to identify a superior animal at an early age. In the present study, the various physiological indicators are identified with performance criteria in a normal healthy herd of beef cows, rather than with pathological phenomena in the animal.

6.1.2 Materials and Methods

A herd of 92 cows, maintained as four separate herds, subjected to different grazing and supplementary feeding treatments, was monitored over a three-year period. Details on the animals and treatments are given in part 2. Performance of the animals is based on the three-year experiment period. It does not necessarily reflect lifetime performance of the cows, so that even positive results of this study must be regarded as preliminary.

The parameters chosen to characterize the cows include not only age, weight, breed and physical characteristics but also a set of metabolic parameters that characterize the blood profile and metabolic status of the cow. Because of logistic necessity, the list is limited and so the choice of parameters is arbitrary. However, it was chosen to include the standard metabolic blood parameters as well as some that are more specific to the present study.

6.1.2.1 Criteria for productive success: The simplest and most direct criterion of productivity of a beef cow is the total weaned liveweight over a productive life-time in a relevant environment and production system. Where such long-term data are unavailable, the next best criterion is total production over a number of years. The total liveweight weaned over

the three years of this study years under the operating conditions of the experiment, will be designated as criterion W.

Dividing the total liveweight weaned into 5 groups, gives criterion P. The groups are:

1-(<250 kg); 2-(251-350 kg); 3 (351-450 kg); 4 (451-550 kg); 5 (>550 kg).

A criterion of reproductive success is the number of calves weaned over a lifetime or over a lesser period. However, as the weaning weight is also an important criterion, the reproductive performance can be weighted or classified by the mean weaning weight, or by the mean daily liveweight increase of the calf. Both criteria were defined in the present study as follows:

Grade	Number of conceptions in 4 years	Mean weaning wt* kg/calf (criterion G)	Daily live wt increase* kg/calf/day (criterion L)
1	0-2	-	-
2	3	<180	<0.70
3	3	<u>≥</u> 180	<u>≥</u> 0.70
4	4	<180	<0.70
5	4	<u>≥</u> 180	<u>≥</u> 0.70

*Refers to 3 calving seasons. The 4th weaning occurred after the end of the project. The threshold values for criterion G and criterion L are approximately the median values for the data.

6.1.2.2 Physical and metabolic parameters: The following characteristics of the cow were measured:

Physical characteristics

- w - Live weight of the cow after 16-17 hours without food or water (kg)
- h - Height at withers (cm)
- b - Width at hips (cm)
- a - Age (yr)

Physiological characteristics (water metabolism and blood profile)

Water metabolism:

- t - TOH space (fraction of liveweight w, kg/kg)
- v - water turnover (fraction of liveweight w, kg/kg/day)

Blood profile

Enzymes:

- c - Lactic dehydrogenase
- g - Aspartate amino transferase
- k - alkaline phosphatase

Organic nutrients:

- p - total blood protein
- m - albumin
- n - globulin
- f - total lipids
- s - glucose

Mineral nutrients:

Ca - calcium

P_i - inorganic phosphorus

Mg - magnesium

Waste products:

u - urea

6.1.3 Results

The relationship between the production criteria and the cow characteristics will be analysed at two different levels:

-Mean values of cow characteristics measured over the whole three year period.

-Detailed analysis of the data to account for variation due to sampling date, physiological state of the cow and pasture season.

In this chapter, we present the analysis of the mean values.

6.1.3.1 Mean values of simple correlations

The mean values for all the performance criteria and cow characteristics are given in Table 6.1. The mean values for the cow weight indicate that the cows were moderately small with a few very small cows and some moderately large ones.

The simple correlation coefficients between the production criteria and the cow characteristics are given in Table 6.2. Among the production criteria, W and P are closely related, as are G and L. However, between these two pairs of criteria, the correlation is relatively low. It indicates that the number of conceptions per cow changes the production criterion

qualitatively. We can therefore choose one of each pair of criteria. Comparing the criteria with the cow characteristics illustrates that W and P are characterized by similar cow characteristics, and either criterion could serve equally well (or equally badly!). Surprisingly, criterion P, which contains less information than criterion W, is slightly better than W. These criteria are significantly correlated with age ($r = 0.29, 0.30$); lactose dehydrogenase ($r = -0.25, -0.26$); albumin ($r = 0.22, 0.26$); blood lipids ($r = 0.24, 0.25$); and magnesium ($r = 0.31, 0.32$). There are also some correlations that border on the $P = 0.05$ significance level. These include cow weight ($r = 0.19, 0.21$); water turnover ($r = 0.18, 0.21$); and urea ($r = 0.19, 0.22$). There are 5 characteristics that are significant with the W criterion and 8 characteristics that are significant with the P criterion (Table 6.2). Whether the one or the other is superior in a multiple regression will be examined below, but on the basis of simple correlations, P would appear to be a slightly more sensitive criterion.

The characteristics that are significantly related to the G and L criteria include age ($r = 0.31$); lactic dehydrogenase ($r = 0.36, 0.39$); and blood magnesium ($r = 0.31, 0.34$). The W and P criteria are also sensitive to these characteristics and to others in addition. Consequently, they can be regarded as overall more sensitive criteria.

Summarizing the 3-year mean characteristics on the basis of simple correlations, indicates that the more productive cow tends to:

1. Be older (within the range of 2 to 7 years at the beginning of the experiment;
2. Have lower lactic dehydrogenase levels in the blood serum;

3. Have higher serum albumin and total lipids levels in the blood;
4. Have higher magnesium levels in the serum;
5. Be slightly heavier;
6. Have slightly higher water turnover rates;

Whereas all these characteristics are significant, their simple correlation coefficients are low and their predictive value, accordingly low. It will therefore be necessary to investigate whether combining the characteristics in a multiple regression can improve their predictive value. Some of the characteristics are correlated between themselves. Thus cow weight is positively related to height at withers, width at hips and age (Table 6; 3). TOH space is related to globulin and magnesium; total serum protein is related to Ca and Mg; total serum lipids is positively correlated with serum glucose and magnesium but negatively correlated with inorganic phosphorus. Urea is positively correlated with water turnover, but negatively with blood glucose. Overall, magnesium appears to be related to more characteristics than any other single characteristic.

6.1.3.2 Multiple regression analysis

The regression analysis was conducted with the GLM procedure of SAS, 1985 (p. 433). When all the characteristics of 'the full model' are entered into the multiple regression, the statistics of the performance criteria indicate that the F values and R^2 of the W and P criteria are slightly higher than those of the G and L criteria, but that $R^2 = 0.44$ is the highest explainable variance that can be accounted for (Table 6; 4).

Table 6.4. Multiple regression statistics for production criteria based on all measured parameters ('the full model').

Criterion	W	P	G	L
F value	2.42	2.46	2.12	2.16
Pr>F	0.0062	0.0053	0.0166	0.0149
R ²	0.437	0.442	0.406	0.409
CV %	29.9	35.5	31.6	31.3

(BARD 2 A - D)

However, in the type III SS, where the marginal effect of each variable is determined, only blood lipids and glucose were significant in the W and P criteria and only lactose dehydrogenase and glucose in the G and L criteria.

After removing non significant variables in gradual stages a model emerged that had seven significant characteristics for the W criterion (Table 6.5)

Table 6.5. Significance level of characteristics in multiple regression models with the W criterion after elimination of less significant parameters, with and without Mg in the regression model.

Variable	Pr > F (Type III SS)	
	with Mg	Without Mg
Cow weight	0.0750 -	0.0222 *
Water turnover	0.0239 *	0.0083 **
Aspartate aminotransferase	0.0082 **	0.0169 *
Lactic dehydrogenase	0.0026 **	0.0031 **
Albumin	0.0008 ***	0.0016 **
Lipids	0.0562	0.0035 **
Glucose	0.0119 *	0.0097 **
Mg	0.0571 -	
F - value for model	6.02 ***	6.15 ***
R ²	0.367	0.338
CV (%)	29.7	29.7

Asterisks designate significance level (BARD 3A-B)

From these results, we can conclude that the seven significant variables are related to accumulative weaning weight to a modest degree. Addition of Mg increases the R^2 from 0.338 to 0.367 but as it is marginally non-significant it reduces the F value and the significance levels of 'cow weight' and 'lipids'. Urea is similar to Mg in this respect.

The coefficients for both these models are given in Table 6.6

Table 6.6. Coefficients of variables in the regression equation for criterion W.

Variable	Coefficients	
	(with Mg)	(without Mg)
Intercept	-1461	-1051
Cow weight	0.47	0.60
Water turnover	1232	1440
Aspartate amino transferase	4.54	4.11
Lactic dehydrogenase	-0.133	-0.133
Albumin	279	264
Lipids	0.335	0.477
Glucose	-3.17	-3.31
Mg	183	-

(BARD 3A - B)

The model (without Mg) was defined slightly differently by combining albumin and globulin as a ratio as well as lipids and glucose. This slightly improves the F value, but R^2 is slightly reduced. The detailed results are given in Table 6.7

Table 6.7. Coefficients and their significance levels (t-test) for model with albumin/globulin and lipid/glucose ratios for the W criterion.

Variable	Coefficient	Pr>T (for coefficients)
Intercept	-813	0.0083 **
Cow weight	0.64	0.0154 *
Water turnover	1404	0.0102 *
Aspartate amino-transferase	4.03	0.0181 *
Lactic dehydrogenase	-0.128	0.0044 **
Albumin/Globulin ratio	554	0.0024 **
Lipids/Glucose ratio	28.9	0.0003 ***
F - value for model	6.94	0.0001
R ²	0.329	
CV	29.7	

(BARD 3C)

As there is no clear cut advantage to this formulation, the inclusion of the characteristics as separate variables is to be preferred.

Replacing cow weight by cow age reduces the explanatory value of the model only slightly, but as it is more strongly correlated with other variables, it causes interpretation problems in the type III SS and complicates the allocation of R² to the contributing variables.

(BARD 3 D-E)

Removing the non-significant variables from the G and L criterion models, leaves us with only three significant characteristics: serum glucose, lactic dehydrogenase and Mg. The detailed results are given in Table 6.8.

Table 6.8. Coefficients of significant variables and their t-test Probabilities in the regression equations for the G and L criteria.

Variable	G criterion		L criterion	
	Coefficient	Pr> T	Coefficient	Pr>T
Intercept	1.01	0.607 -	2.19	0.3519 -
Lactic dehydrogenase	-0.0016	0.0001 ***	-0.0018	0.0001 ***
Glucose	-0.024	0.0300 *	-0.026	0.0234 *
Mg	2.86	0.0004 ***	2.63	0.0013 **
F-value of model	11.52	0.0001		
R ²	0.252			
CV (%)	32.4			

The G and L criteria are both based on the reproductive performance of the cow as well as on calf performance. There is very little difference between them, even though G is based on the mean weaned weight and L on the daily liveweight increase. In both cases, the productive cow tends to have lower lactic dehydrogenase and glucose levels, and higher Mg levels.

6.1.4 Discussion

The cow characteristics in this analysis are three year means for each characteristic and include observations that were taken during different seasons of the year and on cows in different physiological states. Nevertheless, highly significant relationships emerge, but which leave unexplained most of the variance in the production criteria. In addition, the significant characteristics differ with the different performance criteria so that interpretation of the results is not made easier.

Two characteristics are common to all criteria. They are the negative relationship between both lactic dehydrogenase and glucose in the blood and the performance criteria (Tables 6.5 and 6.8). Lactic dehydrogenase which occurs widely in the body (Kaneko, 1980) reflects tissue turnover and can be an indicator of generalised stress. The negative relationship indicates that the more productive animals tend to have lower overall lactic dehydrogenase levels. This could result from a better ability to cope with stress that is reflected in lower tissue damage. The lower blood glucose levels in the more productive cows could indicate that they are more conservative with regard to energy expenditure and as a result can withstand nutritional stress more effectively.

In addition to these characteristics, accumulative weaning weight criteria are positively related to cow weight, water turnover, aspartate amino-transferase, serum albumin and total lipids. Cow weight is commonly related to higher weaning weights (Preston & Willis, 1970) and higher water turnover would indicate that the intake of the more productive cows tended to be higher than in the less productive ones. The biological rationale behind the relationship between performance and the other parameters, is

less clear. Why should higher AST levels be associated with higher producing cows.

The same question can be asked with regard to albumin and lipids.

When the conception rate is included in the criteria the only significant parameters are lactic dehydrogenase, glucose (negatively related) and magnesium (positively related). The variance accounted for is lower for these criteria than for the accumulative weaning weight criteria.

The effect of pasture condition and physiological state of the animal on these parameters could possibly help to interpret the results. These effects will be discussed in the following chapter.

6.1.5 Conclusion

Some physiological parameters when averaged over 12 observations during three years, are significantly related to cow performance. The characteristics that are consistent over all criteria are negative relationships between lactic dehydrogenase and serum glucose levels. This relationship indicates that cows that cope with stress more successfully tend to have lower lactic dehydrogenase levels. The lower overall serum glucose levels of such cows may indicate that their use of energy is more efficient.

Among the other parameters, blood magnesium appears to be related to higher conception rates. Cow weight and water turnover (intake?) are related to higher accumulative weaning weights. The significant relationship between accumulative weaning weight and aspartate amino-transferase, blood albumin and lipids is more difficult to interpret.

Despite the relatively low proportion of overall performance variance that can be accounted for by the measured parameters a fair number are

significant and some of them, highly significant. These results themselves indicate that superior cows have measurable physiological characteristics that can be meaningful over and above fluctuations between seasons and physiological state of the animals. The effects of these factors on the predictive value of these parameters will be presented in the following chapter.

Table 6.1. Performance criteria and cow characteristics - 3 year herd means.

Variable	No. of cows	Mean	SD	Range of values	
				Minimum	Maximum
W - total weaning wt (kg/cow)	92	392	137.4	120	705
P - graded weaning wt *	92	2.94	1.239	1.0	5.0
G - criterion G *	92	3.36	1.263	1.0	5.0
L - criterion L *	92	3.46	1.296	1.0	5.0
w - cow live weight (kg/cow)	92	319	48.6	191	433
h - height at withers (cm)	92	120	5.3	109	132
b - width at hips (cm)	75	37	2.1	32	41
a - age in 1982 (yr)	92	4.3	1.88	2	7
t - TOH space (kg/kg)	92	0.72	0.031	0.658	0.797
v - water turnover (kg/kg/day)	92	0.16	0.024	0.09	0.22
c - lactic dehydrogenase (mu/ml)	92	2161	285	1604	2953
g - aspartate amino transferase	92	76	7.9	56	97
k - alkaline phosphatase (mu/ml)	92	116	48.2	48	344
p - total protein (g/100 ml)	92	7.6	0.10	7.4	7.8
m - albumin (g/100 ml)	92	3.6	0.16	3.0	4.0
n - globulin (g/100 ml)	92	4.0	0.17	3.7	4.5
f - total lipids (mg/100 ml)	92	534	80.6	378	824
s - glucose (mg/100 ml)	92	62	10.4	39	101
Ca - calcium (mg/100 ml)	92	9.6	0.47	8.5	11.2
Pi - inorganic phosphorus (mg/100 ml)	92	6.0	0.62	4.3	7.7
Mg - magnesium (mg/100 ml)	92	2.6	0.15	2.2	3.0
U - urea (mg/100 ml)	92	38	4.0	30	49

* See materials and methods

Table 6.2: Simple (Pearson) correlation coefficients
(T) between production criteria
and cow characteristics.

Cow charact.	Production criteria			
	W	P	G	L
P	.97			
G	.61	.62		
L	.61	.62	.96	
w	.19	.21	.	.
h	.	.	.	.
b	.18	.18	.	.20
a	.29	.30	.31	.31
t	.	.	.	.
v	.18	.21	.	.
c	-.25	-.26	-.36	-.39
g	.	.	.	.18
k	.	.	-.19	-.16
p	.	.	-.19	-.16
m	.26	.22	.18	.20
n	-.18	.	.	.
f	.25	.24	.	.
s	.	-.17	-.19	-.20
Ca	.	.	.	.
Pi	.	.	.	.
Mg	.31	.32	.34	.31
u	.19	.22	.	.

Significance levels: (d.f. >90)

P = 0.001, $r > 0.343$

P = 0.01, $r > 0.267$

P = 0.05, $r > 0.205$

P = 0.10, $r > 0.0170$

All correlations marked by have $r < 0.170$

i.e. non significant even at P = 0.10

Table 6.3. Correlation matrix of cow characteristics

Physical characters				Water metab		Enzymes			Organic nutrients					In organic nutrients		Waste prod.	
w	h	b	a	t	v	c	g	k	p	m	n	f	s	Ca	Pi	Mg	u
h	.63																
b	.35																
a	.27	.	.29														
t	.	.	.	.21													
v	.	.	.	.	.39												
c	.	.	.	-.35	.	.											
g	.	-.18	.	.	.	.	.										
k	.	.	.	.	.	-.26	.	.									
p	.	.	.	.	.18	.	.	.	.								
m	.	.	.	.	.	.	.	-.27	.	.21							
n	.	.	.	.18	.24	.	.	.24	.	.36	-.81						
f	.	.	.	.	.17	.	.	.	.	.	.	.					
s	.	.	.	.	.	.	.	.21	.	.	.	.	.24				
Ca.	.	.	.	.	.	.	.	.	.36	.31	.	.	.	.			
Pi.	.	.	.28	.	.	.	.22	.18	.	.	.	.	-.27	.	-.25		
Mg.	.19	.25	.	.34	.34	.18	.	.	.27	.	.21	.40	.	.	.	-.22	
u	.	.	.	.	.	.24	.	.	.	.	.	.	.	-.23	.	.	1
w	h	b	a	t	v	c	g	k	p	m	n	f	s	Ca	Pi	Mg	u

Significance levels: see footnote to Table 6.2.

6.2 Effect of physiological state of the cow and pasture condition on the relationship between physiological parameters and performance of the beef cow.

6.2.1 Introduction

The analysis of the mean blood profile and other values for the whole experimental period indicated that some of the biochemical factors monitored are significantly related to performance (see part 6.1). In the following section, we will analyse the relationship in greater detail, with special emphasis on the effects of the physiological state of the cow and of pasture condition.

6.2.2 Method of analysis

The data for the following analysis were divided into four groups according to the physiological state of the cow and availability of green feed:

- (1) Lactating cows during the green season (LAC GREEN)
- (2) Dry cows during the green season (NOLAC GREEN)
- (3) Lactating cows during the dry season (LAC DRY)
- (4) Dry cows during the dry season (NOLAC DRY)

The physiological and performance data for each group were averaged for each cow over the three year period of the experiment. The performance

criteria are discussed in part 6.1. The number of animals in each group is given in Table 6.2.1.

Table 6.2.1 Numbers of cows in the data sets used for analysis of physiological indices.

Group	No. of cows in set	No. used
LAC GREEN	89	89
NOLAC GREEN	66	60
LAC DRY	90	87
NOLAC DRY	80	58-71

The number used can be less than the number in the data set because of missing values for some variables. The number of observations used depended on which variables were screened as significant in the final regression model.

The data in each set were analysed as follows. Initial screening was performed in the context of a multiple regression model on cow performance. The backward elimination technique was used whereby indices that contribute least to reduction of the error sum of squares are eliminated sequentially until only variables with $Pr > F$ less than 0.05 are left (SAS, 1985; p.763). This technique has the advantage that the R^2 of the model is reduced very 'cautiously' and the elimination is effected in relation to all the remaining variables. The disadvantage is that the SAS procedure cannot handle discrete variables defined as classes, in our case, the treatments of the experiment. In addition, the SAS procedure uses a fixed

set of observations determined at the beginning of the elimination procedure by the presence of all variables, including those that are eventually eliminated during the screening process. This is not a problem where the data set is complete, but where there are missing values for individual variables, the whole set of non-missing values for that observation (cow) are eliminated too. This partial set puts an unnecessary bias on the analysis, especially when many observations are dropped because of missing values of variables that are eventually eliminated from the model because of non-significance.

In order to overcome these disadvantages, the data were analysed by the RSQUARE procedure (SAS, 1985; p.711) whereby the R^2 values for all possible combinations of variables are computed and arranged in decreasing order. Inspection of this output can then indicate what alternative multiple regression models can give R^2 close to that obtained by the variables selected by the backward elimination technique. It is then possible to check whether alternative models with variables that are more fully represented can be used to exploit the data more efficiently. Finally, the provisionally screened variables are subjected to further analysis with the GLM procedure (SAS, 1985; p.433) that allows classes to be included in the regression model. Variables that do not attain significance ($Pr > F$ less than 0.05) are eliminated after checking for possible non-linear relationships by entering squared terms into the analysis.

The final screened set of variables with the appropriate statistics are given in Tables 6.2.4 - 6.2.9 and summarized in Table 6.2.2.

6.2.3 Results and discussion

a. Overall relationship between performance and measured characteristics

The proportion of the total variance explained by the models composed of significant variables ranges between $R^2 = 0.16$ and $R^2 = 0.42$ (Table 6.2.2). The R^2 attainable by including all the measured variables is greater and exceeds 0.50 in some data sets, but as the full model contains many nonsignificant variables, their retention in the final model cannot be justified even though they do contribute to a higher R^2 . The range of R^2 values for the final models are all highly significant ($\text{Pr} > F < 0.0001$) but the total amount of variance accounted for in the various models is seldom greater than one third. The rest of the variance is due to measurement errors and to the multitude of elusive genetic, health, physiological, nutritional and environmental factors that are not reflected in variables that were measured and which play a dominant role in determining the productive performance of the beef cow. Nevertheless, a considerable part of the overall variance in performance is related to the variables that were measured and the high levels of significance attained indicate that they may have value in characterizing superior cows.

b. Effect of sampling conditions on efficiency of performance characterization.

The variables that are significantly related to performance depend heavily on the physiological state of the animal and on the condition of the pasture at sampling. This is clearly illustrated in Table 6.2.2 where both the total explainable variance (R^2) and the specific significant variables are generally different for each sampling scenario and for the different performance criteria. Unfortunately, no single variable was

identified among those chosen for the study that was clearly related to long term performance under all sampling conditions. However, it would have been pretentious to expect one such variable to emerge given the complex nature of the animal production system and the dynamic nature of all physiological processes. It is, therefore encouraging to find that under clearly defined sampling conditions, there are physiological indices that are significantly related to relatively long-term performance criteria. Overall, the lowest R^2 values were attained in the lactating group (LAC GREEN, LAC DRY, criteria W and P); the highest values were obtained in the group of dry cows in the dry season for the criteria that included the frequency of pregnancies over the 4 breeding seasons monitored (NOLAC DRY, criteria G and L). All other combinations of sampling conditions and performance criteria, gave intermediate R^2 values (Table 6.2.3). Even though the combinations with the highest R^2 values should be the most useful indicators of performance, there are qualifying conditions that will be discussed below, so that it is necessary to evaluate the other combinations too. Overall, the mean R^2 was 0.253 for all criteria in the set of lactating cows and 0.336 in the non-lactating set, with the non-lactating dry season set averaging 0.360. The total weaning weight performance criteria averaged R^2 values of 0.242 whereas those that included reproductive performance averaged $R^2 = 0.345$.

c. Significant variables in the different sampling situations

(1) Lactating cows in the green season: Three factors are significantly related to animal performance in this group: AGE, PI and experimental treatment, with AGE and PI consistently significant over all criteria (Table 6.2.4). The W and P criteria are very similar with AGE being

somewhat more significant than PI. The G and L criteria are also similar to each other, but, in contrast to the W and P criteria, the treatment effect is significant and the response of performance to PI is not linear, but quadratic (i.e. the PI^2 term is significant). The values of the coefficients (Table 6.2.4) indicate that the (maximum) extremum of the quadratic function is just beyond the range of PI values (Table 6.2.3), indicating that performance has a positive but diminishing response to PI. Among the treatment conditions, only the low stress treatment is significantly different from the other treatments.

The relation between this data set and the performance criteria can be summarised as follows: When lactating cows are examined during the green season, the factors which characterize better long-term performers are primarily age (within the range of this experiment) and PI level in the blood. When calving frequency is included in the performance criteria, the response to PI level is positive, but diminishes as PI approaches the highest values of the measured range. In addition, the effect of applied stress (heavier grazing pressure in this case) is more closely reflected by the criteria that include calving frequency.

As age and treatment account for about half of the accounted for variation, and as the residual relationship between PI and performance is linear in some criteria, quadratic in others, it can be concluded that lactating cows in the green season are not easily characterized for long term performance.

2. Lactating cows in the dry season: Here, in addition to age, three other factors have a significant relationship to performance; blood magnesium (MAG), globulin (GLOB), water turnover (TURN) and cow weight (CWT) (Table

6.2.5). However, the accumulated weaning weight criteria (W and P) are poorly related to specific cow characteristics. Besides cow age, which is significantly related to performance, both MAG and CWT have relatively low levels of significance.

The criteria that include calving frequency (G and L) are more sharply characterized, with water turnover and globulin giving similar relations for both criteria. Turnover is positively related to performance and could indicate that cows with better performance records have better appetites because water turnover is closely related to feed intake (Siebert, 1971). Globulin has a quadratic relationship with performance. The coefficients in Table 6.2.5 indicate that the (maximum) extremum of the response occurs below the lowest values of the recorded range of globulin values (Table 6.2.3). As a result, the response of performance to globulin is negative and falls more steeply as globulin levels increase. This negative relationship is only vaguely indicated in the raw data (Table 6.2.6) and is significant only in the multiple regression context with turnover and age.

Here too, we must conclude that we are left with a poor diagnostic situation, especially as the measurement of water turnover involves using tritiated water, which not only can be expensive with beef animals but is subject to limitations that are imposed on the use of radioactive materials in the field.

3. Dry cows in the green season: In this data set, age emerges as a significant factor only in the accumulative weaning criteria together with blood albumin (ALB), globulin (GLOB) and calcium (CAL). With the criteria that include calving frequency, only lactic dehydrogenase (LDH) and the treatment effects are significant (Tables 6.2.7 and 6.2.2). The factors

that are significant for the W and P criteria are consistent both with regard to the specific factors and the significance levels; the G and L criteria are also consistent in this respect (Tables 6.2.7 and 6.2.2).

Of the factors significantly related to the accumulative weaning weight criteria (W and P), ALB and GLOB are positively related, whereas CAL is negatively related. It should be pointed out again that these relationships emerge in the multiple regression analysis and may not necessarily be obvious in the mean values for the criterion class. Thus, whereas the mean values for CAL are clearly negatively related to performance (Table 6.2.8) and the values of ALB are positively related, the values for GLOB, which should also be positively related, are not. Thus, when evaluating these factors for characterization efficiency, the multiple dimensional context must be taken into account.

The G and L criteria, after taking into account age and treatment effects, are significantly characterized by LDH only: there is a negative correlation between LDH and performance, which emerges not only in the multiple regression analysis (Tables 6.2.7 but also in the class means (Table 6.2.8). These criteria, which include calving frequency, are more fully represented in the sample (Table 6.2.8) than the W and P criteria, where the highest class is not represented in the data set, indicating that none of the cows with the highest cumulative weaning weight were dry in any of the three green seasons monitored. Note that only 66 cows qualified for this set, of which only 60 observations could be used (Table 6.2.1).

The efficiency of the G and L criteria is about the same, the L criterion being slightly inferior. However, this difference may be due to the fact that the observations are more evenly distributed among the

classes in the L criteria (calving frequency/daily liveweight increase) than in the G criterion (calving frequency/ mean weaning weight).

In conclusion, the dry cows in the green season are more easily characterized with regard to long term performance. The best performers are not prominent in this group (Table 6.2.8) as they would all be lactating during the green season. However, this group is of special interest, as it includes most of the candidates for culling, and it is important to be able to separate it into subgroups that reflect long term performance. The factors identified, especially albumin, calcium and lactic dehydrogenase, appear to have potential in this regard.

4. Dry cows in the dry season: In this sample group, the age factor has been replaced by other parameters and the treatment effects are significant only for the G and L criteria (as in previous data sets). Lactic dehydrogenase (LDH) and magnesium (MAG) emerge as consistent indicators for all criteria, with blood inorganic phosphorus (PI) and sugar (SUG) appearing as significant variables in the W and P criteria (Tables 6.2.9 and 6.2.2). Among the W and P criteria, LDH, MAG and SUG behave consistently with similar signs and similar levels of significance: performance is negatively related to LDH and SUG and positively related to MAG (see also Table 6.2.3).

However, the relationship with PI is different in the two criteria: quadratic in W and linear in P. The coefficients for PI and PI^2 (Table 6.2.9) indicate that the (minimum) extremum of the performance response is attained at a PI level of 6.37 mg % which marks the lower third of the recorded range for this data set (Table 6.2.3, NOLAC DRY). Consequently, for the upper two thirds of the range of PI values, the relationship with

performance is positive, increasing quadratically with higher values of PI. This overall positive response can be vaguely detected in the mean values of the P criterion classes, but as pointed out previously, the significant relationship emerges only in the multiple regression analysis (Table 6.2.10).

The results for the G and L criteria are more straight-forward. After accounting for the treatment effect, mainly due to grazing pressure (or stocking rate), both LDH and MAG are highly significant indicators of performance based on calving frequency and either mean weaning weight or mean calf liveweight gain. If anything, the relationship is stronger for the L criterion than the G criterion (Table 6.2.9 and 6.2.2). The relationship is negative between performance and LDH and positive between performance and MAG (Table 6.2.11).

The biological rationale for these relationships is a matter for speculation. Starting with the most clear-cut situation, the G and L criteria, we need to account for the negative LDH and positive MAG relationship to performance. As LDH is a widely distributed enzyme in skeletal and heart muscle, liver, kidney and other organs (Schmidt and Schmidt, 1983) and is released into the blood serum as a result of cell turnover and damage, it could well be related to physical stress conditions. The wide distribution of LDH in the body is not conducive to diagnosis of specific organ damage, but is probably an effective indicator of general cellular damage. As the sample set of animals is a normal herd of generally healthy animals, one would not expect acute pathological symptoms to be common. However, the response of different animals to poor nutritive conditions, including intake of significant amounts of unbalanced feed like poultry litter, as well as to environmental stresses associated

with difficult foraging terrain and heat, can well be associated with performance and be reflected in their ability to cope with a minimum of distress. Animals that succeed better, appear to have lower LDH levels; if not absolutely, then at least in relation to the rest of their peer group.

The relationship between magnesium in the blood serum and performance is not clear. This divalent cation, is located mainly intracellularly and elevated serum levels could result from cellular leakage as result of physical stress in the grazing animals. On the other hand, Mg plays an important role in the activity of many key enzymes in the metabolism (dehydrogenase, phosphatases). Thus levels of this ion could be related to performance and fertility. This could explain the result obtained in this analysis, where MAG emerged as a significant factor only when calving frequency was included in the performance criteria. MAG is more usually related to nutritional disorders but as stated earlier, the cows were managed under normal conditions, albeit with varying degrees of stress, with no imposed differential treatment that explicitly involved MAG. It must therefore be concluded that the effect of higher MAG levels (and associated superior performance) are specific responses of the animal and indicate a better ability to cope with the stress situation that is particularly severe in the dry season.

The biological rationale behind the relationships between the significant factors and performance in W and P criteria must explain, in addition to LDH and MAG, also the positive correlation with inorganic phosphorus (PI) and the negative correlation with blood glucose levels (SUG). Whereas the PI effect could be similar to that of MAG, the SUG relationship is more directly related to the energy balance. Could it be

that superior cows are more conservative in energy use and consequently have lower glucose levels in the blood?

6.2.4 Conclusion

In general, most diagnostic characteristics are defined in order to identify the cause of abnormal or pathological phenomena. In the present study, similar techniques are used to identify superior characteristics in an essentially normal population. As the characteristics of superior performance relate to the whole organism, it is not likely that a relatively small set of diagnostic characteristics will point unambiguously to individual animals with superior long-term production capabilities. This possibility is further limited by the fact that a herd is generally composed of animals that have undergone some degree of selection and have achieved a certain minimum performance level. It is therefore encouraging that the variance accounted for by the diagnostic parameters monitored, exceeded 40% in certain data sets. The high significance of the identified parameters and their consistency between different performance criteria, is some indication of their potential utility. From the discussion of the results it appears that non-lactating cows are in a suitable physiological state for such diagnostic sampling and that such cows in the dry season can be most easily characterized as to long-term performance.

The parameters identified are based on a herd of 90 cows monitored over a 3 year period. Even though the results are highly significant, the sample is small and relates to one herd with its specific characteristics. The result must therefore be seen as tentative and be checked on other herds under different management conditions in order to determine the generality of our findings.

Table 6.2.2. F values in Type III SS of significant variables related to cow performance.

Data set	LAC GREEN				LAC DRY				NOLAC GREEN				NOLAC DRY			
Criteria	W	P	G	L	W	P	G	L	W	P	G	L	W	P	G	L
<u>Variable</u>																
AGE	11	11	13	11	11	8	11	10	7	6						
PI ₂	4	7	11	6									5	8		
PI			10	6									6			
MAG					4								6	5	15	20
CWT						5										
TURN							5	7								
GLOB							7	8	5	6						
GLOB ²							8	10								
ALB									15	14						
CAL									12	16						
LDH											9	14	19	14	15	18
SUG													7	6		
TRT			6	3							17	5			5	3
R ² (1	.16	.19	.36	.28	.18	.17	.32	.34	.31	.32	.30	.32	.33	.27	.42	.42
R ² (2	.31	.31	.36	.27	*	*	*	*	.38	.36	.44	.43	.39	.36	.50	.51

1) Full model including significant variables only

2) Full model including all monitored variables.

* Full model applies to only 17 observations.

Table 6.2.3 Range of values of significant variables related to cow performance¹⁾.

Data set	LAC GREEN				LAC DRY				NOLAC GREEN				NOLAC DRY													
Criteria	W	P	G	L	W	P	G	L	W	P	G	L	W	P	G	L										
Variable																										
AGE	$\frac{2}{7}$	$\frac{3.56}{5.67}$	$\frac{3.00}{5.31}$	$\frac{3.00}{5.12}$	$\frac{2}{7}$	$\frac{3.40}{5.67}$	$\frac{3.67}{5.31}$	$\frac{3.67}{5.24}$	$\frac{2}{7}$	$\frac{3.70}{5.50}$																
PI	$\frac{3.41}{7.95}$	$\frac{4.89}{5.43}$	$\frac{5.16}{5.50}$	$\frac{5.16}{5.45}$									$\frac{4.50}{9.91}$	$\frac{6.83}{7.04}$												
MAG					$\frac{1.49}{3.29}$																					
CWT																										
TURN					$\frac{.13}{.17}$	$\frac{.13}{.16}$																				
GLOB					$\frac{3.98}{3.62}$	$\frac{3.90}{3.54}$	$\frac{3.30}{5.00}$	$\frac{4.40}{4.22}$																		
ALB					$\frac{3.10}{3.90}$	$\frac{3.34}{3.50}$																				
CAL					$\frac{7.24}{13.75}$	$\frac{10.03}{9.08}$																				
LDH					$\frac{2813}{2692}$	$\frac{2813}{2181}$	$\frac{1489}{2694}$	$\frac{2065}{1745}$	$\frac{2270}{1819}$	$\frac{2270}{1829}$																
SUG					$\frac{27.1}{106.3}$	$\frac{62.5}{48.9}$																				

¹⁾ Values for criteria W are the mean values of the observations recorded in the respective data sets for the cows with the mean minimum/maximum values for the respective parameters.
 Values for criteria P, G, L are the mean values for the lowest class/highest class (=class 1/class 5) of the respective criteria.

to determine the effect of treatment on the physiological indices and experimental treatment: Lactating cows in the green season (LAC GREEN).

Table 6.2.4 Multiple regression models for animal performance as a function of physiological indices and experimental treatment: Lactating cows in the green season (LAC GREEN).

Criterion 1)	W	P	G	L
Statistic	Coeff. Pr > F	Coeff. Pr > F	Coeff. Pr > F	Coeff. Pr > F
Parameter				
Intercept	143 0.1001	0.062 0.9385	-9.00 0.0082	-7.08 0.0570
AGE	22 0.0014	0.200 0.0015	0.21 0.0006	0.22 0.0013
PI	32 0.0418	0.399 0.0080	4.00 0.0017	3.33 0.0168
PI ²	2010.0 0.101		-0.36 0.0020	-0.30 0.0210
TRT-Low ²	4700.0 0.004		1.25 0.0003	0.99 0.0081
High			0.51 0.1249	0.50 0.1765
MS	715.0	0.11.0	0.30 0.4325	0.00 0.9997
MD	25.2	78.7	0.00 0.181.0	0.00 0.00
Model R ²	0.163	0.190	0.356	0.282
" F	8.37	10.6	7.54	5.37
Pr > F	0.0005	0.0001	0.0001	0.0001
No. observations	89	89	89	89

(1) Criterion : W - Total weaning weight (Kg)

P - Total weaning weight classes

G - Mean weaning weight x conception frequency classes

L - Mean calf daily weight gain x conception frequency classes

(2) Treatment Low - low stress

High - high stress

MS - medium stress

MD - medium stress, deferred early season grazing

Table 6.2.5 Multiple regression models for animal performance as a function of physiological indices and experimental treatment: Lactating cows in the dry season (LAC DRY).

Criterion ¹⁾	W		P		G		L	
Statistic	Coeff.	Pr > F	Coeff.	Pr > F	Coeff.	Pr > F	Coeff.	Pr > F
<u>Parameter</u>								
Intercept	123	0.2601	0.646	0.4346	-16.3	0.0257	-18.2	0.0159
AGE	23.5	0.0016	0.177	0.0067	0.254	0.0014	0.246	0.0025
MAG	83.7	0.0576						
CWT			0.053	0.0371				
TURN					6.74	0.0293	7.97	0.0131
GLOB					10.76	0.0105	12.12	0.0055
GLOB ²					-1.612	0.0074	-1.839	0.0033
Model R ²	0.181		0.170		0.317		0.339	
" F	7.50		7.87		6.26		6.92	
Pr > F	0.0011		0.0008		0.0003		0.0001	
No. observations	71		80		59		59	

¹⁾ See footnote, Table 6.2.4.

Table 6.2.6 Mean class values of blood globulin levels for the G and L criteria in the lactating cows/dry season data set.

Criteria	G	L
Class		
1	3.98	3.98
2	3.44	3.56
3	3.57	3.46
4	3.49	3.54
5	3.62	3.54

Table 6.2.7. Multiple regression models for animal performance as a function of physiological indices and experimental treatment: Dry cows in the green season (NOLAC GREEN)

Criterion ¹⁾	W		P		G		L	
Statistic	Coeff.	Pr > F	Coeff.	Pr > F	Coeff.	Pr > F	Coeff.	Pr > F
<u>Parameter</u>								
Intercept	-915	0.0280	-8.90	0.0284	4.18	0.0001	4.99	0.0001
AGE	16	0.0108	0.15	0.0160				
ALB	325	0.0003	2.99	0.0006				
CAL	-34	0.0009	-0.38	0.0002				
GLOB	95	0.0233	0.97	0.0181				
LDH					-0.0008	0.0043	-0.0011	0.0006
TRT Low ²⁾					1.39	0.0001	1.34	0.0005
High					0.79	0.0232	0.89	0.0168
MS					0.48	0.2592	0.37	0.4204
MD					0.0	-	0.0	-
Model R ²	0.313		0.319		0.300		0.324	
" F	6.26		6.43		5.89		6.58	
Pr > F	0.0003		0.0003		0.0005		0.0002	
No. observations	60		60		60		60	

1), 2) See footnote, Table 6.2.4.

Table 6.2.8 Mean class values of significant factors for the various criteria in the dry cow/green season data set.

Criterion	P			G	L
Factor	ALB	GLOB	CAL	LDH	LDH
<u>Class</u>					
1	3.34(10)	4.40(10)	10.03(10)	2813(7)	2813(7)
2	3.45(17)	4.17(17)	9.84(17)	2322(17)	2390(12)
3	3.45(23)	4.29(23)	9.03(23)	2560(15)	2460(20)
4	3.50(10)	4.22(10)	9.08(10)	2073(18)	2146(12)
5	-	-	-	2692(3)	2181(9)
Total	(60)	(60)	(60)	(60)	(60)

() Number of observations in each class.

- no observations in this class.

Table 6.2.9 Multiple regression models for animal performance as a function of physiological indices and experimental treatment: Dry cows in the green season (NOLAC DRY)

Criterion ¹⁾	W		P		G		L	
Statistic	Coeff.	Pr > F	Coeff.	Pr > F	Coeff.	Pr > F	Coeff.	Pr > F
<u>Parameter</u>								
Intercept	11.67	0.0036	1.68	0.3461	0.39	0.8038	0.09	0.9569
LDH	-.01843	0.0001	-0.0015	0.0004	0.00155	0.0002	0.00176	0.0001
MAG	144	0.0210	1.36	0.0253	2.23	0.0002	2.65	0.0001
PI	-209	0.0353	0.30	0.0050				
PI ²	16.4	0.0160						
SUG	-2.07	0.0085	-0.018	0.0149				
TRT Low ²⁾					1.14	0.0002	0.88	0.0062
High					0.46	0.1330	0.39	0.2240
MS					0.40	0.2864	0.12	0.7588
MD					0.0	-	0.0	-
Model R ²	0.329		0.265		0.422		0.422	
" F	7.934		7.40		11.83		11.84	
Pr > F	0.0001		0.0001		0.001		0.0001	
No. of observations	87		87		87		87	

1), 2) See footnote, Table 6.2.4

Table 6.2.10 Mean class values of blood inorganic phosphorus for the P criteria
in the dry cow/dry season data set.
(BARD/CLASS MEANS)

Criterion		P	
Class	Mean level	Stand. Error	No. observations
1	6.83	0.30	10
2	6.72	0.22	21
3	7.02	0.23	29
4	6.81	0.28	18
5	7.04	0.43	12

Table 6.2.11 Mean class values of lactic dehydrogenase (LDH) and magnesium (MAG)
for the G and L criteria in the dry cow/dry season data set
(BARD/CLASS MEANS).

Criterion	G		L	
	LDH	MAG	LDH	MAG
<u>Class</u>				
1	2270 (103)	2.27 (.06)	2270 (103)	2.27 (.06)
2	1939 (56)	2.31 (.03)	1963 (66)	2.27 (.04)
3	2107 (71)	2.40 (.06)	2048 (62)	2.40 (.05)
4	1833 (36)	2.44 (.03)	1828 (46)	2.41 (.04)
5	1819 (60)	2.48 (.05)	1829 (43)	2.49 (.04)

() Standard error.

PART 7

RANGE OF BLOOD PROFILE AND OTHER
PHYSIOLOGICAL PARAMETER VALUES

(Blood profile and other physiological parameters in a beef herd grazing seasonal Mediterranean range).

7.1 Introduction

Metabolic blood profiles have been used to monitor health (Zamet et al., 1979), reproductive and nutritional status of dairy cows (Parker and Blowey, 1976; Rowlands et al. 1977; Rowlands et al., 1980; Lee et al., 1978; Sommer, 1975; Bogin et al., 1982). Bogin et al., (1982) showed that the ratio of total lipids to glucose in the blood serum was significantly related to the overall conception rate. Avidar et al. (1981) showed that the physiological status of the cow, milk yield, duration of lactation, age and season of the year, significantly affect some of the blood parameters. Normal values for blood parameters vary between species (Schmidt and Schmidt, 1980) and values in dairy cows are different to those in beef cows (Collins et al., 1978). Whereas numerous studies have been done on blood profile of dairy cows, very few have been done on beef cows under free ranging conditions. As the present experiment monitored a normal beef herd over a fairly long period, it is possible to examine the range of values obtained and to determine their sensitivity to changing environmental and nutritional conditions. Such data are useful as a background for evaluating

diagnostic tests for pathological and other abnormal phenomena in beef cows, especially those that are managed under extensive conditions.

In the present study, 92 beef cows were monitored over three years and blood profile parameters were measured regularly to cover a range of physiological states and pasture conditions. The data gathered reflect the condition of a herd of commercial European x Local Arab (Balady) crosses, and back crosses, managed extensively with supplementary feeding limited to poultry litter (ad lib.) during the dry summer and an addition of barley grain and occasionally straw during the autumn transitional period, before the establishment of the new season, green herbaceous pasture. Details of the experimental conditions are described in part 2.

7.2 Materials and Methods

The parameters measured, their symbols and units are listed in Table 7.1. The analytical procedures employed are described in Part 5.5.1.

7.3 Results and Discussion

The coefficient of variation around the mean values differs widely between variables and ranges from 4.5% in the total blood protein (PROT) to 52.7% in alkaline phosphatase (ALP) (Table 7.2). As these statistics are based on hundreds of observations sampled over three years they reliably reflect the magnitude of variation that can be encountered in beef cows on range. The variation also includes sampling error as well as errors accumulated as part of the laboratory procedures.

The effects of physiological state of the cow (lactating, pregnant dry or empty dry), pasture condition (dry, early season and green) and year of observation are given in Tables 7.3, 7.4 and 7.5. Analysis of the

significance of these effects as well as of different nutritional treatment effects is given in Table 7.6. These effects account for 15.7% (R^2) of the variation in blood protein to 63.8% in aspartate amino transferase (ASP). After accounting for these effects, the CV is reduced, but only slightly in those parameters with low R^2 . Whereas the combination of these effects is highly significant in all cases, there are considerable differences in the sensitivities of the various parameters to the specific effects. Only a few parameters are highly sensitive to the physiological state of the cow and they are lactic dehydrogenase (LDH), urea (UR), total lipids (TL) and water turnover (TURN). Most of the parameters were shown to be highly sensitive to pasture conditions with blood albumin (ALB) and TL content being the only two that are not sensitive. Practically all parameters varied significantly from year to year. The year effect was not significant only in alkaline phosphate (ALP) and LDH, but then, these parameters were the only two that were not measured in 1983. Treatment effects were significant to highly significant in all parameters except inorganic phosphorus (PI), total serum protein (PROT) and TL.

The coefficients for the different levels of various significant effects is presented in Table 7.7. These multiple regression coefficients are determined by the GLM procedure (SAS, 1985; p.433) which ascribes the value zero to one variable of a class and coefficients to the others which reflect the magnitude of the effect of each level in relation to the zero variable. Thus ALP values are significantly lower in lactating cows than in pregnant or empty dry cows; LDH is significantly lower in lactating and pregnant cows than in empty dry cows; UR is not significantly different between empty and lactating cows, but significantly lower in pregnant cows than in lactating cows.

Regarding seasonal effects, dry season and transitional early green season values were generally lower than green season values with few exceptions (Table 7.7). Inorganic blood phosphorus (PI) was higher in the dry and transitional season than in the green season whereas urea was higher only in the transitional season. The reasons for this pattern could be related to poultry litter consumption. Previous studies (Bogin, unpublished observations) showed that feeding cattle with relatively large amounts of poultry litter, resulted in significant increases in urea and sometimes also of PI. This was also observed in the present study whenever large amounts of poultry litter were fed to the cattle during the poor transitional grazing period (Table 5.5.1.3). Elevated urea levels however were not the result of permanent kidney dysfunction but were rather nutritional in nature and fluctuated between seasons. It should be noted that urea levels were lower in the dry season when poultry litter was available than during the green season, when it was not. The high protein levels in the green pasture increased nitrogen intake and consequent urea levels in the blood.

The variation in values from year to year do not follow a fixed pattern. Most values were lower in 1983 than in 1985; but in 1984 some were higher and some were lower than in the other years. Only total blood protein and albumin were significantly lower in 1985. This could be a result of the fact that this was a difficult, relatively dry year. Despite the high significance of the year effect, it is difficult to point to specific reasons why it should be so prominent, especially as there is no consistent trend in values of the various parameters. However, this is not surprising as the proportion of the total variance about the means of the parameters that is accounted for by these effects is low, seldom higher

than 40% and less than 20% in a number of cases (Table 7.6). The major source of variation is therefore in the individual responses of the cows to the complex of influences to which they are exposed and, of course, sampling and analysis error.

Conclusions

Electrolyte and protein values in this experiment were similar to those observed in dairy cows in Israel while mean values of blood enzymes levels were different (Avidar et al., 1981). AST and LDH levels were higher, probably due to the greater environmental stress imposed on animals grazing extensive pasture, and possibly due to stress imposed during sampling after an overnight fast in a relatively crowded corral (Kaneko, 1980). Consequently, when using blood profile and other physiological parameters for diagnostic purposes in beef cows extensively managed on range, it is undesirable to rely on standard values as they can vary significantly not only because of the physiological state of the animals but because of environmental effects related to pasture condition, animal handling conditions and to other effects that can vary from year to year, but are difficult to pin-point.

It is hazardous to draw conclusions from individual observations, except in extreme cases. Evaluation of individual animals should be conducted in relation to a peer group of healthy animals managed under similar conditions, preferably in the same herd (Rowlands et al., 1974). The use of fixed standards for beef cows derived from cows of widely different breeds and managed for milk production can be seriously misleading.

Table 7.1 Physiological parameters measured.

Parameter	Symbol	Old Units	SI Units	Conversion factor (old to SI)
Alkaline phosphatase	ALP	u/l	u l ⁻¹	
Asp. am. transferase*	AST	u/l	u l ⁻¹	
Lactic dehydrogenase	LDH	u/l	u l ⁻¹	
Urea	UR	mg %	mmol l ⁻¹	0.1665
Calcium	CAL	mg %	mmol l ⁻¹	0.2495
Magnesium	MAG	mg %	mmol l ⁻¹	0.4113
Inorganic phosphorus	PI	mg %	mmol l ⁻¹	0.3229
Albumin	ALB	g %	g l ⁻¹	10
Globulin	GLOB	g %	g l ⁻¹	10
Total lipids	PROT	g %	g l ⁻¹	10
" fat	TL	g %	g l ⁻¹	10
" glucose	SUG	mg %	mmol l ⁻¹	0.0555
Water turnover	TURN	kg(water) kg ⁻¹ (liveweight)		
Body condition	BCOND	kg (liveweight) cm ⁻¹ (shoulder height)		

* Synonym: Glutamic oxalacetic transaminase

Table 7.2 Mean values and coefficients of variation of physiological parameters measured on beef cows grazing Mediterranean herbaceous range (Data set: all observations over 3 years).

Data set	All			Angus cows 1)			Israeli dairy cow 2)		
Parameter	Mean	CV%	No. obs.	Mean	SD	CV%	Mean	CV%	No. obs.
ALP	117	52.7	508	41.40	18.30	44.5			
AST	75	38.7	783	69.88	11.64	16.6			
LDH	2150	20.6	510						
UR	38	34.8	786	22.82	3.71	16.3	30.1	72.8	92
CAL	9.6	16.0	744	20.07	0.69	6.9	8.97	9.8	45
MAG	2.56	14.8	772	2.06	0.17	8.3	2.47	13.0	45
PI	6.02	31.1	769	3.75	0.72	19.2	6.66	12.3	88
ALB	3.57	13.5	787	3.69	0.21	5.7	3.57	8.4	46
GLOB	4.04	12.9	780				3.58	10.1	46
PROT	7.60	4.5	782	7.00	0.57	8.1	7.16	1.5	92
TL	532	28.1	621				652	29.8	140
SUG	62	36.3	662	53.56	6.88	12.9	48	8.3	92
TURN	0.16	43.8	567						
BCOND	2.67	16.1	899						

1) Collins, S.E., J.F. Hentges and J.C. Gudat, 1978.

2) Avidar, Y., M. Davidson, B. Israeli and E. Bogin, 1981.

Table 7.3 Mean values and standard deviations physiological parameters measured on beef cows grazing Mediterranean herbaceous range.
(Observations classified by physiological state of the cow)

Class	Lactating cows			Dry pregnant cows			Dry empty cows		
Parameter	Mean	SD	No.obs.	Mean	SD	No.obs.	Mean	SD	No.obs.
ALP	115	61.7	185	114	61.4	249	13.4	60.9	74
AST	74	32.4	356	73	26.2	353	89	20.2	74
LDH	2248	379.5	187	2022	446.8	249	2336	454.5	74
UR	40	11.9	357	36	13.6	355	36	15.3	74
CAL	9.6	1.62	335	9.6	1.49	335	9.3	1.26	74
MAG	2.7	0.36	344	2.5	0.36	354	2.3	0.33	74
PI	5.4	1.38	339	6.3	2.05	354	7.3	2.00	74
ALB	3.7	0.52	356	3.6	0.43	357	3.3	0.30	74
GLOB	4.0	0.61	351	4.0	0.45	355	4.3	0.32	74
PROT	7.7	0.36	353	7.6	0.31	355	7.6	0.34	74
TL	576	160.2	296	495	123.0	279	477	148.6	46
SUG	68	17.6	264	58	24.1	327	61	27.3	71
TURN	0.19	0.07	262	0.13	0.05	249	0.15	0.06	56
BCOND	2.69	0.42	412	2.67	0.42	417	2.61	0.47	70

Table 7.4 Mean values and standard deviations of physiological parameters measured on beef cows grazing Mediterranean herbaceous range (Observations classified by pasture condition).

Class	Dry pasture			Early season pasture			Green pasture		
Parameter	Mean	SD	No.obs.	Mean	SD	No.obs.	Mean	SD	No.obs.
ALP	101	57.9	81	105	55.9	159	129	63.6	268
AST	57	27.6	221	71	21.7	217	90	26.6	345
LDH	1906	314.8	81	1956	349.3	159	2338	440.6	270
UR	32	12.6	224	43	14.8	220	38	10.6	342
CAL	9.3	1.30	210	10.1	1.32	191	9.5	1.69	343
MAG	2.3	0.34	213	2.5	0.37	220	2.7	0.31	339
PI	6.9	2.22	211	6.2	1.99	217	5.4	1.18	339
ALB	3.8	0.61	225	3.5	0.45	220	3.5	0.33	342
GLOB	3.8	0.52	220	4.0	0.39	219	4.2	0.53	341
PROT	7.6	0.31	221	7.5	0.30	219	7.7	0.36	342
FAT	507	138.4	215	567	170.5	135	536	143.6	271
SUG	59	21.9	145	55	26.8	214	69	17.2	303
TURN	0.11	0.04	101	0.13	0.05	198	0.20	0.07	268
BCOND	2.71	0.39	251	2.49	0.42	251	2.77	0.42	397

Table 7.5 Mean values and standard deviations of physiological parameters measured on beef cows grazing Mediterranean herbaceous range (Observations classified by year).

Year	1983			1984			1985		
Parameter	Mean	SD	No. obs.	Mean	SD	No. obs.	Mean	SD	No. obs.
ALP	-	-	0	120	60.7	331	112	63.3	177
AST	46	17.6	273	94	20.3	331	86	20.4	179
LDH	-	-	0	2160	432.5	331	2134	462.0	179
UR	37	8.6	279	34	12.9	331	46	15.6	176
CAL	9.4	1.29	236	9.0	1.21	331	10.9	1.55	177
MAG	2.6	0.39	267	2.5	0.36	331	2.7	0.32	174
PI	5.1	1.49	261	6.9	2.07	331	5.7	1.11	175
ALB	4.0	0.47	278	3.4	0.29	332	3.3	0.29	177
GLOB	3.6	0.47	273	4.3	0.33	331	4.1	0.46	176
PROT	7.6	0.29	275	7.7	0.29	331	7.5	0.43	176
TL	526	143.1	267	499	133.4	240	617	165.0	114
SUG	54	16.7	195	61	24.2	326	76	19.1	141
TURN	0.14	0.04	177	0.17	0.07	267	0.17	0.08	123
BCOND	2.51	0.40	348	2.75	0.40	341	2.82	0.43	210

Table 7.6 Marginal significance level (Type III.SS) of factor in multiple regression analysis that influence physiological parameters in beef cows grazing Mediterranean herbaceous range.

Parameter	R ² 1)	F _m 2)	No. obs. 3)	CV (%) 4)	PHYS. STATE		PASTURE COND.		YEAR		TREATM.	
					F ₅	Pr 6)	F ₅	Pr 6)	F ₅	Pr 6)	F ₅	Pr 6)
ALP	0.162	12.0	508	48.6	4.6	.0106	17.4	.0001	3.7	.0563	15.0	.0001
AST	0.638	151.5	783	23.4	1.5	.2259	51.2	.0001	380.2	.0001	4.5	.0039
LDH	0.275	23.8	510	17.7	17.4	.0001	62.2	.0001	0.4	.5343	2.7	.0471
UR	0.220	24.3	786	30.9	7.4	.0007	31.9	.0001	36.0	.0001	4.3	.0052
CAL	0.273	30.6	744	13.7	0.2	.8062	5.4	.0045	105.4	.0001	2.8	.0420
MAG	0.333	42.2	772	12.1	5.7	.0035	103.5	.0001	37.1	.0001	4.3	.0051
PI	0.390	53.8	767	24.4	4.5	.0113	110.6	.0001	129.0	.0001	1.13	.3351
ALB	0.434	66.2	787	10.1	1.8	.1734	1.5	.2339	196.1	.0001	3.9	.0084
GLOB	0.433	65.5	780	9.8	1.5	.2266	16.4	.0001	170.9	.0001	5.6	.0008
PROT	0.157	16.0	782	4.15	2.8	.0644	15.3	.0001	40.6	.0001	2.3	.0801
TL	0.188	15.7	621	25.5	36.5	.0001	2.0	.1420	23.5	.0001	2.2	.0930
SUG	0.231	21.8	662	32.1	3.0	.0494	21.9	.0001	57.4	.0001	2.8	.0378
TURN	0.455	51.7	567	30.9	66.0	.0001	42.8	.0001	44.1	.0001	2.9	.0332
BCOND	0.231	29.6	899	14.0	3.3	.0363	45.9	.0001	61.4	.0001	15.2	.0001

1) Model R²

2) Model F value

3) No. observations that qualify for the analysis

4) Coefficient of variation

5) F value for variable in Type III sum of squares

6) Significance level of the factor (Pr > F)

Table 7.7 Coefficients of significant factors in multiple regression on physiological parameters
beef cows grazing Mediterranean herbaceous range.

Factor	PHYSIOLOG. STATE			SEASON			YEAR		
	Lact.	Pregn.	Empty	Dry	Transit.	Green	1983	1984	1985
Parameter									
ALP	-24.9 (3)	(-8.0)	0.0	-42.2	-33.3	0.0	*2) -35.1	(11.1)	0.0
GOT	-	-	-	-16.9	-16.4	0.0	-	8.9	0.0
LDH	-336	-287	0.0	-481	-444	0.0	*2)	-	-
UR	(2.75)	(-1.22)	0.0	-3.72	5.79	0.0	-6.36	-9.80	0.0
CAL	- 3)	-	-	(0.16)	0.44	0.0	-1.46	-1.88	0.0
MAG	0.13	0.14	0.0	-0.45	-0.29	0.0	(0.05)	-0.18	0.0
PI	-0.42	-0.57	0.0	2.26	0.98	0.0	-1.44	0.79	0.0
ALB	- 3)	-	-	- 3)	-	-	0.67	(0.06)	0.0
GLOB	- 3)	-	-	-0.23	-0.22	0.0	-0.47	0.20	0.0
PROT	- 3)	-	-	-0.19	-0.16	0.0	0.20	0.27	0.0
TL	117.7 (3.13)	(24.6)	0.0	- 3)	-	-	-118.1	-122.6	0.0
SUG	(3.13)	(-2.00)	0.0	(-1.64)	-12.78	0.0	-24.4	-17.4	0.0
TURN	0.050	(-0.011)	0.0	-0.054	-0.034	0.0	-0.050	(-0.003)	0.0
BCOND	0.129	0.128	0.0	0.110	-0.223	0.0	-0.384	-0.098	0.0

() not significantly different from level with zero coefficient. However if the sign is different between two bracketed coefficients, then they are significantly different from each other.

1) Threshold significance level $Pr > F < 0.05$

2) Not determined in 1983

3) Effect not significant

Part 8. GENETIC MARKERS AND PERFORMANCE OF BEEF COWS

8.1 Screening of beef cattle at the growth hormone and prolactin genes

(E.M. Hallerman, Hebrew University of Jerusalem, Dept. of Genetics)

8.1.1 Introduction

Restriction fragment length polymorphism (RFLP) is a relatively new class of genetic marker based upon variability at the DNA sequence level. Although numerous RFLPs have been documented in human and laboratory species such as mouse, relatively little work has been carried out upon cattle. RFLP's in cattle have been discovered at several genes, including growth hormone (Beckmann et al., in press) and prolactin (Camper et al., 1984). Interest in these particular polymorphisms stems from their direct effects upon growth and milk production.

Expression of restriction fragments at the growth hormone (GH) and prolactin (PRL) genes was observed within a sample of the Karei Deshe beef cattle stock. Experimental methods and results of this preliminary screening are summarized in this report.

8.1.2 Methods

Work upon DNA-level markers was carried out at the laboratory of Prof. Morris Soller, Dept. of Genetics, Hebrew University of Jerusalem. Methods utilized are based upon modification of those of Maniatis et al. (1982).

Purification of DNA. DNA was prepared from samples of blood totalling approximately 20 ml. Such samples were centrifuged, and the serum was withdrawn before storage at - 70°C. DNA was prepared from white blood cell nuclei, and steps in its preparation reflect progressive removal of various blood components. Blood cells were ruptured by osmotic shock in hypotonic solution. White blood cell nuclei were ruptured with SDS, a detergent, and nucleic proteins were digested with proteinase K, an enzyme. Proteins were removed from aqueous solution by phenol/chloroform extraction, and the DNA was precipitated in ethanol.

Preparation of southern blots. 10ug samples of bovine DNA were digested completely with excess amounts of restriction enzymes, which recognize and cut DNA at specific sequences. Such digests were electrophoresed in agarose gels, producing a gradient of fragment size. Size-sorted DNA's were transferred and fixed to a solid support, in this case a nylon filter, for subsequent work.

Hybridization. Cloned and sequences used as probes were bovine growth hormone (Avigdor Levanon, Biotechnology General, Nes Ziona, Israel) and bovine prolactin (Fritz Rottman, Case Western Reserve University, Cleveland Ohio). Such sequences were removed from plasmid vectors and ³²P-radiolabelled by nick translation.

Probes were applied to the prepared filters in a hybridization mix and annealed onto corresponding sequences immobilized at certain locations upon the filters. Upon subsequent incubation of the filters with x-ray film, the location of such sequences was visualized as dark bands.

8.1.4 Discussion

8.1.3 Results

Individual genotypes were inferred on the basis of hybridization phenotypes exhibited by the various probes (Table 8.1). Several RFLP's were noted among the animals examined.

Growth hormone. Results at the GH gene indicated a high level of variability. Digestion of DNA by BamHI and BglII enzymes showed two alleles at approximately equal frequencies in the herd. Agreement of phenotypes produced using either of these enzymes supports our earlier conclusion that these polymorphisms are related (Beckman et al., in press), apparently the result of an insertion of a sequence of DNA into the GH gene of animals bearing the faster allele.

Two types of variants were observed among HindIII-digested DNAs. Three individuals showed expression of an 8-kb band allelic to the common 5 kb band. One individual showed evidence of a rare variant at the sequence normally exhibited as a 26.5 kb restriction fragment; its bands at 16.5 and 11.0 kb indicate the presence of an additional Hind III restriction site.

Two individuals showed high molecular weight bands when EcoRI digests were hybridized. All individuals exhibited the same low molecular weight band. This hybridization will be repeated to clarify results regarding the high MW band.

Prolactin. A very low level of variability was observed at the PRL gene. Single individuals DNAs digested with BamHI or EcoRI enzymes exhibited an additional hybridization band, indicating a modification of the DNA

sequence at or near one of their PRL gene homologues. Work at the prolactin gene is not yet completed, and additional polymorphisms may yet be found.

8.1.4 Discussion

a. Practical value of the observed polymorphism. Beyond their interest as genetic polymorphisms per se, the existence of polymorphisms at or near key quantitative genes stems from their possible effect upon the quantitative performance of the animals themselves. Such polymorphisms may be the results of modifications of the structural gene proper or of regulatory sequences upstream of the gene or within introns. The location and nature of regulatory sequences at the particular genes is currently being elucidated (e.g., Moore et al., 1985), but is not thoroughly explored. Although the direct effects of sequence polymorphisms cannot presently be determined, indirect methods for testing for linkage of genetic markers to quantitative genes have been devised (Geldermann et al., 1985). The small sample size in this preliminary sample precludes even tentative assessments of the value of alternative potential markers. Present results to indicate the expression of variability at key genes, which might warrant further examination.

b. Rates of variability in beef and dairy cattle. Comparing results of screenings within beef (this study) and dairy (Beckmann et al., in press) herds, we find that the beef herd is much more variable, in terms of both additional alleles, and of higher frequency of shared variant alleles. This can perhaps be explained in terms of the Karei Deshe stock being derived from the crossing of four breeds, the dairy stock being derived from a Holstein-Friesian cross. We suspect, in addition, that selection practiced upon the dairy herd has changed allele frequencies at

loci directly affecting production. Other studies (Bonczek et al., 1985) showed that levels of GH and PRL are correlated with selection for mild production. Such correlations support the utility of marker-assisted selection in cattle improvement.

8.2 The relationship between RFLP and the quantitative performance of the animals.

8.2.1 Introduction

The use of RFLPs as genetic markers, can help to separate out genetic characteristics from environmental effects in identification of animals with superior performance. We have tried to establish a quantitative relationship between performance criteria as defined in other parts of this project and genetic polymorphisms. The small number of animals studied allow for only a preliminary examination of the relationship between the restriction fragment length polymorphism (RFLP) and performance of the animals.

8.2.2 Performance criteria

Performance is evaluated here by two criteria:

1. The total liveweight of weaned calves (kg) over three consecutive weaning seasons (S-criterion).
2. A scale that reflects the number of conceptions in four consecutive seasons weighted for the daily liveweight increase (DLWI) between birth and weaning (L-criterion). The L criterion is defined in Table 8.2.

Table 8.2. Performance criterion based on cow conception rate and daily liveweight increase of the calf.

L-criterion	No. of conceptions in 4 years	Mean calf DLWI kg d ⁻¹
5	4	≥ 0.8
4	4	< 0.8
3	3	≥ 0.8
2	3	< 0.8
1	≤ 2	-

The RFLP variability at the growth hormone gene obtained from DNA digestion by either Bam HI or Bgl II enzymes is divided into 3 groups: fast(F), slow (S) and heterogeneous (H) alleles (Table 8.1).

8.2.3 Results and Discussion

The relationship between these groups and animal performance criteria is given in Table 8.3.

Table 8.3. Relationship between performance criteria and RFLP's

Allele	No. of animals	Criterion	
		S	L
		(mean $\pm$ S.E)	(mean $\pm$ S.E)
F	2	558 $\pm$ 42	4.5 $\pm$ 0.50
H	6	432 $\pm$ 47	3.8 $\pm$ 0.48
S	8	395 $\pm$ 52	2.5 $\pm$ 0.60
Significance	Pr>F	0.32	0.18

The different alleles appear to be related to both performance criteria, albeit at a low level of significance. Nevertheless the trend would seem to indicate that the fast allele at the growth hormone gene is related to animals with good performance records; the slow allele with those with poor records and the heterogenous alleles fall in between.

The sample of animals is too small to draw hard conclusions, but the relationship between allele type and performance should be investigated carefully in order to determine whether the fast allele is indeed related to beef cows that have higher fecundity and production potential. As the animals were maintained under relatively harsh, extensive range conditions, superior performance indicates not only higher productive potential, but also robustness that allowed the animals to thrive under such conditions. However, the 'robustness' is probably dependent on other factors not

related to the growth hormone. These, and other factors, could easily confound the expression of a genetic characteristic, especially over a period of three years. It is therefore promising that in spite of such confounding factors, a trend emerged that could relate genetic markers to field performance.

Table 8.1. Raw data on hybridization of growth hormone probe with DNA's of Karei Deshe beef cattle¹⁾.

Cow id.	Performance criterion	Probe		Growth hormone			
		Enzyme	Bam HI	Bgl II	Hind III		EcorRI
					Large fragm.	Small fragm.	Large fragm. Small fragm.
	S	L			2)		
18/10	610	5	H	H	26	F	
3/30	500	5	H	H	26	F	
7/30	625	5	S	S	26	F	
26/50	577	5	S	S	26	F	S
20/20	465	3	S	S	16+11	F	
2/40	314	1	S	S	26	H	
5/20	516	4	F	F	26	F	
4/30	443	4	H	H	26	H	H
32/60	282	4	H	H	26	F	
39/60	344	2	H	H	26	H	
14/30	197	3	S	S	26	F	
19/30	285	1	S	S	26	F	
38/50	411	3	H	H	26	F	
7/40	337	2	H	H	26	F	
45/6	355	1	S	S	26	F	
11/2	600	5	F	F	26	F	

1) V-indicates monomorphism; F, S, H-indicate individuals bearing fast and slow electrophoretic alleles and heterozygous for both alleles.

2) Numbers indicate size of fragments (kb).

Part 9. ENERGY TRANSACTIONS IN SUPPLEMENTED BEEF COWS ON RANGE

9.1. THE EFFECTS OF LEVEL OF SUPPLEMENTATION ON
REPRODUCTIVE PERFORMANCE OF RANGE COWS

INTRODUCTION

The object of supplementary feeding is to increase the production of beef from range through increased pregnancy percentage of the breeding herd or through heavier weaning weights or a combination of both.

Nutrition plays a major role in reproductive processes. Dunn (et al. 1969) showed that cows on a higher energy level exhibited estrus sooner after calving than those on a lower energy level (69% vs 44%) and that the pregnancy rate of 2 year old heifers was directly related to the post-calving energy level, (87% vs 72% vs 64%) for heifers on high, moderate and low levels of energy supplementation, respectively. Studies by Wiltbank (et al. 1965) also showed incidence of estrus to be affected by nutritional status.

Supplementation of cows has been shown to affect the calving percentage, weaning percentage, and weaning weights of cows on semi-desert range (Speth, 1962). Similar studies have shown that supplemental feeding of range cows can result in increased weaning weights of calves (Clanton and Zimmerman, 1965 and Thomas, 1982).

Supplementation is more beneficial to younger cows than mature cows and has a greater effect on cow productivity when forage conditions are inadequate, as in drought years, but is of questionable value in adequate forage years (Bellido et al., 1981). In good forage years, a high level of supplementation reduces grazing time, and in so doing, tends to lead to substitution, rather than true supplementary feeding (Bellows and Thomas, 1976).

Climatic conditions, forage quality and age of the cow are just a few factors which can affect the optimum level of supplementation. The object of this experiment is to determine an optimum level of supplementation for the California foothill range area, using biological input-output relationships. Biological response data to be derived include treatment effects on cow weights, calf weaning weight and pregnancy percentage.

9.1.2.

METHODS

Experimental Design One hundred and ninety two pregnant cows were divided into five groups by stratified randomization on an age basis. The five groups were then randomly allocated to one of the following treatments- supplementation during late fall (mid August) to the commencement of the green season (early

March) with either 0, 200, 400, 800, or 1000 kg of alfalfa cubes per cow. (The five levels of supplementation will be referred to as 0, 0.5, 1.0, 1.5, and 2.5 times the basal level of 400 kg/cow/year.) The experiment commenced in June 1979 and terminated June 1985. Cows continuously grazed non-irrigated cleared rangeland which had been seeded to subterranean and rose clovers. (Medicago subterraneum and Trifolium hirtum.) For management and other purposes they were rotated through a series of fenced pastures on the station.

Cows were mated for a 65-70 day period commencing January 3-6 each year, and rectally palpated for pregnancy in third week of May. (Approximately 9 weeks after the bulls were removed.) Cows were run as separate groups only during the period of supplementation, at all other times of the year they grazed common pastures. Culling was on the basis of age or being open for two consecutive years. A few were culled for other physical defects. Approximately equal numbers of cows were culled from each group to maintain the same age structure.

Calves were all weaned within a one week period during the last week of May or first week of June. All calves had free access to a creep feed up until weaning. The creep feed contained ground maize 68%, alfalfa 10%, molasses 10%, cottonseed meal 5%, soybean meal 5%, dicalcium phosphate 1%, trace minerals 0.5%, urea 0.5%.

Cows were weighed at the start of the supplementation period, calving, the beginning of the breeding season, the start of the green season, and at weaning of the calves. Calves were

weighed at birth and at weaning.

9.1.3.

RESULTS

The six year mean age structure of the cows in the five treatment groups is shown in table 91, which indicates all groups had an equivalent age structure.

Body Weight of Cows. Table 92 presents the body weight of the cows at calving, the start of the green season, at weaning of the calves, and at the start of supplementation in the fall. At calving, and at the end of supplementation (beginning of the green season) and at weaning, the mean body weights of the groups of cows was directly related to the quantity of supplement fed. ($r^2 = 0.96, 0.96, \text{ and } 0.89$) In contrast, mean body weight gain of the cows from calving to weaning of the calves was inversely related ($r^2 = 0.89$) to the previous level of supplementation. The gain in the weight of cows from the start of the green season to weaning of the calves was also inversely related to level of supplementation. That is, those cows receiving the least supplement and having the lowest body weight at the commencement of the green season made compensatory gains compared to the heavier cows which had been supplemented. Thus part of the body weight response of the cows to supplementation was lost by the time the calves were weaned.

A further important change in body weight occurred following weaning of the calves. Body weight of cows at weaning of the calves remained positively related to level of supplementation the previous fall and winter ($r^2 = 0.89$). However, at the commencement of supplementation the next year, the differences in group mean body weight had virtually

disappeared due to the greater loss of weight by the heavier (previously higher supplemented) cows over the dry summer. These changes illustrate the ability of breeding cows to regain losses of body weight provided they have a period of good nutrition in their annual food cycle.

Reproductive Performance The mean 6 year percentage of cows diagnosed pregnant according to level of supplementation, age of cow and body weight is shown in Table 9.3. Supplementation had only a small effect on pregnancy rate. The linear regression of percentage of cows pregnant (y) on yearly intake of alfalfa cube (x, kg) was: $Y = 83.5 + 0.0041x$ ($r^2 = 0.352$). These were significant between year effects ($P < 0.01$) on percentage of cows pregnant which were related to the feed year. In one year (1980), the percentage of cows pregnant in all groups was markedly depressed due to a high incidence of enzootic bovine abortion.

When cows were classified according to age and percentage of pregnancies (Table 9.4) higher pregnancy percentages occurred in the aged cows and the other categories.

Post-calving body weights of the cows were positively related to pregnancy rate, (Table 9.5). Numbers of cows in the extreme classes (less than 336 kg and greater than 553 kg) were low and these percentages are not limited significance. Nevertheless the differences between the class 336-408 kg and 409-480 kg and 481-553 kg were 6.8% and 3.1% respectively.

Calves Birth weight of the calves showed a small but highly significant effect due to level of supplementation of the cow,

(Table 6). The regression of calf birth weight (y) on supplement intake was $y \text{ (kg)} = 30.5 + 0.0027x \text{ (kg of supplement)}$ $r^2 = 0.99$.

Weaning weight of the calves was significantly ($P < 0.0001$) effected by level of supplementation and cow age. Weaning weight corrected for age of weaning and sex of calves and is presented in Table 7. The linear regression of corrected weaning weight (Y,kg) on quantity of supplement consumed (X) by the cows was: $Y = 174.9 + 0.0292x$, $r^2 = 0.97$. Correction for age and weaning and sex made only minor differences to the six year grand means for treatments.

Because the relationship between calf weaning weight and quantity of alfalfa supplement consumed by the cows was linear , the economic response to supplementation will be the same over the entire range from 0 to 1000 kg alfalfa cubes/cow/year. Over this range of supplementation the value of the calves has to be greater than the recipricol of the slope of the above regression equation (0.0292), i.e. 34 times that of alfalfa, for the practice to be of economic value

9.1.4.

DISCUSSION

The results of this experiment were not anticipated, and their consequences run counter to some of the management practices advocated in California.

The mean pregnancy rate for the six years was not significantly affected by level of supplementation. This contrasts with the findings of Wagnon, Guilbert, & Hart (1942) who reported a mean increase of about 14% in calf crop due to supplementation at the San Joaquin Range Station in Southern

California. The reasons for the lack of agreement in the results from the two locations are not easily identified. In both experiments cows calved in the fall, and stocking pressures were moderate. Possibly the contribution of the clovers, and hence protein, may have been greater to the cow's diet at our location than at the San Joaquin Range Station. This could explain the marked response obtained mainly to a protein (cottonseed meal) supplement at the San Joaquin site. If this is the true explanation, then the contribution of clovers to reproduction in cattle in California has largely been unrecognized.

Weaning weight of the calves was increased rectilinearly with level of supplementation. But, the conversion rate of 32 units of supplement per unit of extra weaning weight would not be viable under current economic conditions. It was anticipated at the onset of the experiment that the response of weaning weight to supplementation would constitute a diminishing returns relationship. The reason for the linear response in calf weaning weights to increments of supplement, appears to be related to the effect of the supplement on milk production of the cow. Differences in weaning weight between groups were established before the commencement of the green season, when the gain of the calves would have been a function of the milk production of the cows. As the quality of forage available to the cow is lowest early in lactation (see section B of this report), a linear response in milk production to supplementation would be possible and be consistent with the observed effect on the calves.

Table 9.1. Mean Percentage of cows in each age group over the 6 years of the experiment

Treatment	Age class			
	Heifers	Three	Four	Aged
0	18.3	24.3	19.3	38.1
0.5	17.8	23.6	19.1	39.6
1.0	17.7	23.7	19.1	39.5
1.5	19.8	23.8	21.1	35.2
2.5	19.4	24.5	21.3	34.7
Mean	18.6	24.0	20.0	37.4

*Supplementation level, multiples of 400 kg/cow/year

Table 9.2. Mean body weights of the cows over the 6 years
of observation

		Mean (sem) body weight (kg)									
Time of Observ.		Treatment Group									
		0		0.5		1.0		1.5		2.5	
Calving	¹	ace		bdf		efg		cd		abg	
		388	(3.5)	404	(3.3)	421	(3.9)	425	(3.6)	444	(3.9)
Green	²	ace		bdf		efg		cdg		ab	
		367	(3.5)	370	(3.5)	390	(3.6)	404	(3.8)	420	(3.8)
Weaning	³	ad		bc		m		cd		abm	
		439	(3.9)	439	(4.1)	450	(4.3)	454	(4.1)	458	(3.9)
Supplem		n		m						mn	
		413	(3.5)	412	(3.7)	416	(3.7)	415	(3.5)	423	(3.4)

Changes in body weight C=calving, G=start of green season,
W=weaning

C.to W.	⁴	51	35	29	29	15
G.to W.	⁵	72	68	60	50	38
W.to S.	⁶	-26	-27	-34	-38	-36

Means with a common superscript are significantly different

$P < 0.01 = a, b, c, d, e, f, g$

$P < 0.05 = m, n$

Linear regression equations of body weight or body weight
change Y(kg) on intake of alfalfa X (kg)

$$1. Y = 392.5 + 0.0543x \quad r^2 = 0.96$$

$$2. Y = 365.0 + 0.0574x \quad r^2 = 0.96$$

$$3. Y = 438.6 + 0.0213x \quad r^2 = 0.89$$

$$4. Y = 45.9 - 0.0320x \quad r^2 = 0.89$$

$$5. Y = 73.3 - 0.0357x \quad r^2 = 0.99$$

$$6. Y = -27.0 - 0.0118x \quad r^2 = 0.70$$

Table 9.3. Mean percentage of cows pregnant according to treatments (levels of supplementation) and years and total numbers of observations per treatment

Year	Treatments					Mean	P+
	0	0.5	1.0	1.5	2.5		
1979	93.7	96.8	90.3	88.2	80.6	89.9	0.27
1980*	57.6	45.2	75.0	84.8	60.0	64.8	0.009
1981	93.5	93.9	86.7	84.4	96.6	91.0	0.40
1982	97.0	91.4	90.6	90.9	93.5	92.7	0.85
1983	76.9	81.4	70.0	85.4	94.9	81.7	0.06
1984	94.7	82.5	91.9	95.2	94.6	91.8	0.20
mean	85.4	82.2	83.2	88.4	87.3	85.3	
n	200	213	197	215	197	1028	

* Low pregnancy rate due to high incidence of enzootic bovine abortion

+ Pearson's chi-square probability

Table 9.4. Mean percentage of cows pregnant by age class and years and total numbers of observations per age class

Year	Age class				Mean
	Heifer	Three	Four	Aged	
1979	81.2	97.8	100.0	86.0	89.9
1980*	66.7	55.9	59.2	93.3	64.6
1981	89.3	90.6	84.8	100.0	90.9
1982	87.5	92.9	93.0	95.7	92.6
1983	78.9	75.0	82.8	85.6	82.0
1984	100.0	77.1	96.9	92.3	91.7
mean	80.7	83.1	83.4	90.4	85.4
n	197	242	211	376	1026

* Low pregnancy rate due to high incidence of enzootic bovine abortion

Table 9.5. Mean percentage of cows pregnant according to post calving body weight and years and total number of cow years (n) per weight class.

Year	Post calving body weight					Mean
	<336	336-408	409-480	481-553	>553	
1979	100.0	81.2	93.6	91.7	100.0	89.9
1980*	31.2	66.7	67.9	63.6	100.0	63.6
1981	71.4	87.3	96.3	100.0	-	89.4
1982	85.7	91.9	91.5	95.7	100.0	92.2
1983	60.0	76.2	90.5	96.3	100.0	84.9
1984	80.0	91.9	92.5	100.0	-	92.3
mean	64.9	82.2	89.0	92.1	100.0	85.2
n	57	359	381	101	7	905

* Low percentage due to high incidence of enzootic bovine abortion.

Table 9.6. Birth weight of calves (kg) according to level of supplementation of cows.

		Treatments					
		0	0.5	1.0	1.5	2.5	Mean
		adf	be	cf	de	abc	
Weight		30.5	31.0	31.5	32.2	33.1	31.7
Number		182	187	179	196	192	936

Means with common superscript are significantly different,

$P < 0.01 = a, b, c, d, e, f.$

Table 9.7. Corrected weaning weights of the calves according to treatments and years.

Year	Treatments					Mean
	0	0.5	1.0	1.5	2.5	
1979	194	207	205	227	217	210
1980	135	146	161	175	181	159
1981	191	181	193	185	209	192
1982	175	186	186	196	198	188
1983	158	179	174	191	199	181
1984	194	191	195	207	211	200
Mean	173	183	185	198	203	189 [*]
Number	165	179	165	185	178	872

SEM = 1.1

9.2. ENERGY INTAKE AND EXPENDITURE OF RANGE COWS RECEIVING SUPPLEMENTS WHILE GRAZING ANNUAL RANGE

Few measurements have been reported of energy expenditure of grazing cattle and most of these have been over short time periods (Young et al. 1969, Havstad and Malechek 1982). In this phase of the study, simultaneous measurements were made of food intake and energy expenditure of grazing cows over a complete yearly cycle. For part of the year cows received one of three levels of supplementation : 0, 2, or 4kg of alfalfa cubes /cow / day.

9.2.1. Methods

Animals : Eighteen pregnant Hereford or Hereford x Angus cows varying in age from 2 to 7 years were selected from the Station herd . In the summer prior to the initiation of the study, a blind rumen fistula was established on all cows by adhesion of the rumen wall to the skin (Olsen, 1979). This preparation allowed infusion into the rumen of the marker to measure feed intake without the problems associated with the maintenance of a permanent fistula. For the first part of the study (April to June

1983) measurements were made on 12 lactating (4th to 7th month) and pregnant cows, for the second part (October 1983 to March 1984) repeat measurements were made on six cows. Calves were weaned in early June (at the same time as the general herd) and the cows calved in the second year of the study in late October and November 1984.

Measurement of energy expenditure : The carbon dioxide entry rate technique was used to measure carbon dioxide production rate and from this measurement the heat production. A continuous infusion of NaH^{14}CO was used to label the body pool of bicarbonate (Young et al. 1969) and a continuous sample of saliva was withdrawn from the parotid salivary duct to monitor the specific radioactivity of the body bicarbonate pool. The technique used for cannulation has been described in detail by Sanchez (1984).

Serious problems with the CO_2 entry rate technique as originally described by Young et al. (1969) were encountered. These problems were associated with cross contamination of $^{14}\text{CO}_2$ between the infusion and sampling pumps and plastic infusion tubes. Contamination was overcome by using two peristaltic pumps, (a "hot" pump to infuse the label and a "cold" pump to aspirate the salivary sample), and keeping the infusion and sampling tubes separated. Heat production (energy expenditure) was calculated from CO_2 production by the equation of Engels et al. (1976). Excellent agreement was found between measurements on consecutive days on the same animal for details see Sanchez and Morris (1984).

Measurement of feed intake. Feed intake was measured indirectly from fecal output and in vitro digestibility of the forage. Fecal output was measured by continuous infusion of inert rare earth markers. Two markers were used, samarium (Sm) and ytterbium (Yb) as their chlorides. As samarium proved to be more difficult to analyze than ytterbium, it was the only marker used for the measurements after the April and May 1983. The markers in solution (1.39 mg of Yb/ml or 2.78 mg of Sm/ml) were infused directly into the rumen at a rate of 180 ml/day. Primer doses of 10mg Yb or 20mg Sm / 100kg body weight were infused into the rumen at the start of the 7 day infusion period prior to collection of fecal samples. The above technique was based on results of equilibration measurements made on stall fed steers given known amounts of alfalfa cubes. Mean recovery of ytterbium over the last 2 days of the infusion in four steers was 97.8% with a c.v. of 3.5%.

Feed intake was computed from fecal output and in vitro indigestibility. Samples for in vitro digestibility were collected by esophageal fistulated steers which grazed with the cows on which fecal outputs were measured. As samples collected by esophageal fistulae may have varying degrees of soil contamination, organic matter intake and organic matter indigestibility were used to compute feed intake.

Analysis of Ytterbium

Yb was measured by graphite furnace atomic absorption spectrometry. One gram duplicate samples of feces were ashed in porcelain crucibles at 600 degrees celsius for 9-12 hours to oxidize organic matter. The resulting ash was transferred to a

polyethylene beaker and 2 ml conc. nitric acid was added to decompose carbonates and oxidize residual organic matter. After reduction of the volume on a steam bath to a moist residue one ml of hydrofluoric acid was added and the silica was volatilized as SiF_4 by further heating on a steam bath to dryness. To the residue, 5 ml 1M nitric acid was added and the sample reduced to dryness to remove the HF. The dry residue was transferred with 25 ml water to a 50 ml graduated glass digestion tube. 1 ml of conc. nitric acid was added to dissolve the salts.

For the analysis of Yb, the volume of the digestion tube was made up to 50 ml and from this a 1 ml aliquot was transferred to a 100 ml volumetric flask. To this 20 mg lanthanum nitrate in solution was added the pH was adjusted to 3.9 using bromophenol blue indicator and made up to volume. Ten microliter samples of this final solution were injected in the furnace.

9.2.2.

RESULTS

Figure 9.1 shows the mean body weights of the cows at intervals throughout the year. Maximum full body weight occurred at June at weaning of the calves. This body weight was virtually maintained over the summer, but as the dam's body weight included the products of conception, cows were actually losing body mass. Minimal body weight was recorded after calving. These body weight changes were similar to those reported for the main herd. Figure 9.2 shows the in vitro digestibility of organic matter in the esophageal samples and Table 8 the fecal organic matter output. The results of these two sets of measurements allow

calculation of digestible organic matter (DOM) intake which is also shown in Table 18. Forage and fecal nitrogen were closely correlated as shown in Figure 13.

Table 19 shows the individual measurements of energy expenditure on the unsupplemented grazing cows which varied more than two fold over the year on a daily per animal or per kg body weight basis. The highest heat productions occurred in the spring and early summer measurements of both years which resulted in the U-shaped nature of the energy expenditure plot, (Figure 14). Heat production therefore was directly related to intake of DOM. (Figure 15).

These results show that the cows reduced their energy expenditures during periods of feed shortage while in times of feed abundance energy expenditure greatly increased. The ability of cows to modify heat production, as observed in this study, must play significant role in their survival and maintenance of reproductive capacity.

The energy expenditure of cows receiving the three levels of supplementation are shown in Figure 6 shows that at the October, November-December and January measurements energy expenditure followed level of supplementation. Thus part of the additional energy provided by the supplement went to higher heat production and consequently was wasted.

Supplementation reduced the intake of range forage by the cows. Figure 17 shows the intake of digestible organic matter as contributed by range forage and by the supplement at four different times during the period of supplementation. It is

apparent that the supplement did not act as a true supplement to range forage but partially replaced range forage in the diet.

9.2.3.

DISCUSSION

This study has shown that with appropriate precautions, the carbon dioxide entry rate technique can give highly repeatable values for heat production (energy expenditure) of free-grazing cows on range. Though the values are not presented here, the technique also gave measurements of CO_2 production which closely agreed with those obtained from measurement of gas exchange in an open-circuit respiration apparatus.

At the beginning of the study (April 1983) the highest heat productions were measured: 112 ± 6.6 MJ/d which on a body weight basis equalled 243 ± 5.0 kJ/kg/d. These measurements coincided with the highest quality of the forage (DOM of 79.8%), and highest intake of DOM recorded, 2.48 kg DOM/100kg BW/day. At this time, the cows were gaining 0.7 kg body weight/day and possibly producing the most milk as the calves were gaining at the maximal recorded rate of 1.2 kg/day. The lowest heat productions measured were in the October, November-December and January samplings when values of 49.8 ± 3.1 , 49.2 ± 4.3 and 49.1 ± 7.7 MJ/d were recorded which are less than half the values of April 1983 or February 1984. Feed quality from October to January was low, and although fecal output progressively increased over this period, (presumably due to the stimulus of lactation) see Table 1, intake of DOM showed only a small change.

The greater DOM intake of cows receiving the two levels of supplement than those not supplemented provides a

explanation for the small but positive, production response to supplementation recorded in the overall experiment. The first factor which had a major dampening effect on a production response was the substitution of supplement for range forage. Cows that were given the supplements either spent less time grazing or were more selective in their grazing, with the net effect that they consumed less forage. The second factor which dampened the response to supplementation was the higher energy expenditure of supplemented cows than those not supplemented.

Table 9.8. Organic Matter (OM), fecal output, and feed intake of beef

cows grazing annual rangeland.						
Per* 1	2	3	4	5	6	7
Cows 7	7	6	5	6	6	6
Fecal Output (kg OM /100kg BW/d)						
0.76+0.07	0.73+0.14	0.63+0.11	0.65+0.07	0.99+0.16	1.17+0.11	0.88+0.05
Feed Intake(kg OM/ 100 kg BW/d)						
3.13+0.29	1.97+0.36	1.63+0.03	1.64+0.18	1.93+0.32	2.42+0.22	
Feed Intake(kg DOM/ 100 kg BW/d)						
2.37+0.23	1.22+0.22	1.00+0.18	0.98+0.11	0.94+0.16	1.24+0.11	1.89+0.11

Periods*

- 1.- April 27 to May 5, 1983
- 2.- May 1 to June 2, 1983
- 3.- June 20 to 30, 1983
- 4.- October 3 to 16, 1983
- 5.- November 23 to December 7, 1983
- 6.- January 12 to 26, 1984

Table 9.9. Carbon Dioxide Entry Rate and Energy Expenditure of Beef

cows grazing annual rangeland								
Periods*	1	2	3	4	5	6	7	8
Cows	3	8	9	10	5	6	6	6
Obser.	5	15	15	17	9	11	12	12

Carbon Dioxide Entry Rate (l/day)

6432+379 5060+746 4574+536 3389+451 2886+178 2856+250 2851+446 5757+331

Energy Expenditure

(MJ/d)

112+6.6 87.9+13.0 79.4+9.3 58.6+7.8 49.8+3.1 49.2+4.3 49.1+7.7 100.2+5.8

(kJ/kg BW/d)

243+5.0 117+24.6 160+14.7 118+22.0 101+7.6 129+7.4 131+15.5 255+29.4

Periods*

- 1.- April 7 to 8, 1983
- 2.- April 27 to May 5, 1983
- 3.- May 24 to June 1, 1983
- 4.- June 22 to 29, 1983
- 5.- October 5 to 16, 1983
- 6.- November 25 to December 7, 1983
- 7.- January 14 to 23, 1984
- 8.- February 24 to March 3, 1984

Figure 9.1. Full body weight of the cows throughout the year.

Figure 9.2. In vitro organic matter digestibility of esophageal fistula samples from April 1983 to March 1984.

Figure 9.3. Kjeldahl nitrogen percentage in the organic matter of feces from beef cows and of the esophageal forage samples.

Figure 9.4. Energy expenditure in kJ per kg of body weight per day of beef cows grazing annual rangeland calculated from the carbon dioxide entry rate. Values from April 7 1983 (day 1) to March 3 1984 (day 332). The relation is described by the equation: $\text{Energy expenditure} = 229 - 1.77 T + 0.00543 T^2$ (kJ/kg BW/d) where T is the time in days from day 1. $r^2 = 0.74$

Figure 9.5. Digestible organic matter intake (Kg per 100 Kg body weight per day) of beef cows grazing annual rangeland from April 1983 to March 1984.

Figure 9.7A Digestible organic matter intake (kg/d) of cows receiving 0 (1), 2 (2) or 4 (3) kg of alfalfa cubes per day. Pasture intake ($\square$), alfalfa intake ($\hatched$).

Figure 9.7B Digestible organic matter intake in kg/100kg BW/d of cows receiving 0 (1), 2 (2) or 4 (3) kg of alfalfa cubes per day. Pasture intake ($\square$), alfalfa intake ($\hatched$).

Figure 9.6A Energy expenditure of cows receiving 0 (1), 2 (2) or 4 (3) kg of alfalfa cubes per day.

Figure 9.6B Energy expenditure (kJ/kg BW/d) of cows receiving 0 (1), 2 (2) or 4 (3) kg of alfalfa cubes per day.

Part 10. GENERAL CONCLUSIONS

10.1. Primary conclusions

The following conclusions pertain to the central theme of the project which is to identify behavioural and physiological characteristics of cows that exhibit superior performance under stress imposed by seasonal fluctuations in forage quality and availability.

1. Characterisation of a superior beef cow from indirect behavioural or physiological parameters can only give a partial indication of potential performance. Nevertheless, certain characteristics do appear to be related to performance at least on a probabilistic if not on a strictly deterministic level. Some of these characteristics are highly significant and could be useful as supporting or corroborating evidence for selection or for determining feed management strategy.
2. Cows with superior performance records tend to be better grazers, as indicated by the fact that under equivalent conditions of pasture availability they spent up to 20% more time grazing than animals with poorer performance records.
3. Dry cows during the dry season can be characterized for superior performance from certain blood profile parameters. In particular LDH (lactic dehydrogenase) and serum Mg were highly significantly related to superior performance. Superior cows tended to have low LDH levels, low glucose and higher Mg levels in the blood. Mg is significantly related to performance especially when conception rate is part of the performance criterion.
4. Cows that conceive within 60 days after parturition tend to raise faster growing calves than cows that conceive later.

Superior cows thus appear to be able to maintain high fertility levels even while they maintain relatively high lactation ability.

5. Superior animals appear to have recognizable and measurable genetic characteristics as reflected by restriction fragment polymorphism at the growth hormone gene. However, the sample tested was too small to be conclusive.
6. Nutritional stress per se turned out to be extremely difficult to characterise mainly because of complex interactions between supplementation, pasture quality and availability and the feed selected. These interactions masked effects of different supplementation levels even at similar stocking rates, as evidenced in the USA component of the project. In addition, cows appear to adapt their energy expenditure to feed availability (see Part 9), a characteristic that could possibly explain the low glucose levels in superior cows during the dry season. Consequently, the performance of the animals in the high stress treatment turned out to be better than that of the animals in the medium stress treatment where, under similar stocking rates, the animals were given supplements with higher energy concentrations. It may have been possible to characterise nutritional stress more clearly had the difference in feed quality between treatments been greater.

As it was not possible to measure intake of pasture and supplementary feed of the individual animals in the herd with sufficient precision, we have only their performance as an indirect indicator of their nutritional status. If this assumption is valid, then nutritional stress was greater in inferior animals. The parameter that identified inferior animals can then also be regarded as indicator of nutritional stress. Thus, high LDH and blood glucose levels together with low Mg in non lactating cows in the dry season, would indicate that the animals were probably

suffering from nutritional stress. Even though some evidence to support this statement can be found in the results of the project, this is only a tentative conclusion and requires further study.

7. Potential beneficial effects of supplementation with high quality supplements (alfalfa cubes) on performance were dampened , mainly because of significant substitution of pasture intake by supplementary feed.

10.2. Secondary conclusions

These conclusions pertain to aspects of the project not directly related to the central theme of the proposal.

1. Heavy stocking density adversely affects animal performance. Supplementation with low energy feed cannot eliminate the negative effects of high stocking density on animal performance. In order to maintain cow fertility and calf liveweight gain, energy concentration of supplementary feed in the transitional period should be above 1.85 Mcal/kg ME.
2. At relatively high stocking rates, animals can adapt and attain satisfactory performance over a few years, especially when given supplementary feed of moderate quality during the autumn transitional period.
3. Weaning weights are more stable than calving rates and appear to reflect more closely current pasture conditions.
4. Low quality supplementary feed during the autumn transitional period could not maintain milk production at high stocking rate

but did contribute to maintaining cow fertility. In this regard, complex interactions between pasture characteristics and grazing behaviour can mask effects of supplementation per se.

5. Energy expenditure of cows in a small deferment paddock (0.2 ha/cow) is apparently similar to that under continuous grazing where 1.5 - 2.0 ha/cow are available, as foraging time during the day is similar in both cases.
6. Many blood profile parameters fluctuate widely as a result of changing pasture conditions, supplementation regime and physiological state of the animal. Consequently it is particularly important that the blood profiles of individual beef cows be evaluated in relation to the means for a peer group maintained under equivalent conditions.
7. Despite the advantages of the tritium dilution technique in determining intake, it is almost impossible to attain precision with a standard deviation better than 20%. Consequently the intake values for individual animals are not sufficiently reliable to serve as a basis for identifying cows with superior foraging ability. Nevertheless, on a herd level, water turnover was sometimes significantly and positively related to cow performance.
8. Carotene levels in the blood are highest during the early green transitional period when pasture availability is low but apparently very rich in carotene. It is suggested that blood carotene could be used as an indicator of the amount of young green vegetation ingested at the beginning of the new growing season and indirectly of the availability of very sparse green feed.
9. Performance of cows improved as age increased above three years in both USA and Israeli components of the project.

10. In measuring energy expenditure in cows according to Young et al. (1969), it was found that cross contamination of $^{14}\text{CO}_2$ occurred between infusion and sampling pumps and plastic infusion tubes. The technique was improved by using separate pumps and by separating the sampling and infusion tubes.

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DESCRIPTION OF COOPERATION

The Israeli component of the project was concerned mainly with identifying physiological and behavioural characteristics of cows with superior performance in nutritionally stressful environments, while the USA component was more concerned with the energy relations of cows subjected to such conditions under different supplementation regimes.

Cooperation between the Israeli and USA collaborators was concentrated in the planning and summary phases of the experiment. Visits of Israeli participants (Dr Zvi Holzer and Mr Roger Benjamin) to the USA experiment site together with the USA collaborator (Prof J.G. Morris) enabled the participants to become acquainted with the experimental conditions and methods. The USA collaborator visited Israel at the end of the project and participated in the analysis of the results. Some of the results of both components of the project are complementary and strengthen the validity of some of the major conclusions.

MAIN ACHIEVEMENTS OF THE RESEARCH

1. The values of a range of behavioural and physiological parameters of beef cows grazing seasonal Mediterranean range were established for a herd that included animals with different performance achievements. It was found that despite the high degree of variation between animals, it was possible to correlate certain physiological and behavioural characteristics with performance. In particular, lactic dehydrogenase, glucose and magnesium levels in the blood, as well as time spent grazing, forage intake and age of the animals were significantly related to performance.
2. It was found that under high stocking rates, interactions between the pasture quality and availability and intake of forage and supplements are complex, so that simplistic conclusions on effects of imposed treatments are liable to be misleading. In general, stocking density has a dominating effect on performance that is difficult to eliminate with low energy supplements. On the other hand, high quality supplements tend to replace pasture intake and the overall benefit can be dampened to such an extent that the need for supplementation in such cases becomes questionable.
3. The extensive blood sampling and analysis under a wide range of physiological and pasture conditions has provided a strong data base from which standard values for a series of blood parameters can be derived. These can serve as a basis for diagnosis of pathological conditions by providing a reliable range of values for what is to all intents and purposes, a healthy beef herd maintained under extensive range conditions.

4. The results of this project have indicated the degree of complexity that is encountered in a beef herd on range, even when objectives are relatively modest. The experience of the present project can provide a more reliable basis for defining future research objectives relevant to beef cow performance on range.
5. The cooperation between the Israeli and USA scientists created strong professional (and personal) links that will certainly be maintained in the future.

List of publications

1. Sanchez, M.D. and J.G. Morris (1984) Energy expenditure of beef cattle grazing annual grassland. Canadian Journal of Animal Science. 64(Suppl.):332-334.
2. Selanikove, N., Holzer, Z., Cohen, D., Benjamin, R. Gutman, M. and Meltzer, R. (1986). Interrelationship between metabolism of tritiated water, Na²² and dry matter intake by beef cattle consuming wheat straw and poultry litter. Comp. Bioch. and Phys. Sect.A. (Submitted).
3. Hallerman, E.M., Nave, A., Kashi, J., Holzer, Z., Soller, M. and Beckman, J. (1986). Restriction fragment length polymorphisms in dairy and beef cattle at the growth hormone and prolactin loci. Animal Genetics (Submitted).

In preparation

- Comparisons of methods for determining intake in free grazing beef cows (A note).
- Performance of beef cows on Mediterranean grassland supplemented with low energy feeds.
- Milk production of beef cows grazing Mediterranean grassland.
- Behaviour patterns of beef cows grazing Mediterranean grassland in winter and in summer.
- Pasture intake and body composition of beef cows on Mediterranean grassland.

- The effect of feed supplementation treatments on volatile fatty acid and ammonia levels in the rumen of beef cows grazing seasonal Mediterranean range.

- Factors that influence conception of beef cows under nutritionally harsh conditions.

- Metabolic characteristics of the productive beef cow under environmental and nutritional stress.

- Effect of physiological state of the cow and pasture conditions on the relationship between physiological parameters and performance of the beef cow.

- Blood profile and other physiological parameters in a beef herd grazing seasonal Mediterranean range.