CHAPTER I

INTRODUCTION

'All that Mr. Wright, the rubber estate manager ever knew of the business was that an army patrol had ambushed a band of terrorists within a mile of his bungalow, that five months later his Indian clerk, Girija Krishnan, had reported the theft of three tarpaulins from the curing sheds, and that three years after that someone had removed the wheels from an old scooter belonging to one of his children. As it never occurred to him to look for a possible connection between the three incidents, he remained unaware even of that knowledge.'

Eric Ambler (1955) Passage of Arms
(Heinemann : London)

1. Paradox in the distribution of food

The last few decades have witnessed remarkable progress in our knowledge of animal production, motivated by the dire need to supply food for the ever-increasing demands of the worlds human population. It has indeed become a matter of etiquette at all conferences or symposia on animal production to refer to the horrifying statistics of the human population explosion and the role of the animal scientist and all those concerned in food production in the combat of an ominous world food shortage, starvation and famine.

Paradoxically though, and for obvious reasons amongst which health hazards and preoccupation with appearance play prominent roles, another campaign, namely that against over-eating and obesity, is beginning to receive ever increasing prominence.

The incidence of overweight has increased among the affluent society of civilized countries to such an extent that according to the Financial Times (1968)*

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* Financial Times, 13 April 1968, p.12.

almost half the population of the United Kingdom is now carrying excess weight. J.H. Leatham (1961) states that it is something of a paradox in our culture that so much time and effort have been devoted to investigations of the effect of deficiencies and undernutrition rather than to the affects of excesses and overnutrition. He provides evidence that supports the view that the aggregate of the latter are fully as deleterious as the former but the means by which this result is achieved, are largely unknown.

An editorial in the Journal of the American Medical Association (1970)* under the title 'Obesity – a continuing enigma' stated that the condition was a major public health problem in the U.S.A. The Medical Journal of Australia (1969)** in an article 'Obesity – our national problem', described how the condition was due to a high food intake and low activity. Both publications refer to treatment as frustrating and depressing.

Sedgwick (1971) concludes that obesity is the largest single medical problem in the affluent countries of the Western world. He states that the rate of increase in mortality in man is proportional to the degree of overweight and that a man who is 20 per cent overweight, has a 25 per cent greater chance of an early death. Cardiac disease, circulatory disorders and diabetes are more common among the overweight than among the lean. He further provides evidence that cancer, pneumonia, influenza and diseases of the digestive system are also increased among the obese and that because of slowness of movement, the overweight are more prone to accidents. Reduction of weight virtually eliminates the excess mortality.

The importance attached to obesity in life insurance is enlightening. An extra mortality rating based on statistics and experience over many lifetimes, is allotted to overweight persons. According to the actuary of the S.A. Old Mutual, Cape Town (personal communication), a person who is 50 per cent over the mean weight for his height for instance, would be assessed as having an extra mortality rating of 75 per cent above the normal rating.

Netter (1965) also quotes statistics collected by life insurance companies and states that for persons that are 25 per cent or more overweight, the death

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* Editorial, 1970. J. Am. Med. Ass. 211, 492.
** Leading Article, 1969. Med. J. Austr. 1, 919.

rate is approximately 1,7 times above the average and in those who are 40 per cent overweight, the death rate increases to 2,2 times above the average.

In man obesity is referred to by Sedgwick *op. cit.* as a serious disease entity and a complex disorder in which the central nervous system, psychological facts and the metabolic organization of the body are involved.

Control of body weight in man is one of the most delicate of homeostatic mechanisms (Wright, 1962) and although some cases of obesity arise through psychological peculiarities others represent cases where the control mechanism for output/intake is 'set too low'. He also refers to the bad prognosis afforded to life and health by obesity and the need for further studies on the control of appetite in man.

In livestock, a similar and no less paradoxical situation prevails which is identical with the health hazards in man of underfeeding and starvation of certain sections of society and obesity in others.

The all important role of underfeeding as a limiting factor in animal production needs no accentuation. It is of such vast amplitude that producers, research workers and extension services naturally direct their efforts towards feed production and the elevation of nutritional levels in livestock, the upper limit of which is essentially determined by economic considerations rather than the physiological limits of the animal concerned.

This was a natural consequence based on man's experience over many centuries of livestock production in the face of adverse environmental and nutritional conditions. The fat animal being synonymous with progress and wealth, has become romantically, albeit, empirically, linked with quality and production.

1.1 The physiological regulation of food intake

Production depends on food intake and conversion. Above a certain level of food intake the efficiency of conversion of food to product declines, and the surplus or excess of energy is deposited as fat.

During growth, with fattening of adult stock and with cows with a high potential for production of milk, increase performance obtained by high food intake

is usually associated with an increase in the overall efficiency of the production process. Blaxter (1962) explains this by the fact that the non-productive moiety of food intake – that is the maintenance requirement – is spread over a larger amount of product.

The generalization in the broad sense is that animals adjust food intake according to energy expenditure. Exercise, manual work, pregnancy, lactation, etc. is associated with energy expenditure and increased appetite in man. According to Blaxter (1962), regulation of a comparable type occur in cattle and sheep, but not of the same relative magnitude as in man. He argues that dairy cows have appetites that exceed those of dry cows or steers; that sheep exercised on a tread mill eat more than when they are not exercised, but that the evidence of a regulation of food intake in proportion to energy expenditure, makes it difficult to understand the ease with which ruminants fatten. Old steers for instance, when given unlimited access to food, increase weight to well over 1 000 kg, most of the gain being fat, a clear indication that calorie intake is not adjusted to energy expenditure.

Blaxter (1962) further argues that even during the growing phase, cattle on food of very high quality, including grain, will grow and reach bodyweight far in excess of average weights obtained even under the best natural conditions; a further suggestion that calorie intake is not related to energy expenditure.

This clearly implies that food intake in ruminants increases with the quality of food in terms of its every content.

Larsson (1965) presents evidence of the role of the hypothalamus in the regulation of appetite. Marked biochemical changes take place in the hypothalamus during hunger as compared with satiety, but on the other hand, satiety after a meal before the digestion of food has started suggests other additional regulatory mechanisms. He concludes that the regulation of food intake is brought about by many integrated mechanisms, the individual importance of which is impossible to grade except for an intact hypothalamus.

Blaxter (1962) summarizes the merits of these mechanisms in which the physical effects of food in the alimentary tract plays a role namely, the space fitting attributes of food, including its dry weight, its volume after swelling and

the indigestable material that it contains as well as the digestability of the food. He concludes that the underlying reasons for the association of food intake in ruminants with quality, all appear to be related to the rate at which food is fermented and leaves the rumen.

This was confirmed conclusively by McCullough (1969) who studied the voluntary intake of food by cattle and reported that daily intake of dry matter was maximal when the diet contains 80 per cent of concentrate and 20 per cent of hay, but only at certain weight levels. The relationship between voluntary intake and the ratio of hay to concentrate was not constant at different live weight levels. McCullough also reports that there is no direct relationship between digestibility and retention time and intake so that differences in gut fill were insignificant in relation to intake.

Frear and Campling (1963) also showed that on high concentrate diets, regulatory mechanisms other than the amount of ingested food in the digestive tract before the meal, determine satiety.

It is quite clear therefore that neither the nutrient demands of production, nor the energy expenditure by exercise nor the physical properties of food, determine with any accuracy the intake of food by animals. It has to be accepted that where economic considerations fail to restrict nutrient supply to cattle, physiological limitation of intake will hardly suffice to restrict intake and the level of feeding has indeed been reported to influence the productive life span of cattle profoundly.

1.2 Some effects of the nutritional level on production and longevity of animals

Longevity is defined as length of life. In usage in commercial cattle production, this definition is qualified for obvious reasons to denote the length of the productive life.

Seventy years ago Kellogg & Bell (1903), working on silk-worms, recorded an increased number of moults due to a reduction of food and Northorp (1917) recorded that the duration of life-expectancy of Drosophila flies can be prolonged by restriction of feed intake. Since then, numerous reports appeared on the reduction of life expectancy in animals, and in particular in cattle, due to increased feed intake.

Results reported by Parker, Bayley, Fohrman & Plowman (1960) are of extreme importance in this respect. They reported that the differences in longevity between individual cows are determined largely by non-genetic influences. They showed that longevity in the Holstein and Jersey herds at Beltsville was greatly influenced by the reproductive performance of the cows and that there was no evidence that longevity was associated with low production in the first lactation, which means that high producers do not "burn out" or stay in the herd for a shorter time than others.

However an abundance of evidence is available that feeding level exerts a profound influence on bovine longevity.

Hansen & Steenberg (1950) studied the influence of the quantity of feed units on the growth of young cattle and reported that there was no doubt that the heavily fed cows possessed lower keeping properties than the poorly fed cows which maintained their yield for a longer number of years. Heavy feeding affected the yield in the first lactation in a positive direction, but this effect was not apparent during the second lactation period. Their animals on a low level of nutrition, increased their production from first to second lactation by 607 kg of FCM, whilst the animals on the medium level increased only by 293 kg FCM, and on the high level by only 131 kg.

In a study of the financial returns in heavily fed cows as compared to cows on a normal level of feeding, Larsen & Larsen (1956) recorded better financial returns in the cows on a normal level of feeding. They further reported that the prospects of pregnancy decline with rising intensity of feeding, while the increase of feeding intensity had a beneficial influence on the conceptions only of the highest yielding cows.

Another most relevant aspect in this context was recorded by Lutwak-Man (1958) namely that nutrition as represented by food intake and the magnitude of anabolic processes, is itself governed to a not inconsiderable degree by the endocrine status of the gonads thus making the relationship a reciprocal one.

The effect of the plane of nutrition on the life-time performance of dairy cattle was studied in great detail at Cornell and reported on by Reid (1960) and Reid, Loosli, Trinberger, Turk, Asdell & Smith (1964). The performance of cows

on a high plane of nutrition was inferior to that of cows reared on a low plane of nutrition. There was a tendency for cows from the higher nutritional level to encounter breeding difficulties later in life and thereby to have a shorter productive life. They concluded that intensive rearing was uneconomical, particularly when heifers were bred as late as 18 months of age. The main reason for losses of high level cows was sterility and for low level cows, mastitis.

Uncertainty is common, however, on the role of excessive fatness as a direct cause of sterility in cattle. As early as 25 years ago Asdell (1958) stressed the importance of investigations in this gap in our knowledge and he suggested extreme pilot experiments with laboratory animals for more efficient and rapid collection of biological data.

Berg (1960) and Berg & Simms (1960) studied longevity and the incidence of disease in relation to nutrition in rats. They reported that rats on *ad libitum* feeding attained a large skeletal size and became obese. When food intake was restricted by 33 or 46 per cent, fat accumulation was prevented without any retarding effect on skeletal growth, while longevity was extended and the onset of disease delayed. At 800 days of age, only 48 per cent of unrestricted male rats were alive as compared to 87 per cent survival for restricted rats.

In male rats the incidence of tumours and cardiac, renal or vascular lesions at 800 days was 100 per cent in unrestricted rats, as compared to a 64 per cent incidence for the 33 per cent restricted rats and a 24 per cent incidence for the 46 per cent restricted rats.

The survival rate of restricted and unrestricted female rats was higher than for male rats with an equally striking difference between the two groups. At 800 days, all females on restricted diet were free from disease while 57 per cent of unrestricted females had lesions.

Equally astounding results were reported by Ross (1961). Mortality patterns in rats varied with variations in protein and carbo-hydrate levels in their diet. Restrictions of protein and carbo-hydrate showed no pronounced effects early in life but life expectancy was greatly enhanced. Death in unrestricted rats resulted from a tracheal mucous plug at the age of 13 months and the rate of attrition was so high that it could be termed epidemic in proportion. Several months later

myelogenous leukemia was encountered in the *ad libitum* colony The greatest number of tumours (an incidence of 28 per cent) was found in the *ad libitum* rats and the lowest incidence (7 per cent) in rats on restricted diet.

Ross quotes other experimental results where glomerulonephrosis of severe degree occurred in 35 per cent of rats on *ad libitum* diet.

He also demonstrated that the enzyme activity levels of 22 out of 23 systems studied, increased or decreased continuously with increasing age during the growing period. The patterns of enzyme activity was so precise for each age that it was possible to estimate the physiological age of animals from enzyme data. Feeding diets high in protein to young animals resulted in a pattern of enzyme activity more like that of old animals. Ageing processes are correlated with enzyme activity levels and the latter again were directly dependant on the levels of protein and carbohydrate in the diet.

In a summary of longevity and fertility in bovines in relation to nutrition, Loosli (1962) concluded that retardation of growth through restricted nutrition in cattle, resulted in animals staying young in appearance longer than their litter mates with an increase in actual life-span.

The effects of winter supplemental feed on the life-time performance and longevity of beef females were studied by Pinney, Stephens & Pope (1972) in Texas. They reported greater longevity for cows on low winter feed levels than on high supplemental feed levels. Low winter feed levels were associated with the birth of a significantly higher percentage of more vigorous calves and with fewer losses from calves born dead or dying shortly after birth. The total weight of calf weaned per cow during her life-time was therefore significantly affected with the average cow on low winter supplemental feed level weaning more calf than the average cow on medium or high winter feed level.

Arnett & Totusek (1963) fed twin heifers for three lactations on high or moderate energy levels and recorded apart from a higher number of services per conception for the high energy diet, mortality in 4 out of 12 high energy heifers as well as a high incidence of calving difficulties and even calf mortality. These results were confirmed by Eaton (1969), who also reported difficult calving, abortion, still-birth and losses of calves before weaning to be more frequent in heifers on an

increased plane of nutrition, as well as by Koriath, Schüler & Girschewski (1970), who recorded 1,70 services per conception for heifers on a higher level of nutrition and 1,42 services on a restricted level of nutrition. Calving intervals were 373 days on the higher feeding levels and 356 days on restricted feeding and they concluded further that intensified rearing was accompanied by the need for more veterinary treatment of genital diseases.

Elevated nutritional levels were reported even to affect cancer of the eye in cattle significantly. Anderson (1959) recorded a significant increase in the incidence and severity of cancerous lesions in the eyes of cattle on a high level of feeding. He suspected the high nutritional plane to hasten the ageing process so that animals reach an older physiological age at a younger chronological age than at lower feed levels. Bonsma (personal communication) blames fat deposition in the orbital cavity for the increased incidence of diseases of the eye in well fed cattle. The eye protrudes and becomes more exposed to irritation and infection.

According to Johansson (1962) the average productive life-span of dairy cows has been decreasing during the last 30 years, and it is shorter in herds and districts with a high level of production than under more primitive conditions. High producing cows on an average had completed 4,0 lactations at the time of culling and cows in low producing herds 5,2 lactations.

Johansson (1962) also quotes determinations of the productive life-span of cows in several countries. In the Iowa cow testing associations it was 3,5 years from the date of the first calving. In Great Britain the estimated number of lactations per cow were 3,9 and in Germany it was 4,2 for registered and 3,7 for non-registered cows. It was agreed by all the reporters quoted by him, that about one third of all cows which are eliminated from dairy herds, are culled because of reproductive disturbances.

In this country the life-span of registered Friesland cows averaged 66,8 months during which 3,9 calves were produced. (Head, Research Institute of Animal Husbandry and Dairying, 1967. Personal Communication).

Johansson *op cit* argues that a short productive life-span has a dual disadvantage, firstly, in terms of annual cost of cow replacement and secondly, through a decrease in the proportion of cows in the highest producing of groups.

Furthermore, and as early as 1946, Herman & Ragsdale (1946) reported on the performance of overfed Friesland heifers. Their production was disappointing over the first three lactations and some heifers developed heavy, meaty udders. The entire group was characterized by a heavy, coarse build with a great deal of fat deposition in the udder before freshening. Their conclusion was that overfitting of dairy heifers is objectionable and costly and not conducive to the optimal production potential.

Swanson (1957) also studied the milk production of identical twin Jersey heifers on different levels of feeding. He reported that at the end of the second lactation highly fed heifers had retained more fat and produced less secretory tissue in their udders than normally fed heifers. This reduced their milk secreting potential.

Summarily then, little doubt exists that when the nutritional level of the bovine is elevated above a certain level, life-span is reduced. At the same time over-feeding as a means of increasing production beyond the physiological limits of the individual animal, is, in the light of the information quoted above, not only economically wasteful but also potentially an instrument which lowers the productive ability of the animal.

1.3 The reproductive performance of cattle on a high level of feeding

The influence of underfeeding on bovine reproduction has been extensively studied and is widely recognized as one of the major causes of bovine reproductive failure.

Doubt is however sometimes expressed on the role of over-fatness on bovine fertility. Cole & Cupps (1969) state that it remains an open question whether the infertility of overfat animals was atrributed to their obesity or whether their obesity was secondary to sterility. They provide evidence from existing reports that the effect, whether of underfeeding or overfeeding, is undoubtedly attributable to a changed production or release of pituitary gonadotropins

Further evidence on the role of nutrition in hormonal function was provided by Wordinger, Dickey & Hill (1970) who studied carbo-hydrate histochemistry of the endometrium in undernourished heifers and concluded that an alteration occurred in the estrogen/progesterone relationship in undernourished animals. It was

also shown in sheep by Bellows, Pope, Meyer, Chapman & Casida (1963) that grain feeding increased the pituilary weight and consequently total FSH and LH potency and follicular development.

This effect of the nutritional level on certain hormonal interrelationships is the only available explanation for several reports on lowered reproductive efficiency associated also with overfeeding in cattle.

In the Cornell work mentioned (Reid *et al* 1964), a high level of feeding had no effect on the number of services required for conception up to the sixth pregnancy. However, 12 per cent of high feeding level animals were discarded because of failure to conceive up to the fourth pregnancy, against none in the lower feeding groups.

Reports from the New Zealand Department of Agriculture (1950–51, 1951–52) however, indicate that heifers fed on a high level of energy soon after birth to first calving, require more services per conception than do heifers on a low plane of nutrition. Heifers on a high nutritional plane according to these reports, conceived as readily as their low-level mates when their feed intake was reduced to the maintenance level for approximately one month before mating and much more readily than heifers that were maintained on a high feeding level before mating.

Results of other experiments (Brännäng, 1954; Joubert, 1954; Koriath, Schüler & Girschewski, 1970); provide additional information that heifers on a high level of energy intake require more services per conception than heifers on a lower plane of nutrition.

In a life-time experiment over 30 years, Larsen & Larsen (1956) concluded that the prospects of pregnancy in the Red Danish Milk Breed decline with rising intensity of feeding, while Dunn, Ingalls, Zimmerman & Wiltbank (1969) showed that the pregnancy rate of Hereford and Angus heifers was directly related to their post calving level of energy intake, while a precalving energy intake x breed of cow interaction was also apparent. The number of services per conception was greater for Hereford cows on high energy pre-calving intake than those on low energy intake (2,08 vs. 1,39), while the opposite was found for Angus cows (1,67 vs. 2,16).

Investigations regarding bodyweight and production in beef cows at Oklahoma were reported on by Riggs (1958). A distinct tendency towards reduced percentage calf crop and lower survival rate of cows was evident as the level of nutritional supplementation increased. A modification of feeding standards was suggested in the light of these findings.

A report by the Willow Francis Group (1971) further accentuates the hazards of over-feeding of highly producing cows with a record of increased susceptibility to diseases near calving such as milk fever, ketosis and retention of the fetal membranes.

Several additional reports are available that pre-partum concentrate feeding increased the incidence of milk-fever significantly as well as the severity of oedema of the udder in heifers, while the incidence of mastitis in heifers was increased two-fold (Greenhalgh & Gardner, 1958; Schmidt & Schultz, 1959; Swanson & Hinton, 1962; Emery, Hafs, Armstrong & Snyder, 1969).

In this respect extensive clinical experience by the writer comes to mind. It became more and more obvious over a period of 18 years that a most profound distinction existed between clinical problems occurring in dairy herds in the peri-urban areas of the Witwatersrand on the one hand where high producing and intensively fed units were established, and, on the other hand, semi-intensive and extensive units further afield but in the same climatological environment, where a lower level of production was attained and where a lower feeding level generally reigned.

Even in the absence of statistics, there is little doubt that the erosion of cows was considerably higher on the more intensive systems. With hardly any exceptions the incidence of metabolic disease, laminitis and arthritis, dystocia, retention of the fetal membranes and the percentage of cows that require treatment for post-partum metritis which is followed by reproductive failure and ovarian dysfunction, accrue to the better producing and intensively fed herds. It is accepted without enquiries that routine post-calving check-ups and treatment pertain to those high producing and well-fed herds and in particular to the so-called stud or show animal which is traditionally and by popular demand subjected to unlimited finishing off or show conditioning, and which amounts basically to nothing else but gross over-feeding far in excess of the physiological requirements of the animal in terms of growth and production.

Sorenson (1966) in a report on nutritional effects on hormone production in animals, expressed his concern that some animals are put on show circuits where they are built up in popularity to demand a very high price and are sold in a highly overfat condition. The practice of over-feeding of show animals should be abandoned according to Sorenson, but it still exists.

A particularly enligthtening study was carried out at the Department of Animal Science, University of Pretoria by Mentz (1960). He investigated the reproductive performance of 30 Afrikaner, 18 Angus and 21 Shorthorn cows, all winners of championships or reserve championships at the Witwatersrand Agricultural Show and he recorded the following ages at first calving and calving intervals for the three breeds

Breed	**Age at first calving (months)**	**Calving Interval (Days)**
Afrikaner	44,5	533
Angus	46,23	432
Shorthorn	38,52	702

It was concluded that these show champions exhibited a very poor reproductive performance and that the high nutritional levels required by show standards might be instrumental in lowering the reproductive efficiency of cows.

For the purposes of this dissertation, a questionnaire was submitted to a number of stud breeders of various breeds of cattle on the nutritional requirements of show standards in particular and the effect of over-feeding of cattle in general. Out of 161 breeders, 123 admitted that present day show standards required animals to be over-fat for exhibition and that overfeeding was objectionable particularly because of poor reproductive performance. A number of breeders refused to comment on show standards but expressed the opinion that over-feeding was fraught with disadvantages and particularly with reduced reproductive efficiency. It was apparent that although over-feeding was objectionable to most breeders for various reasons, they were compelled by show standards to exhibit animals in over-fat condition on which popular demand was based in terms of show results.

For many years Prof. J.C. Bonsma, Head of the Department of Animal Science at Pretoria University, has advocated in publications and numerous public

lectures and demonstrations in many countries, a revision of show standards and standards of excellence of many breeds of cattle, in which functional efficiency should be the only criterion and in which over-fatness at any stage should be discriminated against (Bonsma, 1966; Bonsma, 1969; Bonsma, 1972).

These publications refer in detail to the role of obesity in subfertility and sterility in cattle and in particular to the localization of fat deposits on the face, shoulders, brisket, hips, rump, pins, below the vulva and in front of the udder.

1.4 Intensification and the erosion of dairy cows

Several diseases which are ostensibly unrelated were mentioned in the preceding paragraphs; they have not been reported to occur in association with overfeeding or obesity but they are restricted exclusively to animals on intensive feeding regimes and management.

It could be argued that intensification is conducive to higher concentrations of infective organisms. This is true in relation to diseases like mastitis, specific venereal infections and certain infectious or contagious diseases. The incidence of several most important maladies remains unexplained along these lines however. Amongst these, dystocia, retention of the fetal membranes, post parturient metritis, pleurisy, peritonitis and metabolic disorders are responsible for a severe erosion of dairy cows, and particularly the more intensively fed, valuable or high producing animals.

Admittedly the aetiology of each of these conditions is well recorded in terms of causative factors like bacterial invasion or metabolically induced changes in which more specifically enzymological disturbances or nutritional imbalances have been identified, and in which "stress" of unspecified nature due to high production operates. In all these respects very considerable individual differences are apparent.

It has also been shown (Parker *et al* 1960) that differences in longevity between individual cows are determined largely by non-genetic influences, that high production *per se* does not serve to "burn out" the animal, but that feeding level exerts a profound influence on bovine longevity.

Bauer (1945) provides a background to constitution and disease which is of paramount importance in respect to nutrition and longevity. He postulates that individual constitution pertains to the sum total of an individuals characteristics as they are potentially determined at the moment of fertilization and it comprises all traits induced by the specific constellation of the individuals genes. The biological performance however, includes the genotypical and environmentally induced characteristics which together determine the physiological duration of life.

This again varies in different races and families and, furthermore, not all organs and tissues of an individual are subjected to senile involution at the same time. Some parts of the body may show signs of senility earlier than others and so may bring about a disharmonious senescence of the organism.

The investigation to be reported on now was planned against this background. It was instigated on the assumption that a *locus minoris resistentiae* in each individual animal constitutes the physiological limits within which the organism can operate. This limit is genetically determined and it can be greatly modified by environment and management.

Nutritional input is one of the most important excitations of biological performance and it is postulated that over-feeding overstimulates and strains the constitution and accelerates the manifestation of the *locus minoris resistentiae* whereby life-span or productivity is greatly reduced.

It will be shown that over-feeding *per se* of dairy cows, is voluntary and that it is a trigger mechanism in several well recorded diseases of dairy cows and consequently, that measurement of input and output in dairy animals will, apart from its direct economic imperativeness, be an important factor in the prolongation of the productive life-span of cows.

CHAPTER II

MATERIAL AND PROCEDURE

In this investigation the effect of a high and a low nutritional level on the physical health and reproductive ability was studied in Friesland dairy animals.

Week old heifers were acquired and reared intensively. Ovarian activity and reproductive phenomena were recorded through three consecutive breeding periods while the animals were grouped and put on a high and a low nutritional level respectively.

All clinical symptoms were recorded and various procedures were employed to study the performance of the two groups.

Full details are now presented in chronological order on the animals and on the various procedures employed during this investigation.

2.1 The calves, their management and development until conception

Thirty two grade Friesland heifers were acquired from commercial dairy breeders at the age of 3 to 7 days and reared intensively at the Rumerite Experimental Farm, Germiston, Transvaal.

They were reared on a standard type commercial milk substitute after the usual initial access to colostral milk of their own dams. Regular feeding procedures were carried out and the usual amount of milk substitute was fed, care being taken not to exceed the prescribed level, and all calves were weaned at the age of 10 weeks.

A standard type commercial calf rearing pellet and chopped teff hay were fed *ad lib* from the second week and free access to drinking water was allowed.

Calves were kept individually and in the open by tying them up, with an umbrella of 1,5 meter in diameter over each one to provide shelter against the sun and to protect the hay and grain against rain.

The calves were strictly isolated from all other cattle throughout the trial and they were vaccinated against paratyphoid, contagious abortion and anaplasmosis.

On arrival each calf was administered a 250 mgm chloramphenicol capsule twice daily for 3 days followed by one capsule daily for a further 3 days to control diarrhoea. This was necessary because calves were sometimes introduced from premises where enteritis was rife.

From the age of four months the calves were transferred to pens for group feeding on the following complete ration:

		Protein	TDN
Maize meal	540	48,6	432
Calf fattening concentrate	100	49,0	65
Milled teff hay	360	28,8	209
Total	1 000	126,4	706
		12,6%	71%

The proportions of meal and teff in this mixture were 64% and 36% respectively and access was *ad lib.*

Progress of the calves was uneventful and no losses occurred. The incidence of diarrhoea was mild and although the calves were kept in the open, exposure had no visible or obviously harmful effect on any calf whatsoever.

2.1.1 Examination of the genitalia and inseminations

From the age of $6\frac{1}{2}$ to 7 months as soon as the heifers were sufficiently developed, each one was submitted to a rectal examination twice weekly and the ovaries, follicular development, development of corpora lutea and the uteri were described.

Estrus observations were carried out by observation of the heifers from light until dark each day. Estrus was recorded when symptoms of standing heat was observed and confirmed by the presence of a Graaffian follicle and vaginal mucus on rectal palpation, which was carried out within 12 hours of a report of the onset of estrus.

At estrus, additional rectal examinations were carried out at intervals of between 12 and 24 hours from the first examination, to establish the time of ovulation.

Whenever ovulation failed to take place within the normal time from the onset of estrus, daily palpations were maintained until regression of the follicle became evident, usually after one week, in which case anovulation was recorded.

Delayed ovulation was recorded when ovulation occurred later than at the second examination at estrus, and this was more than 36 hours from the onset of estrus.

Silent heat or quiescent estrus was recorded when mucus secretion and follicular development was established on rectal examination at the time when estrus was expected to occur but without any of the usual signs of overt estrus.

Inseminations were commenced with when the group average body mass was 350 kg and this was reached at an average age of 13 months. All inseminations were carried out with semen of the same bull, a Friesland of known high fertility and one that was selected for low birth weight to facilitate ease of calving.

Inseminations were carried out during the period from 12 to 24 hours from the onset of estrus. Rectal examinations for the determination of ovulation were maintained after insemination as for other cycles and until pregnancy was confirmed.

2.1.2 The level of feeding before insemination

Six weeks before inseminations were commenced with, the ten heifers with the highest incidence of ovulatory failure, based on their records of anovulation delayed ovulation and abnormal cycle length, were selected out of the group and allocated to Group I.

The remaining 22 heifers were divided at random and allocated to Groups II and III.

Groups I and II remained on the same level of feeding. In Group III, the level of concentrate in the ration was reduced as follows:

		Protein	TDN
Maize meal	360	32,4	288
Calf fattening concentrate	100	49,0	65
Milled teff hay	540	43,2	313
Total	1 000	124,6	666
		12,5%	67%

The proportions of meal and teff in this mixture were 46% and 54% respectively and access was *ad libitum*. Group I therefore consisted of heifers of suspected potential low fertility and they were kept on a high level of concentrate feeding.

Group II and Group III consisted of heifers of suspected "normal" fertility, and they were kept on a high and a low level of concentrate feeding respectively.

The growth rate and condition of the heifers simulated that encountered so frequently under intensive systems and particularly the "high" condition in which breeding animals are frequently exhibited at shows.

During the second half of pregnancy the level of feeding of Groups I and II was reduced to that of Group III to avoid over-fatness at calving. All three groups also received moderate excercise by allowing them into a big paddock during the day.

2.1.3 Observations on body temperature, heart and respiratory rates

From the age of ten months, the temperature, heart, and respiratory rates of each heifer were recorded at approximately monthly intervals for a period of six months.

Observations were made in the morning when the heifers had been at rest. It was endeavoured during observations to cause no physical exertion. This was possible because of the extreme docility of the animals at the time.

Heart rates were recorded with the aid of a stethoscope and the average of three counts each of the heart and respiratory rates were recorded.

2.1.4 Observations after the first calving

At the time of the first calving it was obvious that there were considerable individual differences between heifers in respect of ovarian activity and certain other reproductive phenomena vis. uterine size, cycle length, fertility etc. It was also apparent that the high level of feeding had influenced the conception rate of the heifers as well as their heart and respiratory rates.

From these observations and from existing information on the effect of intensification and a high level of feeding on the life long performance of cattle, it was decided to proceed with observations on the performance of the animals on different levels of feeding.

For this purpose they were transferred to the Experimental Farm of the University of Pretoria, a distance of approximately 50 km.

Twenty nine of the original group of 32 animals were available for this purpose. One out of Group II had died from bloat and a further two were retained for production at the Rumevite Experimental Farm.

2.1.4.1 Procedure and re-grouping of cows after the first calving

Four out of the 29 cows available now, had failed to conceive and one was pregnant on arrival at Pretoria. The remaining 24 cows were all cycling again, having calved from 6 to 13 weeks prior to being transferred.

On internal examination, it was clear that uterine involution was complete in all cows, uteri being of normal size and without any clinical evidence of any purulence of cervical mucus, or any discharge or inflammation on examination with a speculum. At estrus vaginal discharge in all the cows was completely transparent.

Internal examination of genitalia was resumed and after it was established that ovarian activity had proceeded uneventfully over a period of 90 days, it was assumed that all cows were reproductively normal and free from any post parturient complications.

The residual effect of the previous feeding levels were considered. At the time of re-grouping, these feeding levels had been discontinued for a minimum of 325 days, all animals having been kept on the same feeding since the fourth month of their previous pregnancy. This period was considered to be sufficient for the elimination of any residual effect of the previous treatment on the data to be collected.

2.1.4.2 Rations

The cows were randomly divided into two groups, a HIGH and a LOW feeding group, and they were put on the following rations for the remainder of the

lactation, the subsequent dry period which was prolonged and the following lactation until they were slaughtered.

Meal concentrate was measured out and fed individually. In the HIGH group the amount of meal for the two lactating periods was based on the average *ad libitum* intake over the first 58 days after grouping and for the dry period on the average *ad libitum* intake over 30 days. On subsequent control checks, these amounts proved to be the true *ad libitum* intake.

The rations for the two groups for the 25th month period of the trial was as follows:

	Duration	Dairy concentrate Daily average (kg)		Eragrostis Hay. Daily average (kg)		Maize silage Daily Average (kg)
Before grouping In milk	July	5,4		5,9		6,8
	Aug.	5,4		5,9		6,8
	Sept.	5,4		5,9		6,8
		HIGH	LOW	HIGH	LOW	
After grouping In milk	Oct.	12,7	4,1	1,9	7,7	–
	Nov.	12,7	4,1	2,0	7,4	–
	Dec.	12,7	4,1	2,1	7,3	–
	Jan.	12,7	4,1	1,7	7,4	–
	Feb.	12,7	4,1	2,0	8,0	–
Dry period	March	9,1	1,4	2,0	7,3	–
	April	9,1	1,4	2,1	8,3	–
	May	9,1	1,4	2,1	10,9	–
	June	9,1	1,4	2,3	10,8	–
	July	9,1	1,4	2,8	11,3	–
	Aug.	9,1	1,4	3,9	10,4	–
	Sept.	9,1	1,4	2,8	9,8	–
	Oct.	9,1	1,4	2,9	9,1	–
	Nov.	9,1	1,4	2,1	7,7	–
	Dec.	9,1	1,4	2,6	8,6	–
Second lactation	Jan.	12,7	4,1	3,5	9,9	–
	Feb.	12,7	4,1	2,3	10,6	–
	March	12,7	4,1	2,1	7,3	–
	April	12,7	4,1	3,3	7,2	–
	May	12,7	4,1	2,4	7,3	–
	June	12,7	4,1	2,6	7,3	–
	July	12,7	4,1	2,7	9,3	–

The dairy concentrate consisted of a mixture of 300 parts by mass of yellow maize meal to which was added 100 parts by mass of a maize free mixture of the following composition:

Protein	40%
Fat	2%
Fibre	8%
Ca	2,4%
Phosphate	1,5%
TDN	65%

The following additional ingredients were added to the above mixture:

Fe	77	grams/metric ton
Cu	80	" / " "
Mn	100	" / " "
$CoSO_4$	8	" / " "
I_2	10	" / " "
Vit A	4,5	million i.u./metric ton

Free access was further allowed to a salt and bonemeal lick.

Insemination of the two groups was deliberately postponed to establish the effect of delayed breeding and obesity on ovarian activity and fertility.

The following procedures and observations were now recorded.

2.1.4.3 Body mass

The body mass of all cows were determined at monthly intervals, each time after a period of fasting without food or water for 12 hours.

2.1.4.4 Body temperature, heart and respiratory rate

The body temperatures, heart and respiratory rates were recorded as before at various intervals throughout the trial.

2.1.4.5 Cyclic and ovarian activity during the first and second lactation

Estrus observations were carried out by the same observer as before. The internal examinations of the genitalia were likewise resumed as before to describe the uteri and to establish ovarian activity.

2.1.4.6 Inseminations

Inseminations were again carried out with semen of the same bull of known high fertility and internal examinations at estrus were intensified to establish the exact time of ovulation as before.

2.1.4.7 Observations at calving

The duration of the actual calving process was recorded and taken as an indication of the ease of calving.

The onset of parturition was recorded at the first signs of physical labour with dilatation of the cervix. Dystocia was recorded when labour had proceeded for not less than 2 hours and not more than 4 hours after the cervix had dilated and when it was suspected that natural birth of a live calf was not likely any longer.

2.2 Post partum observations

2.2.1 Clinical

Three days after calving each cow was examined internally to describe the uterine contents and possible retention of the placenta. Examinations were repeated every third day until uterine involution had proceeded to the stage where the size and tonus were back to normal.

Direct measurement of the size of the uterus in vivo is not possilbe. On rectal examination however, the outlines of the uterus and its extension into the extra-pelvic area can be palpated.

The size of the uterus on palpation was given a numerical value as follows:

Size of the uterus immediately after calving	–	4
Size of 4 to 5 months pregnant uterus	–	3
Size of 3 months pregnant uterus	–	2
Size of 2 to $2^1/2$ months pregnant uterus	–	1
Size of normal non-pregnant uterus	–	0

The presence and appearance of the uterine content or discharge was recorded. No routine treatment to avoid metritis was carried out. At the development of clinical symptoms of metritis, 3 to 6 million i.u. of procaine penicillin was ad-

ministered by intramuscular route once daily until symptoms had improved. In addition intra-uterine pessaries ("Utocyl", Ciba) were inserted every 2nd or 3rd day.

2.2.2 Histological

2.2.2.1 Uterine biopsies

Biopsies were taken from the pregnant horn of the uterus of each cow 7 days after calving and thereafter weekly until the first estrus, when a further biopsy was taken on the day of estrus each time, followed by another further biopsy during the luteal phase on day 10 or 11 after estrus. This was maintained with every cycle in each cow until insemination. In cows that failed to cycle again after calving, weekly biopsies were maintained until the animal was slaughtered.

The biopsy instrument was manufactured on the model of that used by Skjerven (1956). The instrument was modified by additional sharpening and tempering of the cutting edge and by providing a surface of softer copper alloy under the cutting edge. This improved the neatness with which specimens were cut and reduced the extent of bruising and fraying and loss of epithelium which were initially recorded.

Biopsies were fixed in 10 per cent formalin in normal saline and 8 to 10 sections of 6 microns of each biopsy were HE stained.

For most cells, sections were stained with Maximow's Eosine – Azure Stain (Humason, 1966).

2.2.2.2 Examination of biopsy sections

The population of the following cell types was studied in the various strata of the endometrium during the puerperium and also at estrus and during the luteal phase: lymphocytes, neutrophiles, eosinophiles, plasma cells, mast cells and histiocytes.

Infiltration of cells in the surface and glandular epithelia were recorded as well as the appearance of the epithelial cells themselves.

Severity of cellular infiltration was recorded as follows for each individual cell type:

0	–	abscence of cell type
+	–	one or no cells per microscopical field
++	–	2 to 4 cells per microscopical field
+++	–	5 to 10 cells per microscopical field
++++	–	more than 10 cells per field
+++++	–	the cell type predominates in every field occupying more than one half of the entire surface.

For purposes of interpretation and statistical procedure a numerical value of 1 was given to each + sign and these values were submitted to a t test.

Three to five sections were studied of each biopsy and counts of cells were made from entire sections which yielded from 20 to 50 fields each.

Cellular height of the surface and glandular epithelia was recorded as low, medium or high and the appearance of epithelial nuclei was recorded as vesicular (V) or pyknotic and dark (D).

The presence and severity of subepithelial haemorrhages were recorded as well as the presence of lymph follicles in some sections.

The contents and appearance of cells in glandular lumina were recorded and a comparison was made between superficial and deep glands in the endometrium.

2.3 Blood serum analysis

Blood specimens were collected from each animal before they were grouped into high and low feeding groups, and again 8 months after they were submitted to different feeding levels and finally at the end of the trial before they were slaughtered.

Blood was collected early in the morning on three consecutive mornings each time to obtain an average of three specimens. Heparin was used as an anti-coagulant. Blood was centrifuged immediately after collection and serum was de-canted and frozen for analysis at a later stage.

Frozen specimens were submitted to the following treatment after thawing.

Digestion

5,0 ml of representative specimen was digested with concentrated H_2SO_4 (5,0 ml). 1,5 ml solution of catalyst was used (10 gr HgO in 100 ml $4NH_2SO_4$). Digestion in Kjeldahl flasks was maintained for 30 minutes after clearing. The solution was then diluted to 50,0 ml and used for the following determinations.

Phosphate was determined by means of an outo analyser system under regular conditions i.e. ammonium molybdate colour reagent.

Na^+, K^+, Ca^{2+} and Mg^{2+} were determined in the most suitable dilution with a Perkin-Elmer atomic absorption meter fitted with appropriate lamps.

N – Kjeldahl determinations were carried out on fractions of the diluted and digested specimens with $KHIO_3$ as titrating agent.

Lipoid material – 5,0 ml fractions serum was freeze dried and extracted 3 times with petroleum ether (60^o–80^o). The total ether fractions (15 ml) were then dried and the residues weighed.

In addition to the above analysis, blood specimens of each cow were submitted at the end of the trial to the section of Clinical Pathology at the Veterinary Faculty, University of Pretoria for the following determinations.

Total white cell count
Differential white cell count
Serum glutamic oxalacetic transaminase (SGO-T)
Serum glutamic pyruvic transaminase (SGP-T)
Total serum cholesterol
T4 (thyroxine)
Total serum proteins

2.3.1 Clinical observations and treatment

All clinical symptoms were recorded and particularly the incidence of laminitis.

Treatment when necessary was instituted according to regular clinical procedures that would have applied to any commerical herd. Tetracyclines were administered whenever footrot or infectious processes were suspected in case of lameness. Outgrowing hoofs were regularly trimmed to facilitate walking.

Systemic penicillin and intra-uterine pessaries were employed in cases of metritis.

In the two fatal cases, intensive treatment was employed and post mortems were carried out.

2.3.2 Final inseminations and slaughtering

All cows were inseminated finally at or about 60 days after calving, and they were slaughtered after 30 days in the event of a non-return for service. Cows that returned for service were re-inseminated.

At slaughtering all internal organs were examined for abnormalities and specimens of any lesions were fixed in formalin for histo-pathological examination:

Liner specimens in 10% formalin were finally submitted to the Institute for Veterinary Research, Onderstepoort, for the following determination s—

Cu, Zn, Co, Mn, Fe and Mg.