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A. T. G. McArthur,

December, 1949

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## INTRODUCTION.

The world shortage of food is the most serious crisis which faces mankind today. It is a crisis which has no earlier precedent and one for which remedial measures will be hard to find. The problem, first mentioned by Malthus in 1798, is one of limited food resources combined with an increasing world population. The basis of food production lies in the soil mantle of the world which is limited in extent and decreases yearly both in quantity and quality through the use of bad farming practices which lead to soil erosion.

The present level of human nutrition throughout the world is far from adequate. In North America and Australasia, the average daily consumption of calories per head is above 3000 but in the Middle East it is only 2400 while in the Far East it varies between 1700 and 2100, which is well below requirements (Fawcett (1948)). Not only are these people in need of more food energy but they also require more protein, minerals and vitamins. Livestock products are, of course, rich in these 'protective' foods and the expansion of livestock production will play an important part in raising the level of nutrition of the world's population.

Non-ruminant farm animals, pigs and poultry generally require food which can be used for direct human consumption - wheat, barley, maize etc. - so that it seems unlikely that they will be used to increase livestock production. However, the ruminant, because of its capacity to deal with fibrous food, is well adapted to utilizing grass. Grassland farming is often extensive as on the prairie, range or veldt, while in areas most suited to arable cropping, pasture may play only a secondary but nevertheless important part in returning the soil to a level of fertility suitable for further cropping through the judicious use of the legume and the grazing animal. However, where the climate is suitable for high pasture production, well spread throughout the year,

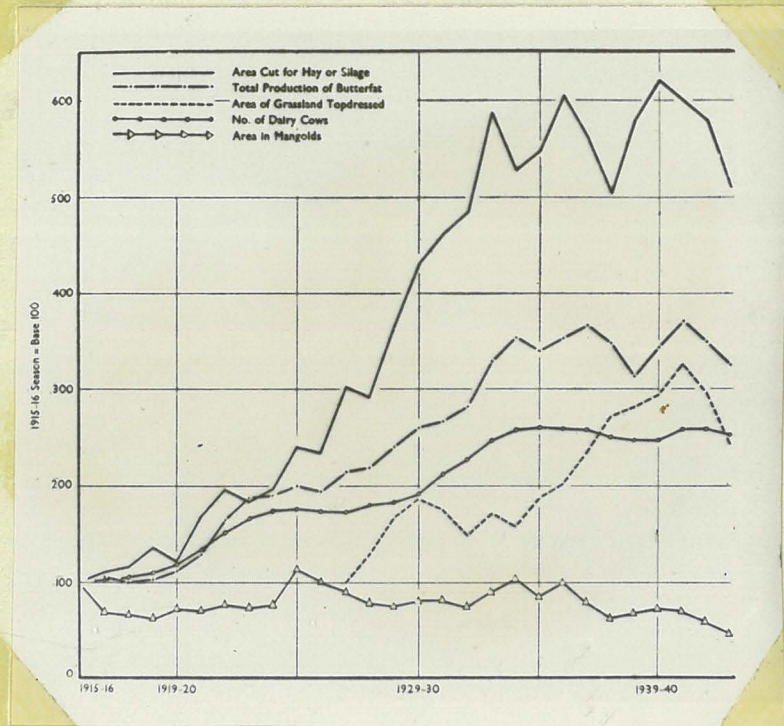


Figure 14. SHOWING THE RELATIONSHIP BETWEEN THE AREA MADE INTO HAY AND SILAGE, THE AREA USED FOR MANGOLDS, AND DAIRY PRODUCTION IN NEW ZEALAND.

So it is with New Zealand farming where grass, because of its predominant part in stock feeding, is treated as a crop capable of high production and improvable by cultivation, manuring and management. An important feature of this intensive grassland farming is the low labour requirement per unit of production, leading to low costs. From a study of the New Zealand dairy industry, Hamilton (1944) has shown that over the years the area of land used for growing mangolds has decreased while the area made into hay and silage has increased. (See Figure 14). The early dairy farmers grew root crops partly because they helped in preparing the land for sowing down grass, and partly because they clung to the traditional methods of the Old Country.

Although the climate in Great Britain is not as well suited generally for grassland production as that of the North Island of New Zealand, there is no doubt that pasture could be used more extensively for stock feeding, especially for dairy cows. Before World War II the production rations of dairy cows were based mainly on the use of cheap imported concentrates. Pasture and pasture products were mainly used for providing for maintenance requirements. Even though the work of Woodman (1926-32) and others showed that properly managed pasture had a high feeding value and could meet the requirement of high producing animals, no reliance was placed on it for milk production.

If more reliance was placed on grass as a food and if the methods of pasture establishment and management used by the New Zealand farmer were adopted by farmers in other countries, they too would obtain high production of livestock products from pasture.

The level of livestock production from intensively managed pasture depends upon:-

(a) the level of pasture production. Increasing pasture production is dependent upon the use of improved strains of grasses and clovers, judicious manuring and management.

(b) the efficiency with which pasture is utilized. Efficient pasture utilization involves the complete removal of grass from the paddock by grazing or cutting at a time when the quality of the pasture is most suited to the needs of the animal using it.

(c) the efficiency of the animal in turning grass feed consumed into the product required.

In this thesis, pasture utilization will be discussed in relation to New Zealand dairy farming. There is no evidence to show the magnitude of the losses of feed which occur through pasture utilization under dairy farming conditions. However the fact that not all the pasture food produced is actually consumed is illustrated below.

Various New Zealand workers have measured pasture production under a system of sheep rotational grazing with complete utilization. Elliot and Lynch (1943) have measured yield by using a grazing and cage technique simulating fairly closely practical farm conditions. During a good season (from Oct. 1st 1940 to Oct. 1st 1941) they obtained a yield of 11,787 lb of dry matter per acre in the Waikato, 4,734 lb of dry matter per acre at Stratford in Taranaki and 11,071 lb of dry matter per acre at Marton in the Rangeitiki plains. Hudson (1933) found yields of 4,638 lb to 8,806 lb at Marton using a mowing and grazing technique. Sears and Newbold (1942) obtained a yield of 13,700 lb of dry matter per acre on very extensively managed pasture at the Grassland Research station in the Manawatu. McMeekan (1947) estimates that the yield of dry matter per acre on a typical New Zealand sheep or dairy farm is between 6,000 and 8,000 lb.

However the butterfat production per acre for New Zealand dairy farms, which is determined by multiplying the number of cows milked by the average butterfat per cow and dividing by the area of the farm, is given in a report of survey work carried out by the Department of Agriculture for the Dairy Industry Commission (1934). A study was made of 550 high selected sample farms

on a district basis. The average figures were:-

|                       |                       |
|-----------------------|-----------------------|
| Northland.. .. 93 lb  | Auckland.. .. 144 lb  |
| Taranaki .. .. 122 lb | Manawatu.. .. 132 lb. |

Now theoretically 6,000 to 8,000 lb of dry matter should produce approximately 240 to 330 lb of butterfat which is well above the figures found in practice. The difference is by no means an accurate estimate of the loss which occurs through pasture utilization, for the average pasture production is merely a rough estimate and the output of butterfat per acre is difficult to calculate in practice. By using a method of measuring intake, it should be possible to measure pasture utilization losses under farm conditions, and such work is urgently required.

The general theme throughout this dissertation is the pasture utilization loss. As a fundamental background, pasture quality and grazing behaviour of dairy cows are discussed. The losses that occur through utilization by grazing are enumerated, and this is followed by a discussion of the factors which prohibit utilization and the solution of pasture utilization problems. The effect which pasture utilization has on production of pasture and the utilization of the grass feed consumed is considered.

Further experimentation in this field demands a knowledge of the intake of feed from pasture by the animal, and there is therefore a final section dealing with the methods which have been developed to measure intake.

The object of this work is to outline the subject of pasture utilization in relation to New Zealand dairy farming, illustrated by the evidence which is available. It is hoped that this dissertation will act as an impetus to further investigation.

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## THE VARIATION IN FEEDING VALUE OF PASTURE.

To provide a background for this thesis, it is necessary to outline in brief the variations which occur in the feeding value of pasture. This discussion will be limited to the major constituents of grass - protein, nitrogen-free-extract, crude fibre, fat and ash. Details of the mineral content of pasture in New Zealand can be found elsewhere while such details as the biological value of the proteins, the vitamins and the hormones present in pasture are not considered relevant to the general theme.

While it is generally recognised that high-quality pasture is an adequate food for all classes of stock, it is surprising that grass has not been subject to more investigation when one considers that it is the most important single food used for farm animals.

### Factors which influence the nutritive value of pasture.

The botanical composition of the sward plays an important role in determining the nutritive value of pasture. Williams and Davies (1932) in Wales have shown that clovers, in comparison with grasses, are high in crude protein and calcium while they have a lower crude fibre content. In New Zealand, Sears (1947) has found similar results. There is but little difference in chemical composition between grass species when compared at the same stage of growth under the same soil conditions (Fagan and Williams (1924)). Weeds, the other components of the sward, generally have a high protein and mineral content but are low in dry matter (Fagan and Walkins (1932)), (Milton (1933)), (Shapter (1935)). Although weeds are often palatable, especially during the winter, (Milton (1943)), they probably compare unfavourably with other pasture species in total production under high fertility conditions.

Broadly speaking, the nutrient content of a plant tends to be directly related to the level of nutrients in the soil (Richardson et al (1931)).

For instance, it is well known that the addition of nitrogenous fertilizers raises the protein content of grass (Fagan, Milton and Proven (1938)), while Sears (1947) has shown that high soil fertility gives pasture with a high nutritive value. The addition of phosphatic fertilizers to the soil raises the proportion of clover in the sward. The presence of clover itself improves the quality of the grass while added symbiotic nitrogen synthesis raises the nutritive value of the sward.

The stage of maturity at which the plant is utilized often overrides the effects which the botanical composition and the soil fertility play in determining the nutritive value of pasture. The rate of carbon assimilation of a plant is proportional to the leaf surface which increases up to the pre-flowering period. Again, the rate of uptake of nitrogen and minerals is most rapid in the early vegetative stages after which it decreases (Richardson et al. (1932)). As the plant matures, the nitrogen and mineral content decreases while there is an increase in structural tissue which leads to a lowered digestibility of all nutrients. This variation in pasture composition with stage of growth is related to the ratio of leaf to stem. Fagan and Jones (1924) have shown that the proportion of leaf to stem decreases with an increase in maturity. The leaf is richer in nitrogen and minerals than the stem. The crude fibre content is lower in the leaf and this leads to a higher digestibility of all nutrients.

Stapledon (1924), Woodman (1926, 1923, 1932, 1933) and Woodward (1939) show that as pasture matures the dry matter percentage increases but the digestible proteins, ash and fats diminish. Lowered digestibility of these nutrients is probably due to an increase of lignin content (Norman (1937)). Also the high content of readily digestible fructosan in immature herbage accounts for its high feeding value rather than its richness in protein.

If pasture is cut frequently in order to obtain grass of a high quality, the total yield of digestible nutrients will be depressed. Woodman's work

7  
showed that the longer the interval between cuts, the higher the yield of dry matter. A compromise between quality and quantity is made if the maximum yield of total digestible nutrients is required. Watson (1939) has recommended cutting pasture at an early stage in order to obtain high food with a high protein equivalent. But when a maintenance feed is required, early cutting may not be economical.

Theoretically a greater yield of nutrients can be obtained by rotational grazing. Under continuous grazing with efficient utilization the quality of the feed may be expected to be high but the total yield of nutrients will be depressed. Under rotational grazing the feed can be utilized when the quality is best suited for milk production so that the largest yield of total digestible nutrients will be obtained.

Sears and Goodall (1942) have shown that 8 - 10 inch spring pasture under high fertility conditions in New Zealand still has a protein content and digestibility comparable with the immature pasture studied by Woodman. It is unlikely that such long grass would have such a high feeding value during the summer or autumn and in any case such herbage would be difficult to utilize efficiently. One may conclude that the intervals between grazings should be as long as possible provided that the quality of the herbage does not fall below a level suitable for milk production. Also the pasture itself must not be too long or its utilization will be difficult.

#### Seasonal variations in pasture composition.

The seasonal variations in pasture composition depend on climatic factors such as the distribution of rain, but these are manifested mainly in changes in the stage of maturity of the pasture. Thus the proportion of leaf to stem is highest in the spring, lowest in the summer, rising again in the autumn (Fagan and Jones (1934)) and this leads to a lowering of the digestibility of nutrients during the summer, a depressed protein content and an increased percentage of fibre (Woodman (1926)). The extent of the depression

during the summer is modified by the botanical composition, for if there is in the sward a high percentage of clover which will make most of its growth during the summer, the depression of feeding value during the summer will not be so great.

Hudson (1933) at Marton, New Zealand, analysed pasture which was rotationally grazed by sheep. He found that the spring flush growth was characterised by a high protein content of approximately 34 per cent and a low fibre content percentage. During the summer the protein content was depressed (27 per cent), while the fibre content rose. The autumn growth had a higher protein content but the protein content of the winter pasture was low. Thus Hudson's work bears out the results of overseas workers.

We may conclude that botanical composition, soil fertility and stage of maturity all play a part in determining the composition of pasture. The quality of pasture varies throughout the year, being manifested in changes in the stage of maturity of the pasture plants. The quality is highest in the spring and autumn and lowest during the summer and winter.

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THE GRAZING HABITS OF DAIRY COWS.

The larger part of pasture output on dairy farms in New Zealand is utilized by grazing. Therefore it seems logical to make a study of the grazing behaviour of the animals that consume it.

Unfortunately, there is remarkably little knowledge readily available about the behaviour pattern of grazing animals, but some references to the relevant literature will be given below.

Ruminants have the ability to make use of more in the way of fibrous feeds than do other grazing animals, and furthermore, they are much less selective in their grazing habits than are non-ruminants. (See Beruldsen and Morgan (1938)). It is quite possible that the ability to take in feed rapidly and then to remasticate it later on is of some selective advantage in wild life.

A general survey of the behaviour of the grazing animal should help to throw some light on many of the pasture and animal management problems with which the farmer is vitally concerned.

Thus James Anderson (1797), a Scots farmer, after making some observations on the grazing behaviour of his fattening beasts, decided to adopt a system of rotational grazing. He noticed that his stock appeared to relish fresh clean feed, and also that they thrived on it, and he therefore adopted the system which today we consider an efficient

method of pasture utilization.

The grazing pattern of a cow appears to be governed by its genetical make-up, its feed requirements, the climate, and the pasture environment. Before the limited data on these factors is discussed, a picture will be given of the normal habits of dairy cows.

Johnstone-Wallace (1944) discussed the foraging habits of beef cattle and states that "the mechanical process of grazing involves the severing of the leaves and stems of grasses, legumes and weeds with the two jaws of the animal measuring on an average, about  $2\frac{1}{2}$  inches across, and having one row of teeth in the front on the lower jaw. A muscular pad on the upper jaw presses against these teeth and enables the tearing action to take place... The tongue is in constant action during grazing usually being protruded with great rapidity, alternately from either side of the mouth. Its function appears to be to simplify the collecting process, as well as the swallowing process. The head of the cow moves from side to side as she moves forward, the neck being flexed within an arc of about 90 degrees".

Undershot jaw may prevent a cow from collecting sufficient food to meet its requirements, especially under poor conditions. Hancock (1948) quotes the case of a set of twins at Ruskura. One gave 350lb of butterfat on adequate pasture supplemented with concentrates while the other only gave 100lb of butterfat on an area of pasture which was 40% smaller. However this difference was very much greater than the average treatment differences. The reason was that both had an undershot jaw but the latter was unable to forage efficiently under poorer conditions.

Hancock and Wallace (1947) at Ruskura, New Zealand, find that the average number of bites per day for four cows that they observed is 23,500. The average number of bites per minute is 51. If it is assumed that the cows consumed 150 lb of green grass per day, then each bite weighs about one tenth of an ounce. As a cow takes in such small quantities at once it can be appreciated

that potentially she is a very selective animal. Selectivity will be dealt with later.

The same workers observed the grazing behaviour of six sets of monozygotic twins (first calvers) for six twenty-four hour periods at monthly intervals through the main lactation season. 7 hours in each 24 were spent in grazing, while 10 were spent in lying down. The remainder of the day was spent loafing, i.e. standing and walking around but not grazing. Similar results have been found by Southcombe (1947) from observations of the dairy herds at Massey College. The most obvious feature of the behaviour pattern is its cyclic nature. Southcombe observed three regular grazing periods during the day and two at night. A similar pattern was noticed by Corbett (1949) from his 24 hour watch on calves. Observations by the present writer (1948) showed how the whole herd tended to act as a unit and also that the intensity of grazing, as measured by the bites taken per minute, decreased during each grazing period.

It was believed by Cory (1927) and Ellingboe (1924) that no grazing takes place at night, but Hancock and Wallace (1947) found that 42 per cent of the grazing took place between 5 p.m. and 4.45 a.m. and 58 per cent between 7 a.m. and 3 p.m.

However, comparatively little grazing is done between midnight and milking time (Levy 1935). Southcombe (1947) has confirmed these results.

The Ruakura workers measured the distance their twins walked, finding it to be approximately 2 miles. Similar distances were found by Johnstone-Wallace and Kennedy (1944) in America, and Anon, (1948) at the Grassland Improvement Station, England, with beef cattle.

These English workers find that nearly 9 hours are spent in cudding.

One observation for a 24 hour period by the American workers showed a cudding time of 7 hours. Hancock (1948) states that the twins he has studied usually spend about three quarters of the time they take to graze in cudding. However,

Southcombe (1947) states that the times devoted to chewing the cud show much variation. His observations did not take account of cudging either in the yard or in the night paddocks. It was noticed, nevertheless, that when a cow began ruminating, she persisted for some 15--20 minutes, before abruptly stopping. This feature has been noted by Corbett (1949) in calves.

Johnstone- Wallace and Kennedy (1944) found that the average number of defecations and urinations made by beef cows on pasture was 8.5 and 12.75 respectively. Hancock (1948) states that of the total time spent in grazing, 60 per cent of the manure falls between the morning and the afternoon milking, and the remainder, or 40% (per cent) between the afternoon and morning milking. It is widely held that more stock manure falls at night than during the day. This has been clearly proved in the case of sheep (Davies (1937) ) and it was generally accepted that the same held good for dairy cows -- hence the build-up of fertility in night paddocks. However, Hancock believes this to be due to their comparatively small size giving them a larger shower of manure per acre than the day paddocks.

This work requires confirmation in terms of actual weights.

Having obtained a picture of the grazing pattern of dairy cows, it is now necessary to discuss the limited information concerning the variations that occur and the factors which cause them.

Hancock and Wallace (1947) found that the identical twin heifers they studied spent from 26 to 32 percent of their time grazing but that the pattern of grazing was strikingly similar within sets of twins. Thus the "within sets of twins" intra-class correlation was 0.9038 for grazing. However, the correlation for time spent loafing and lying down was negligible.

The grazing pattern appears therefore to be determined to a considerable extent by the genotype of the animal concerned.

In consequence, one might expect to find some differences between breeds in grazing behaviour. Indeed Southcombe found that Jerseys grazed for a longer

time than Friesians, especially during the night and they also walked further. As he found that the rate of eating, as measured by the bites taken per minute, was similar in both breeds, he concluded that the Jersey must be a more selective grazer. These facts probably show that the Jersey takes in less feed per mouthful but this does not necessarily make her more selective.

A low correlation has been found between the theoretical T.D.N.requirements and the grazing time ( Hancock and Wallace (1947) ). Now if there is a strong relationship between the amount of food consumed and the grazing time-- this has yet to be shown but would seem probable --, then the low producing cows in the herd consume a larger amount of feed than they require to meet production and maintenance requirements. This reveals a possible weakness connected with free-grazing conditions, for unless the requirements of the cow play a large part in determining the intake from pasture, the low producers consume more than their share.

Seasonal and climatic conditions may affect the grazing pattern. Southcombe (1947) found a definite trend towards shorter grazing hours during the Winter. Hancock (1948) reports that cows walked further on cold and blustery or extremely warm days and emphasized the need for adequate shelter on pasture.

Seath and Miller (1946) studied the effect of warm weather on the grazing performance of three Jersey and three Holstein cows in Louisiana. They found that high day temperatures decreased the portion of the time spent grazing during the day and increased night grazing. Thus on the warmest days 23 per cent of the grazing was done during the day while on cooler days the daytime grazing increased to 44 per cent. The day temperatures are lower in New Zealand and both Southcombe and Hancock have found that about 60 per cent of the grazing takes place during the day. Climatic conditions seem to alter the grazing pattern considerably.

The condition of the pasture may also affect the changes in grazing

behaviour. Hodson (1933) compared the grazing pattern of Holsteins grazed continuously and rotationally. He found that less time was spent foraging under rotational grazing conditions but that grazing time increased after the cows had been on a paddock for some days. Although his data was scanty and he only made observations during daylight hours, he concluded that less energy is expended by cows under rotational grazing. His results are supported by Shepperd's (1921) observation that the larger the paddock the further the animal travels.

Atkeson et al. (1942) found that although cows on poor pasture received supplementary food they were forced by the sparse condition of the herbage to graze for a longer time than on good paddocks. Hancock (1948) states that cows will put in up to 10 hours grazing in a day on scanty pasture which is contrary to the conclusion reached by Johnstone-Wallace and Kennedy (1944), who maintained that cows have not the capacity to graze more than seven hours.

It is obvious that there is a limit to the number of hours a cow <sup>can</sup> put in. Hancock (1948) states that a hard working cow could put in 10 hours grazing, 9 hours rumination, 3 hours off the paddock being milked and 2 hours complete rest, which appears to be their minimum requirement.

A cow that has to eat for a long time may be so enforced to reduce her cudging time, utilizing her food poorly.

As a conclusion, Hammond (1944) may be quoted;---

" The study of animal behaviour should have a great influence in making a science of what was now known as the stockman's art. A good stockman was one who knew exactly what his animal wanted and how it was feeling. The development of a science for this subject would be of great use to animal husbandry"

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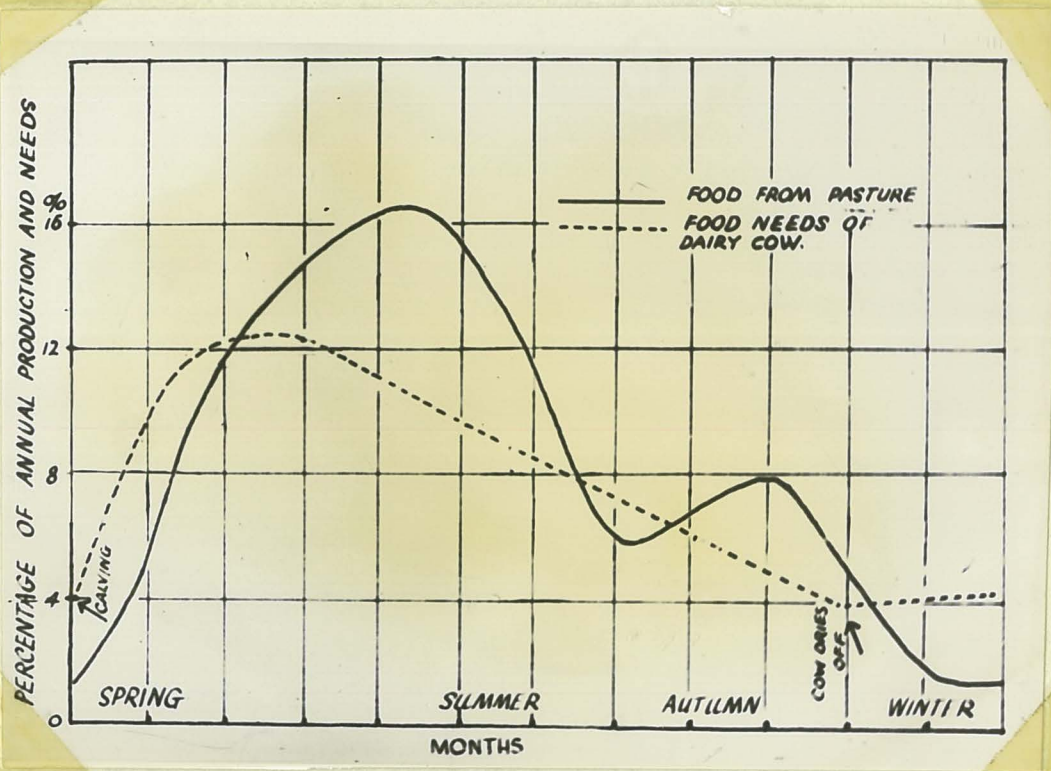


Figure 1. A DIAGRAM SHOWING THE RELATIONSHIP BETWEEN THE REQUIREMENTS OF A DAIRY COW AND PASTURE PRODUCTION.

THE LOSSES THROUGH UTILIZATION BY GRAZING.

The byreman aims to provide his stall-fed cows with sufficient food to meet their requirements; no more or the food will be wasted, and no less or production will suffer. The situation is more complex when feeding cows on pasture because the amount the animal consumes is difficult to control and because of the fluctuating rate of pasture production through the season.

In Figure 1 there is shown in diagrammatic form the curve of pasture production in New Zealand. Pasture starts to grow vigorously in the spring, rising to a peak in November. In December-January the growth rate falls with the onset of dry summer weather. There is another smaller flush of pasture growth in the autumn but pasture production falls to a low level during the winter.

The requirements of a dairy cow rise sharply after calving with the initiation of lactation about six weeks to a month before active pasture growth starts. These requirements reach a peak about two months after calving, and then drop steadily to the maintenance level when the cows are dried off.

There are two periods when there is a surplus of pasture available; in the spring and early summer, and in the autumn. If the spring surplus is not utilized, it will continue growing, run to seed, and its nutritive value will decline. Eventually the leaves will drop off and the herbage will die and rot back into the soil. If this happens, feed will be wasted and maximum production will not be obtained. The autumn flush is less likely to be wasted, for the onset of winter retards the rate of growth, and the herbage will continue to produce vegetatively. In fact the surplus from the autumn flush can be conserved in situ for consumption during the winter without undue loss. Often there is no surplus autumn pasture, depending on the rate of stocking, the number of cows in production during

that period, and the season.

This is the basic problem of pasture utilization. The losses that may occur can be avoided by various practices such as conservation, adjustment of stock numbers, cropping and the use of special-purpose pastures. By these methods the requirements of the herd for pasture may be equated with the production of grass. The details of these practices will be outlined later.

The most common method of equating herd requirements with pasture production in New Zealand is the making of hay and ensilage. In the spring the whole farm will be grazed but as the grass comes away and there is a surplus above herd requirements, pastures are closed for conservation. By this method it is possible to reduce the losses which would otherwise occur. However if too much land is closed, the herd may be on a sub-optimum ration during the early summer. If too little is conserved, there will be a surplus of food which will go to waste. The adjustment of this is very difficult in practice for seasonal conditions play a large part in determining the surplus there will be. However, with rotational grazing and close sub-division of the farm, a fine balance may be struck between the amount of feed offered and the amount the herd requires. Rotational grazing and close sub-division give the flexibility that is required to strike this balance.

Silage-making is more flexible than the making of hay, for it is more independent of the prevailing weather conditions. It takes about six weeks to grow a crop of grass for conservation in the New Zealand dairying areas. Now during the month of November the weather is usually unsettled and not suitable for haymaking. Thus if a paddock is closed for hay at the beginning of the pasture season in order to reduce grazing utilization losses, its date of cutting will coincide with the unsettled November weather unless the crop is allowed to grow to a later stage of maturity when its quality

will deteriorate. Hay paddocks are often closed up later in the season than is consistent with efficient pasture utilization, so that cutting coincides with the finer December weather. By making silage these 'pre-closing' losses may be eliminated.

The dairy farmer who has a stack of hay or silage in hand at the end of the winter is able to adjust the amount of feed offered to the herd more easily, for if the grass production during that period is lower than normal he will not have to underfeed his herd in order to conserve enough feed for the winter.

Thus in some years on New Zealand dairy farms pasture will be wasted through poor utilization. The amount wasted will depend on the season and the flexibility of management.

Pasture clumps.

During the summer, clumps of neglected pasture are a common sight on dairy pastures. They represent a loss which occurs when pasture is utilized by grazing and are mainly the result of unpalatableness of that part of the sward but a surplus of pasture will increase this frequency. These neglected clumps are the direct result of the selective grazing habits of dairy cows about which we know very little.

It is generally assumed that horses are the most fastidious grazers and cows the least. However the fact that about one tenth of an ounce of grass is consumed per bite and that some parts of a paddock are preferred to others shows that the dairy cow is capable of selection.

Grazing animals avoid their own excreta. Horses for instance dung and urinate in the same area or areas of the paddock each time and in consequence these areas are neglected. Beruldsen and Morgan (1938) working in Australia on irrigated pasture charted a one-acre sample from a horse paddock over 3 years at various intervals. They divided the pasture into heavily grazed moderately grazed and lightly grazed or neglected areas,

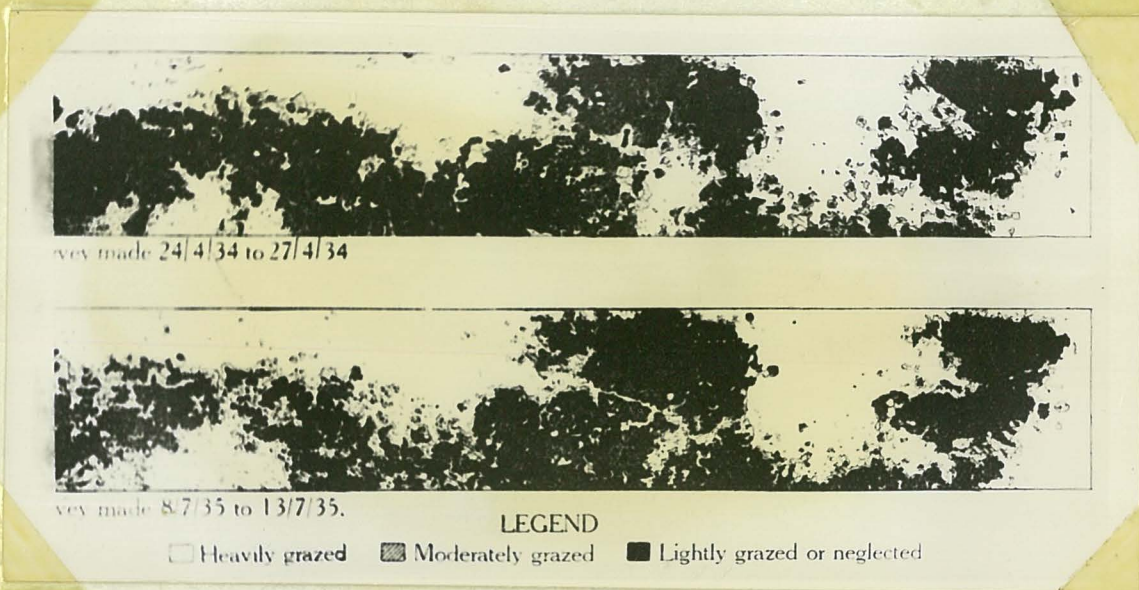


Figure 2. A COMPARISON OF TWO SURVEYS MADE IN A HORSE-PADDOCK BY BERULDSSEN AND MORGAN (1938).



Figure 3. SELECTIVE GRAZING.

Cattle prefer the unsoiled herbage beneath the electric fence when grass is being rationed out by break-feeding.



Figure 4. SELECTIVE GRAZING.

Cattle refuse to eat luxuriant pasture where droppings have fallen, but they will eat the herbage if it is handed to them or placed on the ground a short distance from the place on which it grew. The odour associated with the droppings appears to be the cause of this.

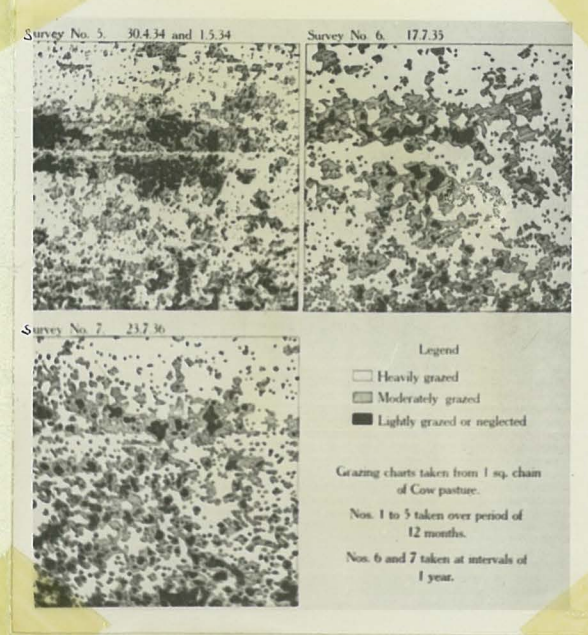
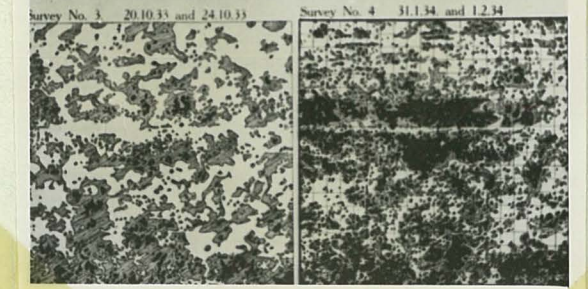
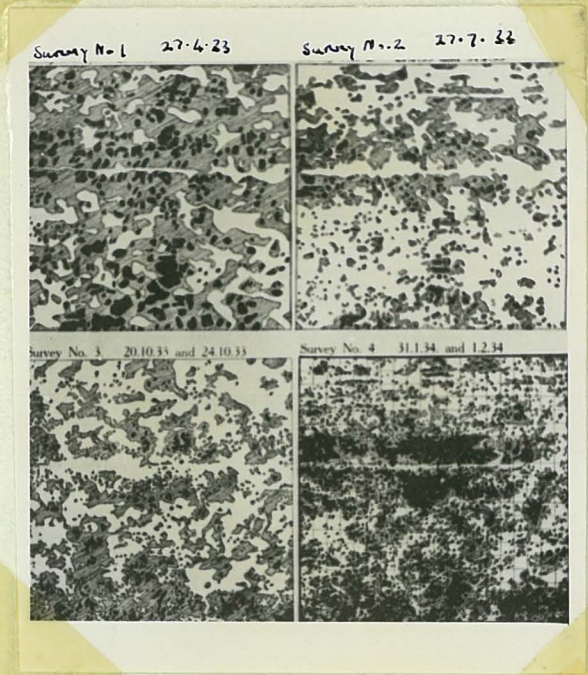


Figure 5. CHARTS SHOWING THE RESULT OF PASTURE SURVEYS IN A COW PADDOCK STUDIED BY BERULIDSEN AND MORGAN (1938).

marking these areas in on a map and estimating the extent of each. Although this subjective method is open to biased error, it did show that the neglected areas of pasture had a constant position in the field. (See Figure 2) Never more than 50 per cent of the paddock was effectively grazed.

Dairy cows on break-feeding often prefer to eat beneath the electric fence (see Figure 3). We may presume that this is because of their preference for clean feed. Clumps in cow-pastures are associated with the presence of excreta. Johnstone-Wallace (1939) has observed that cows refuse to graze luxuriant herbage where droppings have fallen but will eat the herbage if it is handed to them on the ground a short distance from the place on which it grew. (See Figure 4). The odour associated with the droppings appears to be the cause of this. Beruldsen and Morgan noticed an unpleasant odour emanating from the neglected areas in a horse paddock and that even after grazing the herbage off with sheep, the paddocks reverted to their original clump pattern after some months of exclusive horse grazing. This observation shows that it is the smell of the excreta which causes the unpalatableness rather than the contamination of the herbage with excreta. It also demonstrates the persistent effect that horse excreta has on the palatability of herbage.

Cows appear to excrete at random in the paddock and the effect of the dung and urine seems to be less persistent on the palatability of the herbage. Beruldsen and Morgan surveyed cow-paddocks in a manner similar to that used for horse-paddocks. The charts in Figure 5 demonstrate that there is little permanency in the relative positions of the short and long patches in the pasture grazed by cows. However by comparing survey 3 which was made in the spring with the summer survey 4, it will be seen that patches which were lightly grazed or neglected in the spring developed clumps during the summer.

Beruldsen and Morgan also demonstrated the well known fact that clumps

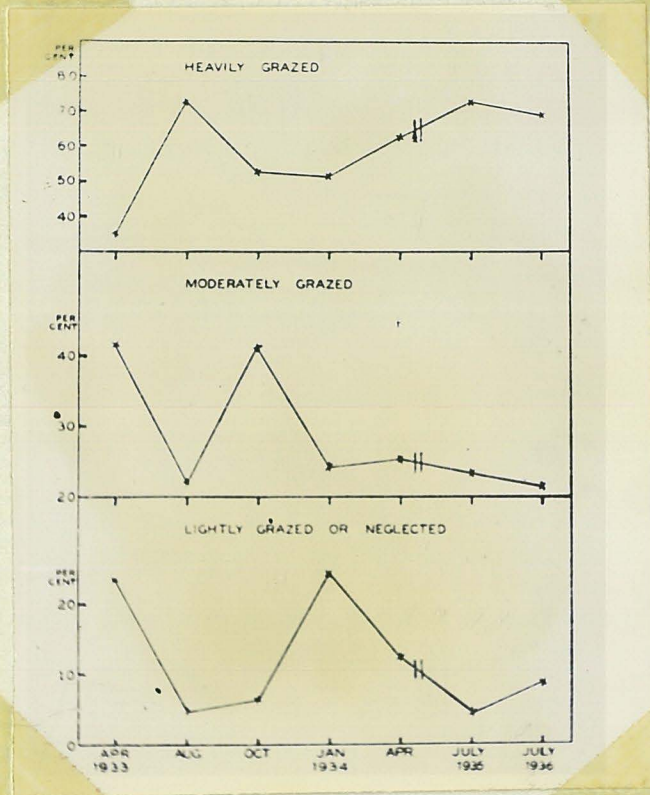


Figure 6. SHOWING THE PERCENTAGES OF HEAVY GRAZED, MODERATELY GRAZED AND LIGHTLY GRAZED OR NEGLECTED HERBAGE FROM SEASON TO SEASON ON A COW PADDOCK.

tend to disappear during the winter when herd requirements for pasture exceed its production, and develop during the summer when there tends to be a surplus. (See Figures 5 and 6). During the winter clumps are chewed out. In order that a cow may obtain sufficient pasture to meet her own requirements for high production it may be necessary for a surplus of pasture to be present. This point will remain in doubt until such time as an adequate method of measuring intake has been evolved. However Johnstone-Wallace (1944) reports that the height of the pasture influences the intake of feed by the dairy cow. He measured the intake by the 'difference' method which will be criticised later on and failed to replicate his experiments so that statistical analysis was impossible. His results are summarized in the following table.

Table 1. The effect of pasture height on intake of dairy cows on pasture.

| Condition of Herbage                    | Available Herbage |        | Herbage Consumed |        |
|---|-------------------|--------|------------------|--------|
|   | Green lb          | Dry lb | Green lb         | Dry lb |
| Sward 4 to 5 inches in height           | 4500              | 1000   | 150              | 32     |
| Sward after a few days grazing          | 2200              | 500    | 90               | 20     |
| Sward after a further period of grazing | 1100              | 250    | 45               | 10     |
| Sward 10-12 inches in height            | 5000              | 1200   | 70               | 20     |

Thus if a paddock is grazed bare to give complete utilization the feed intake may be reduced giving a consequent loss of <sup>output</sup> production. The effect of reducing the density of the pasture on intake will have a different effect with individual cows. The efficient grazers will be more able to maintain their intake even under sparser pasture conditions.

From this scanty evidence and practical observations it may be tentatively postulated that a balance must be struck between good utilization of pasture including the avoidance of clumps and providing the cow with the optimum conditions for consuming sufficient feed to meet her requirements during her limited daily feeding period. It is well known that if clumps are

chewed out by concentrating stock on a small area the butterfat production will fall.

The size of the paddock may affect clumpiness. If the herd is grazed over a large area for a long period, the cows will have adequate 'room' for selection at the beginning of that period and some parts of the sward will be neglected, especially where dung and urine have been dropped. These areas will probably grow at a more rapid rate than the rest of the pasture because of the effect of the nutrients contained in the excreta and will be unpalatable, not only because of the presence of the excreta but also because they are relatively more mature than the surrounding pasture. Several workers including Davies (1925), Beaumont et al. (1933), Archibald (1943) and Rogler (1944) have shown that stage of maturity markedly affects palatability of pasture herbage. As the feed supply becomes limited the herd may be forced to eat these clumps but in doing so their production will fall. In order to avoid clumpiness it is necessary to subdivide the farm and practise rotational grazing so that an area can be cleaned up quickly before clumps can develop. This is probably the essence of rotational grazing.

In the original Hohenheim system of rotational grazing a clean paddock was first grazed by the milking herd and afterwards cleaned up by dry stock (Donald (1945)). Complete utilization of the paddock was thus effected. Unfortunately this system cannot be fully adopted on the New Zealand dairy farm for it is only in the autumn that dry cows are available. These can be used to clean up pastures before the winter. Usually there is not sufficient young stock on the farm to clean up behind the milking cows. It is probably not desirable to use either calves or yearlings for this purpose.

As Beruldsen and Morgan have shown that sheep will eat the neglected herbage on a horse-paddock, it seems reasonable to assume that grazing animals are not averse to eating the herbage contaminated with the excreta of other species. Clumpiness of a pasture can therefore be reduced by mixed

stocking. There may be a strong case for having sheep on dairy farms in order to utilize more efficiently the available pasture. This point needs investigating.

Harrowing the pasture to spread droppings should in theory reduce clumpiness and in practice it has been reasonably successful. (Syme (1946)). Harrowing distributes the fertility in the dung so that the whole pasture benefits from the returned nutrients rather than a small area which is not grazed because of its unpalatableness. It is most important to harrow out the droppings that have accumulated during the winter before active pasture growth commences. Harrowing may not be so important later in the season, as the fresh green herbage is a laxative and droppings are more readily scattered and so tend to break up and become incorporated in the soil. It may be argued that harrowing only increases the area of pasture which becomes unpalatable because of soiling but dung which has been broken down will not have such a lasting effect on the unpalatableness of the herbage.

It is often pointed out that harrowing will not spread the urine which also may cause the pasture to become unpalatable. However Southcombe (1947) and Beruldsen and Morgan have noticed that after heavy rain the pasture tends to sweeten up and clumps which formerly were neglected are now eaten. These clumps were possibly rendered unpalatable by urine which is washed away by the rain. Probably urine does not markedly affect clumping to any serious degree, as long as there is sufficient rainfall. However this point needs supporting by experimental evidence.

Clumping may be caused by differential palatability of the species within a sward. A weed such as a strong growing thistle may prevent an area being grazed. Fast growing species quickly mature and consequently lose their palatability and may form an ungrazed tuft which is wasted. The effect of urine and of species differences in palatability may account for the fact that harrowing is not universally successful in reducing clumping.



Figure 7. BULLOCK WINTER-GRAZING COCKSFOOT  
WHICH HAS BEEN SOWN IN ROWS.

The topping of pastures is usually recommended as a desirable practice for eliminating clumps and seed heads so that young grazable herbage is produced from below. The effective grazing area is increased and one would expect higher productivity. Often the cut material is eaten by stock. An increased yield of butterfat must be obtained in order to make the practice economic.

#### Trampling losses.

Trampling losses are independent of the seasonal production of grass and the selectivity of the cow. Soil moisture content will be the major factor which affects them and the biggest losses are likely to occur during the winter when herbage will be trodden into the soil where it will rot and waste. Trampling losses are not likely to be great, though we have no evidence to demonstrate their magnitude, but they occur at an important time of the year when feed is short.

Breakfeeding will reduce trampling losses. If the herd is folded on winter-saved pasture after each milking long enough to obtain a 'belly-full' of grass and then turned back onto a bare paddock on which hay or silage is fed out, the pasture losses will be reduced. It has been suggested that the best practice is to feed out on one paddock which will be puddled badly rather than to puddle the complete farm. This paddock can be ploughed and resown.

Pearson Hughes (1948) at Stratford-on-Avon, England, reports that very little trampling occurred when bullocks were grazed on cocksfoot drilled in rows. (See Figure 7). The beasts puddled the soil between the rows but although the soil was of a heavy texture the puddling was less severe than expected. The damage could be remedied by inter-row cultivation in the spring. Such a method of reducing trampling losses would hardly be economic in New Zealand.

Conclusion.

No figures are available either to indicate the wastage of feed that occurs on pasture grazed by dairy cows in New Zealand or to show the relative importance of clumping and treading losses. There is a real need for such an investigation and a suitable technique for measuring the losses. The relative efficiency of pasture utilization would be indicated by the degree of clumping, and the latter could be measured subjectively by a method similar to that used by Beruldsen and Morgan in their study of the selective grazing habits of various grazing animals. Such a measurement could be used in survey work and be related to output per acre, output per cow, amount of hay and silage made, in order to find the importance of efficient pasture utilization in contributing to high per acre production of butterfat.

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FACTORS WHICH PROHIBIT THE UTILIZATION OF PASTURE.

On the following pages, the factors which prevent pasture being utilized will be discussed, but only those which cause damage to dairy products or to the cow and which are concerned with pasture per se. Thus farm management factors which prevent pasture being grazed - inaccessability, lack of an adequate water supply, imperfect farm subdivision - will not be dealt with. Again, such hazards of grazing as parasitic infections - worms, foot-rot, contagious abortion - or physiological dysfunctions - milk fever, ketosis, grass staggers - will be left out of the discussion, for in these cases the seat of the trouble does not appear to be simply in the plant nor are they likely to debar the pasture from utilization.

During the spring and summer, taints in the cream caused by pasture may prevent certain paddocks being used for feeding. The two main sources of trouble are clover which gives rise to feedy flavour, and taints produced by weeds of which landcress is the worst offender. It is a problem to find a suitable method of utilizing such pastures especially on dairy farms where there are few dry stock to eat them off and they may waste.

There are no figures for the number of stock <sup>AFFECTED</sup> killed by bloat or poisonous weeds in New Zealand. However, after there has been some such trouble on a paddock, a farmer hesitates to put his stock back into it and the feed will be wasted.

Mineral deficiencies of pasture may completely prevent utilization in some areas of New Zealand. However a better understanding of cobalt and copper deficiency has led to the opening up of large areas of dairying on bush-sick and peat-sour land.

These topics will be discussed in detail.

Although pasture is believed to be the most adequate food it can cause

certain troubles. In countries where pasture plays only a small part in feeding livestock, such problems are not serious, for alternative foods may be used. In New Zealand, where almost complete reliance is placed on grass, it goes hard with the dairy farmer when these troubles arise.

#### FEED FLAVOUR.

Levy (1935), conducted a survey in the Waikato on feed flavour in cream. The creams produced from various farm types were tested for 'feediness' during the Spring and Summer months. He concluded that clover dominant swards were the main source of this feed flavour, especially when in a soft luscious condition. After the clover had hardened there was very little trouble.

Riddet and his colleagues (1937) confirmed these results in both grazing and stall feeding experiments, though they found anomalies due possibly to the stage of growth of the herbage, or the time before milking that the material was eaten. They identified broad red clover, subterranean clover, white clover, Montgomery red clover and suckling clover with feediness, but that no serious tainting is caused by the ryegrasses. Campbell (1959) showed that the amount of clover in the ration was important; in stall feeding experiments he fed cows for a 24 day period comparing two rations, one containing 30 per cent white clover which caused no trouble and another of 70 per cent clover that gave a 'feedy' cream. Repeating the trial for 12 days with rations of 30 per cent and 70 per cent lucerne, he found that the former gave a mild taint while the latter gave a strong one.

Levy (1935), observed that the morning milk was comparatively free from 'feediness'. As several overseas workers had found that if taint producing feeds were fed several hours before milking no taint was produced, Levy thought it possible that the feeding habits of the herd might be responsible for the lack of taints in the morning milk. In consequence he made observations through a night on the grazing behaviour of a Waikato herd. The cows rested prior to the morning milking and very little grazing took place.

Thus the habits of the cows accounted for the lack of taints in the morning milk.

This was confirmed by Riddet et al. (1937) in a stall feeding experiment. They showed that feed flavour was reduced by withholding the tainting feed for four hours prior to milking.

Cows should therefore be removed from feedy paddocks several hours before the evening milking, or better still, such paddocks should be grazed at night for here the cows ration themselves.

Levy (1937) continuing his survey work, presents evidence that high producing grassy paddocks do not give rise to feed flavour in the cream and that the trouble was associated largely with farms of low per acre production with clover dominant swards.

He suggested nitrogenous manuring and management methods, to increase the "grassiness" of the sward and so decrease the feed flavour.

It has been shown that feed flavour can be removed from the cream in the factory. Riddet et al. (1940) compared the results of treating clover tainted cream in a vacreator and in a flash pasteurizer. They found that butter from strongly clover tainted cream treated in the vacreator was markedly superior to the cream treated in the flash pasteurizer although in the former the butter was not entirely free from taint.

As feed flavour can now be removed to some degree in the factory, pastures which cause tainting may be utilized with impunity in most cases.

#### LANDCRESS TAINT.

Landcress, *Coronopus didymus*, is a common weed of dairy pastures in New Zealand. It is an annual plant with trailing stems, highly dissected leaves and small white flowers which are hardly visible. It flowers over a long period and is constantly producing seeds which drop off as they ripen. The seeds are in a kidney shaped pod divided into two valves, each of which contains a seed.

The weed appears in the early Spring in pastures which have been opened up during the winter by heavy stocking. Also it may cause trouble in new paddocks which have been sown in the Spring. Allow (1947) has observed up to 502 cress plants in one square yard of spring sown pasture, the average being 106 plants per square yard.

When this weed is consumed by milking cows a strong flavour may be imparted to the manufactured dairy product. The flavour is not readily detectable in the raw cream but it is accentuated by heating.

Allow (1946) quotes a case where two to three gallons of tainted cream added to a 3,000 gallon vat tainted the whole resultant product.

Riddet and Valentine (1932) have described the taint in cheese but McDowall points out that landcress taint is much more serious in butter than in cheese for the flavour is more apparent.

McDowall (1941) reports that the immature plants cause tainting more readily than those that have hardened off. Campbell (1937) fed landcress juice extract from one pound of material which he found to be sufficient to cause tainting in the milk one hour after administration.

McDowall (1947b) from stall feeding and grazing trials, reports that the cream taint appears in milk within half an hour of ingestion of the weed. With some cows the taint is not completely eliminated in four hours and when large amounts of cress are fed the taint may persist through to the next milking. There appears to be a difference of intensity in the taint with individual cows fed over the same period and individual cows vary in their reaction to the weed. Thus Amon. (1944) reports that 40 cows on a badly infested landcress paddock produced good cream over a period of 6 weeks. Possibly these variations in the passage of the taint to the cream are due to the condition of the cow.

Various attempts have been made by the Dairy Research Institute to identify the principle in landcress that causes the tainting. Benzyl isothio-

--cyanate that occur in both landcress and garden cress and water cress was shown not to be responsible.

Allow (1946) and Allow and McDowall (1941) discuss the problem of taint in relation to farm management. They suggest that cress can be eliminated from pastures by encouraging a grass dominant sward in the Spring. This is attained by spelling in the late winter. Cressy paddocks are best utilised with dry stock but if this cannot be done, they suggest that the herd be removed from a tainting paddock at least four hours before milking.

In their experiments, this method did not always give taint-free cream but our present knowledge points to it as the most satisfactory practice.

Other weeds that cause tainting are pennyroyal, camomiles, sweet vernal and water cress. Allow (1946) advocates the same managerial control methods for these weeds as for landcress.

Landcress taint can be removed to some extent in a vacreator. McDowall (1946) reports that a vacreator with new improvements is <sup>ONLY</sup> partially successful, so that it is important that measure be taken on the farm against producing tainted cream which may mean that a pasture cannot be used.

#### POISONOUS PLANTS.

If a paddock is infested with poisonous plants, it may be dangerous to utilize the feed in that paddock. Those plants which are poisonous to stock in New Zealand are not readily consumed unless the animal is hungry. Thus where there is an abundance of feed which is in danger of wasting if not utilized, it is usually safe to turn stock into that pasture although poisonous plants may be present. Also as Connor (1945) points out, New Zealand is fortunate in having so large a native flora with so few toxic plants.

Of these, Tutu, *Corcharia aborea*, is probably the most serious and has since early times been responsible for the majority of stock losses through poisoning in New Zealand.

Early records show that colonists lost up to 25 percent of their stock from Tutu poisoning. In Spring it produces a luscious young growth and poisonings are common. The symptoms are excessive excitement, exhaustion and death. The poisonous principle is Tatin, which is present in the leaves and the seeds of the plants.

Ragwort, *Senecio jacobea*, is the most important exotic weed causing poisoning of cattle in New Zealand. Gilruth (1903) was the first to show that the hepatic cerrhosis occurring in horses and cattle could be reproduced by feeding animals on fresh or dried ragwort.

Hosking and Brandt (1936) isolated the alkaloid toxin from ragwort which was found to produce the symptoms of Winton's disease.

Other examples of exotic weeds causing poisoning in cattle are pennyroyal, *Mentha pugelium* and the sorrels, *Rumex* spp. Cunningham (1948) describes

the disease known as lame foot, or 'fescued' foot, which is caused by cattle eating tall fescue, *Festuca elatior*. Previously this disease was believed to be caused by ergots parasitic on tall fescue, for ergots give similar symptoms.

Poisonous plants may prevent utilization of pasture as well as causing losses of stock.

#### BLOAT.

Determining the actual loss of stock and stock products attributable to bloat is not a satisfactory means of evaluating the seriousness of the bloat problem. Bloat involves loss of time by the farmer spent in watching his herd when they are grazing on pasture that is likely to cause bloating. Also, if a pasture is causing bloat, it may be necessary to remove cows from it and its utilization prevented.

Bloat is associated with vigorous growth of clovers which often crowd

out the grasses and present the animal with a predominantly clover ration. This makes the problem serious in New Zealand, for it is through the use of the clover plant as a synthesizer of nitrogen that pasture improvement is effected. There are no figures published on the incidence of bloat in New Zealand but opinion holds that it is associated with higher production pastures and its occurrence has increased over the past years. It may well be that the percentage incidence has remained ~~xxxxxxx~~ constant but owing to the increase in cow population its occurrence has been more obvious.

Several theories have been put forward on the cause of bloat. It is difficult to study as no satisfactory method has yet been found for producing bloat experimentally. Ferguson (1948) makes the general criticism of the work done so far that it has been directed mainly towards determining the cause of death rather than the cause of bloat.

#### EXCESSIVE GAS FORMATION THEORY.

The excessive gas formation theory postulates that when ruminants ingest succulent and readily fermentable feeds, large quantities of gas are formed. Palliatives, turpentine and formaldehyde, have a sterilizing effect inhibiting further gas formation. However, these might equally well stimulate the eruction reflex.

But Washburn and Brody (1937) and Jacobsen et al. (1942) have shown that green legumes do not produce more gas than other feeds. Cole and his co-workers (1942) have shown that the animal has the ability to eliminate far more gas through eruction than is produced in the rumen. The evidence therefore points against excessive gas formation as being the cause of bloat per se.

#### PHYSICAL DEFICIENCY THEORY.

Cole et al. (1942) put forward the lack-of-coarse-roughage theory as

a cause of bloat. According to this notion, there is an absence of the stimuli which causes belching in bloat-producing foods. Clovers are known to be low in fibre while bloat can be prevented by feeding coarse roughages.

Schalk and Amadon (1923) have shown that rumination depends upon the stimulation of the nerve fibres in the rumen by coarse roughage, indicating that involuntary muscles are involved. However, it is yet to be shown that stimulation of the nerve fibres in the oesophagus or the rumen elicits the act of eruction.

#### SAPONIN THEORY.

McClandish (1933) and Quin (1943) have noted that the saponins in lucerne and clover promote the formation of a very stable foam in the rumen. They believe that this foam prevents the escape of the rumen gasses.

There may well be two types of bloat,- frothy and non-frothy.

Substances such as turpentine, which increase the surface tension, release the gas held as a foam and cure bloat (Clark (1948)). Quin and his colleagues report the successful use of a new drug- a preparation containing a highly polymerized methyl silicone- for treatment of bloat. (Quin et al., (1949)).

#### LIBERATION OF TOXIC MATERIALS.

Ferguson (1948) at Jealotts Hill observed that certain legume juices ( clover and lucerne) are capable of paralysing isolated rabbit intestine, whilst those of grasses rarely have this property. This work develops the possibility that there are substances in legumes that have an inhibitory effect on ruminal movement which prevents the normal eruction of gas.

At Aberystwyth, Evans and Evans (1948a) found similar inhibition effects of clover juice and hydrocyanic acid on isolated rabbit intestine.

They also found that as little as 1 litre of clover juice-- from four pounds of clover -- which contained 200 m.g.m. of hydrocyanic acid was sufficient to cause bloating and death in sheep. The same workers ~~(1946)~~ starved a bullock and two heifers for twelve hours prior to grazing them on to a clover dominant pasture. After 15 minutes the heifers had stopped grazing but the bullock continued for a further 5 minutes. The bullock showed the usual symptoms of bloat while the heifers, though they appeared uncomfortable showed none. Blood samples from the bullock were higher in hydrocyanic acid than those of the heifers. The high content in the blood from the bullock may not cause bloat but may be the result of bloat.

However, these workers believe that one of the aetiological factors of bloat is the absorption of hydrocyanic acid formed by the hydrolysis of cyanogenetic glucosides present in clover.

South African workers, Quin and Van der Wath (1938) showed that complete stasis of ruminal movement in sheep is caused by small doses of K.C.N.

However, Clark and Quin (1945) showed that the quantity necessary varied with the amount of lucerne hay fed. Thus there was an increased tolerance when the rumen was full.

As it is well known that roughage can prevent bloat, Phillipson (1948) of the Rowett Research Institute repeated this experiment with freshly cut pasture and obtained similar results. Further, Clark and Quin found that a sheep, suffering from paralysis of the rumen caused by K.C.N. feeding, was able to eruct gas which had been introduced through a fistula, at the rate of two litres a minute. Phillipson confirmed these results. It was concluded that cyanogenetic glucosides were not associated with bloat.

Ferguson (1949) finds that flavones, present in clover, cause inhibition in isolated rabbit intestine and suggests that they may cause bloat. Kerr and Lamont (1946) suggest that a spasm of the cardiac sphincter muscle is caused

by an allergic shock. The contraction of the cardiac sphincter prevents the escape of gas produced in the rumen. This suggestion is supported by the fact that adrenalin will relieve bloat.

The results of the research work briefly outlined above have not clearly shown the aetiological factors of bloat. Were these known, it might be possible to formulate a method of prevention. Cole et al. (1944) after extensively reviewing the relevant literature on bloat, only suggest one well known preventive measure -- the feeding of roughage prior to grazing.

It is widely held that pastures dominated by clover, especially the improved vigorous types --- New Zealand No. 1, or its English equivalent, S 100 -- are dangerous bloat-producing feeds. Doak (1933) has shown that there is a fairly close relationship between H.C.N content and type in New Zealand white clovers, the best and highest producing types having the highest H.C.N content. If the conclusions of the Aberystwyth workers are shown to be correct by future research, it will be necessary to breed clovers with a low H.C.N content combined with the normal properties of vigour. However, until such time as this is done and until the aetiological factors are clearly known, it would be inadvisable to proceed to breed "bloat proof" pasture strains.

The evidence points to clover as being a bloat-producing feed. Marryatt (1947) suggests that bloat may be avoided by encouraging a grass dominant sward. This can be done by leniently grazing in the Winter. There is a real need for survey research work to be carried out in New Zealand to find the incidence of bloat under various conditions and to provide a basis on which to build further work.

#### BUSH SICKNESS.

Askew and Rigg (1932) find that the principal bush sick areas are those soils derived from volcanic showers, though not all these volcanic soils are

bush sick. Mc Naught (1938) reports the occurrence of the disease in North Auckland and the Waikato -- two important dairying areas.

The disease occurs in both cattle and sheep and has been described by Reid (1923). The symptoms are emaciation and anaemia, loss of energy followed by death. The symptoms appear within five months of pasturing on deficient pasture though cattle are less susceptible than sheep. Post-Mortem examinations show a condition of chronic starvation and extreme emaciation. Hopkirk and Crimett (1928) state that milk yield is adversely affected which they suggest is probably due to loss of appetite.

Askew and Rigg (1932) found that the administration of certain iron salts prevented the onset of the disease. e.g. ferric ammonium citrate. Rigg and Askew (1934) found that limonite was both a cheap and effective curative with both sheep and cattle. However, all deposits of limonite were not found to be equally effective, (Rigg and Askew (1934) (1936) and Grimmett and Shorland (1934)) nor was the curative effect related to the iron content. At Nelson, Rigg and Askew (1936) found that soil which prevented bush sickness was low in iron but high in cobalt, copper and nickel.

As a result of contemporary work in Australia, Askew and Dixon (1936) found that bush sickness in sheep was cured by a cobalt chloride drench but nickel and copper sulphate were found to be ineffective.

Analysis of the limonites which had previously been used, showed that they contained small quantities of cobalt. This was confirmed by Becker and Goddum (1937) using spectrographical analysis.

Several workers including Hopkirk (1937) showed the effectiveness of drenching bush-sick sheep with cobalt. Askew and Josland (1937) found that most of the cobalt was excreted after drenching, demonstrating the need for frequent dosing.

Studies relating to the cobalt content of soil have shown that bush sick areas are located on soils deficient in cobalt. McNaught (1937) found

that healthy soils ranged from 0.33 to 0.94 p.p.m. while bushsick soils ranged from 0.05 to 0.23 p.p.m. However, Kidson (1937) found some soils in known bushsick areas that were abnormally low in cobalt.

Aston (1924) found that red clover from bushsick areas was deficient in iron as compared with plants from healthy areas. These results were not confirmed by Askew and Rigg (1932). Pasture herbage analysed by Askew and Dixon (1937b), Askew and Maunsell (1937), Askew (1938) and Mc Naught (1938), showed that bushsick pastures were generally cobalt-deficient.

The seasonal variation in cobalt content of pastures was studied by McNaught (1938) and McNaught and Paul (1939). Low cobalt contents were recorded in Summer when bushsickness is at its worst. In Winter the content tended to be higher. Close grazing was also found to increase the cobalt content. Stanton and Kidd (1937) found that although the cobalt content of pasture was usually related to that of the soil, some anomalies occurred. However, as McNaught and Paul (1939) point out, the relationship between the cobalt content of the soil, the pasture, and bush sickness is complicated by the fact that animals may consume soil direct.

Askew and Maunsell (1937a), found that an annual application of two pounds of cobalt chloride to a bush sick pasture raised the cobalt content of the pasture sufficiently to prevent the disease. Several workers including Taylor et al. (1938) showed that even smaller quantities may suffice.

COPPER DEFICIENCY.

Among the hazards of dairying on peat swamps in New Zealand, there was an outstanding problem unsolved until a few years ago. The peat swamp area extends over 200,000 acres, much of which is closely settled and intensively farmed. Cunningham (1944) reports that the main areas are in Northland, Waikato, Hawkes Bay, Christchurch and some parts of Southland.

Cunningham (1947) described the symptoms of peat scours in dairy cattle which are characteristically persistent, severe, debilitating scouring. Its occurrence coincides chiefly with the flush period of growth, i.e. Spring, and to a lesser extent in Autumn. Cows do not winter well and with the advent of Spring there is a further noticeable loss of condition. Scouring clears up when the feed 'hardens off'. Milk and butterfat production are reduced. Young stock develop poorly and are more susceptible to parasitic worm infection.

Cunningham presents evidence that this disease is caused by a deficiency of copper, which element is shown to be low in the herbage from peat lands compared with that collected from non peat areas.

Analysis of the animal tissues revealed that the blood and liver of animals on peat lands were low in copper. (Further well known evidence showed that scouring could be cured by administering copper. This cure was found when copper sulphate had been used as a prevention against internal parasites and had been shown to cure scouring.)

Cunningham tried supplying copper to deficient animals by various methods--- by drenching, by adding copper to the drinking water, by spraying copper sulphate solution on hay, by supplying copper licks and by top-dressing-- all of which were successful in curing the scours.

Cunningham and Perrin (1946) found that the most suitable rate of application of commercial bluestone to raise the copper content of the herbage to a safe level, was five pounds per annum, and that an autumn dressing was more effective than a Spring application. After the first year the copper content dropped to a level slightly above that of the untreated pasture, which remained at that level for two years or more. They also found that copper sulphate encouraged better pasture species on deficient land.

Ferguson and his colleagues (1943) investigated the Teart pastures in

Somerset and found that the symptoms of copper deficiency in cattle can be caused by an excess of molybdenum, and they can be counteracted by dosing with copper. Cunningham, influenced by this work, suggests that unthriftness of cattle with anaemia is caused by uncomplicated copper deficiency but that the scouring is due to copper deficiency plus some other factor.

His reasons for suspecting this are as follows:- (a) On certain areas, although the pasture is very low in copper, scouring symptoms do not occur. (b) Scouring coincides with flush growth periods. (c) Scouring is quickly corrected by transferring a sick beast to healthy country and re-appears immediately it is moved back.

Further work will probably reveal the nature and action of this factor.

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THE SOLUTION OF THE PROBLEM OF PASTURE UTILIZATION.

Previously it was shown that the basic factor which causes poor utilization of pasture is the poor fitting of herd requirements with pasture production (figure 1). In order to get better utilization it is necessary to make the curves of herd requirements and pasture output coincide as nearly as possible. There are three lines of approach to the problem.

- A. To conserve pasture surpluses.
- B. To alter the requirements of the herd to fit curve of pasture production.
- C. To alter the pasture production so that it fits the requirements of the herd.

It is unusual for one of these methods to be used with the exclusion of the others on dairy farms, but for simplification they will be dealt with separately below.

A. CONSERVATION OF PASTURE SURPLUSES.

The conservation of surplus grass is of fundamental importance for the efficient utilization of pasture. In order to equate the requirements of the herd with the feed available, it is necessary to diminish the grazing area to a size that can be utilized with the minimum waste during times of high pasture production. The remaining area will be closed up for hay and/or silage. Such stored pasture is used to provide feed during periods of inadequacy of pasture production.

The area of grassland made into hay and silage each year in New Zealand is given in the following table:-

Table 2 : The area of grassland in thousands of acres made into hay and silage.

| Season  | Hay | Silage |
|---------|-----|--------|
| 1930-31 | 295 | 114    |
| 1931-32 | 318 | 114    |
| 1932-33 | 410 | 116    |
| 1933-34 | 378 | 92     |
| 1934-35 | 404 | 81     |
| 1935-36 | 453 | 83     |
| 1936-37 | 425 | 79     |
| 1937-38 | 379 | 65     |
| 1938-39 | 450 | 68     |
| 1939-40 | 481 | 73     |
| 1940-41 | 463 | 71     |
| 1941-42 | 445 | 68     |
| 1942-43 | 390 | 57     |
| 1943-44 | 475 | 53     |
| 1944-45 | 498 | 56     |
| 1945-46 | 403 | 39     |
| 1946-47 | 500 | 40     |

These figures refer to sheep, dairy and mixed farms. They show that there has been a marked decrease in the area made into silage since the years of the depression (1930-1933). This may be partly due to an increasing shortage of labour.

Making hay and silage involves losses. The main loss is in the feeding value and the causes of these losses and the methods used to decrease them are outlined below. It may well be that these are not the only losses, for the production of a paddock may be lowered by closing it up for hay or silage. But firstly hay and silage feeding value losses will be considered.

Hay making.

In making hay the main change that occurs is the evaporation of water to a safe level for storage. When the crop is cut the cells carry on their metabolic processes until they are killed by desiccation. Then again the rate of drying has a considerable effect on the losses concerned in hay making.

The rate of drying depends on the temperature, the humidity of the air, and the rate at which the surrounding air is removed with its load of moisture. Under artificial conditions - grass and mow drying - the rate of evaporation can be controlled to an extent that is impossible in the field.

Evaporation takes up heat from the surrounding air and causes a drop in the drying temperature. Gaardmand (1935) measured the temperature of the air in cocks and racks, finding that the evaporation was often so rapid that the material was several degrees lower than the surrounding air.

The evaporation of water at first will be aided by the process of transpiration which continues after the herbage has been cut. The rate of evaporation will therefore decrease during the drying process as transpiration ceases. Most workers agree that drying is more rapid in the swath than in the windrow but in the former the leaves and stems dry out at a differential rate (Cox 1927). The difference in moisture content may be of the order of 10 per cent. The leaves are therefore more liable to mechanical loss while the wet stems may cause trouble in the stack.

As the living processes continue during hay making, respiration continues to use up the material in the cell. Fleischmann (1912) found that the chief loss was in the nitrogen-free-extract, while there was no change in the crude fibre or ash constituents. Thus the more digestible material is utilized and lost. Although Fleischmann found no loss in nitrogen, but only a degradation of true protein to non-protein forms, Grosemann (1925) states that the crude protein due to enzymatic changes may lose some 15 per cent. This is supported by Houghamp's work (1915).

Wet weather during hay making lowers the rate of evaporation from the plant and in consequence the losses concerned with respiration increase.

Losses due to leaching do not affect the crop until it is partially dried, for while the cell is still alive the protoplasm prevents the loss of its nutrients. Wallace (1930), Mead (1931) and Weigner (1932) have shown that the feeding value of hay decreases with increasing exposure to rain. Minerals are removed and digestibility is seriously reduced.

When the crop is fit for leading, the leaves will generally be dryer than the stem. In consequence they will be more brittle and liable to mechanical loss during harvesting. Their loss is made more serious by the fact that the leaves are richest in dry matter, proteins and vitamins. If possible, rough handling during harvest and over, or differential drying should be avoided if mechanical losses are to be reduced.

Changes in hay are not limited to the field but occur in the stack as well. When stacked, the moisture content of the material will be approximately 25 per cent, and many of the cells will still be respiring. At first respiration will be aerobic but will change to anaerobic when the available oxygen in the stack is used up. Heat will be liberated, raising the temperature of the stack to about 120° F. Gaardmand (1935) working in Denmark found a linear relationship between the moisture content of the hay and the maximum temperature attained in the stack. As in the field, the losses will fall mainly on the most digestible fractions.

Not all the changes are undesirable. The heated hay allows the sugars to burn slightly, rendering the hay more palatable. Overheating will reduce digestibility considerably. Kellner (1915) found that the digestibility of the crude protein of light brown hay was 86.3 % that of dark brown hay 75.1 %, but black hay was only 2.6 % digestible.

Wet patches in the hay may result in focal points of undesirable bacterial activity. If the material is stacked with too high a moisture con-

tent, temperature may rise sufficiently to cause ignition.

The losses that occur in hay making.

Having outlined the hay making process, some figures for the estimation of losses involved will be quoted. Unfortunately there are no reliable reports in the literature of the losses that occur in making hay in New Zealand. The figures quoted here have been found by workers in Europe where the climatic conditions are not unlike those found in New Zealand, though the methods of curing may not be identical.

Watson (1939), working at Jealott's Hill, England, measured the losses in hay making over a period of 5 years. His average results are given in table 3.

Table 3. LOSSES OF FEED CONSTITUENTS THAT TAKE PLACE IN CURING HAY.

| Constituent        | L O S S E S |                |             |                     |             |                |
|--------------------|-------------|----------------|-------------|---------------------|-------------|----------------|
|                    | In field    |                | In stack    |                     | Total       |                |
|                    | Early Hay % | Ordinary Hay % | Early Hay % | Ordinary Hay %      | Early Hay % | Ordinary Hay % |
| Dry matter         | 18.0        | 14.3           | 5.2         | 5.7                 | 23.2        | 20.0           |
| Crude Protein      | 14.3        | 18.5           | 2.2         | 2.7                 | 16.5        | 21.7           |
| Starch equivalent  | 34.5        | 26.7           | 6.8         | 5.3                 | 41.3        | 32.0           |
| Protein equivalent | 23.0        | 33.7           | 9.0         | +4.3 <sup>(1)</sup> | 32.0        | 29.11          |

(1) - gain

During favourable years the losses of dry matter and of starch equivalent in ordinary hay averaged 8% and 10% respectively; in bad years 34 and 47%. With early hay respective losses were 13% and 25% in good years and 23% and 44% in bad seasons.

Although Watson properly replicated his experiments and applied statistical tests of significance, his work can be criticised from the following viewpoint. He placed plots of hay after they had been cured in the field in open mesh hessian which was then built into a large stack of hay. His losses in the stack are probably underestimated, for there are losses at the bottom,

sides and roof of a stack.

A very complete study of losses has been made in Switzerland by Wiegner (1932) covering a period of ten years. His results are summarized in table 4.

Table 4. PERCENTAGE LOSSES IN HAY MAKING, BASED ON THE NUTRIENTS IN THE FRESH CROP.

| Details of treatment and weather | Dry matter | S.E. | D.P.E. |
|----------------------------------|------------|------|--------|
| No rain, no mechanical loss      | 8.7        | 22.6 | 16.5   |
| No rain, mechanical loss         | 14.7       | 38.6 | 22.3   |
| Rain                             | 23.7       | 49.7 | 34.7   |
| 1 - 2 showers, (1 - 20 mm)       | 18.9       | 43.6 | 22.9   |
| 5 - 6 showers, (12-63 mm)        | 27.1       | 54.2 | 38.3   |
| Average of all trials            | 20.3       | 44.7 | 30.4   |

The losses vary from 20 per cent of the starch equivalent under excellent conditions to as much as 54 per cent under poor conditions. As Wiegner's original paper was not available, it is impossible to comment on his technique of experimentation.

Some unpublished data from the New Zealand Grasslands Division (1949) of losses occurring in baling hay from the result of one season's work are given below.

|  |        |
|--|--------|
| Percentage loss of dry matter between cutting and baling | - 40 % |
| " " " " " " baling and feeding                           | - 6 %  |
| Total loss of dry matter                                 | - 46 % |

This figure of loss in dry matter does not indicate the total loss. No work was done on the digestibility, but the losses of starch equivalent and digestible protein equivalent are likely to be far greater.

Great reliance should not be placed on this one set of figures. More

work should be carried out, for hay is the principal method of conserving surplus feed in New Zealand.

Improved techniques of making hay.

These aim at reducing the losses incumbent on the traditional methods, and do so in the following ways:-

1. Making hay from younger material.
2. Protecting the hay in the field by reducing the area exposed.
3. Using methods whereby the hay can be stacked with a higher moisture

content without risk of undue heating.

1. Making hay from younger material. Although a more nutritious product should result and this method is more desirable from a pasture management point of view, it has three grave disadvantages:- (a) the early summer weather is less dependable; (b) as it is more succulent it takes longer to dry; (c) there is a larger proportion of leaf to stem. The former may become brittle and the resultant losses greater.

2. Protecting the hay from exposure in the field. In Scandinavia and parts of Northern Europe stakes, tripods, hurdles and wire or wooden fences are commonly used for drying hay, reducing the mechanical loss and the leaching by rain in wet years. Watson (1939) reviews experiments carried out under favourable conditions showing this advantage to be slight.

In Scotland and Northern England, the hay is built when sufficiently dry into pikes which usually hold somewhere between 6 and 10 cwt. If built carefully, being well trodden and a good slope being given, the pike sheds the rain. Later it is led from the field to the stack. Recently a machine has been evolved which builds pikes automatically, reducing considerably the work involved.

These methods are of great value when the conditions for curing hay are so undependable that unless such procedures were used the material would never be

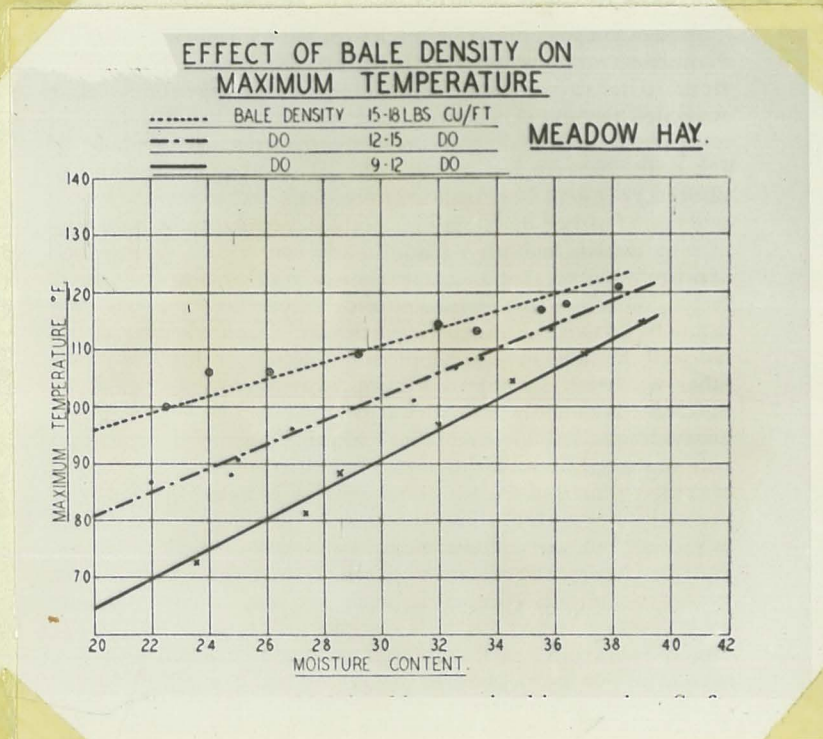


Figure 8. THE EFFECT OF BALE DENSITY ON MAXIMUM TEMPERATURE.

cured.

3. Methods of storing at a higher moisture content. The moisture content at which it is safe to leach hay is about 20 - 23 %. If however by any means the hay could be gathered at a higher moisture content, say about 30 per cent, considerable advantages would be gained. The drier the hay the more rapid does it absorb moisture from a humid atmosphere. This is a further reason why the rate of drying is considerably reduced at lower moisture contents. Another advantage is that by handling the hay at a higher moisture content, the losses from leaf shattering would be reduced.

Recently considerable interest has been centred on baling. The method is gaining popularity in New Zealand.

Cashmore (1938) finds a relationship between bale density, moisture content, and the maximum temperature reached in the bale. (See figure 8 ).

It is generally considered that if losses are to be reduced to a minimum in stored hay, 90° F. is a desirable temperature limit. The formula suggested by Cashmore to achieve this is:-  $D = 30 - \frac{2}{3}M$ , where D is the safe bale density in pounds per cubic foot and M is the moisture content as a percentage. From the figure it will be seen that using a density of 9 - 12 lbs per cubic foot, it would be possible to bale safely at almost 30 per cent moisture content - a factor of great assistance. Risk of mould growth prevents higher moisture contents being used.

The addition of salt to hay during stacking has been a common practice since early times. By this method it is possible to stack hay when it has a higher than normal moisture content. It is generally agreed that the function of salt is to keep the temperature down by controlling bacterial fermentation. Marre (1928) recommends the addition of 1 - 3 lb of salt per 100 lb of hay to a crop at the three-quarter dry stage.

These methods of reducing losses in making hay have at the present very little application to New Zealand dairy farming conditions for usually

the labour requirements are high. Even earlier baling as suggested by Cashmore is unlikely to reduce losses in hay making, for baling in New Zealand is usually carried out by contractors, so that it is difficult to get the work done at the right time. Consequently losses in making hay are not likely to be reduced, and will probably remain somewhere between 30 per cent and 60 per cent of the starch equivalent.

MAKING ENSILAGE.

Although the majority of conserved forage in New Zealand is made into hay, ensilage plays quite a large part in conservation. Here we will consider the changes that occur in the silo, the methods of making ensilage in New Zealand, and the losses involved, and the improved methods which reduce these losses.

Changes that take place in the silo.

Watson (1939) divides the changes into three classes:- the respiration of the living cells; the activity of plant enzymes; and the action of bacteria and fungi.

When green plants are ensiled, the plant cells continue to function, that is to respire, producing carbon dioxide with the gradual exhaustion of any oxygen that may be present in the silo. In this oxidative process the more available carbohydrates are used up first and heat is produced. Thus the temperature attained in the silage will depend largely on the quantity of air present, which in turn depends on the tightness of packing and the imperviousness to air of the silo walls. After the oxygen in the air has been consumed, any available oxygen compounds will be used up with the production of further heat and carbon dioxide.

After the plant cells die, enzymes within the cell bring about the breakdown of complex constituents. Proteins are broken down into amino acids and even ammonia.

The third change in this process is bacterial. On its leaves and stems the crop carries large numbers of bacteria, which now begin to multiply rapidly and it is upon these bacterial changes that the quality of the product is decided. The types of bacteria present depend on the nature of the material and the temperature in the silo, and they are known by the type of acid they produce, namely acetic, butyric or lactic. Among the acids formed, lactic and acetic appear to have a favourable effect on the quality of the silage, while butyric acid, which is the result of putrefactive processes, injures the silage as a feed. The art of silage making is to encourage the right type of bacterial fermentation.

#### Types of silage.

The best type of silage is made when the air has been excluded from the material by compaction and acidification has been rapid. The temperature reached is to a large extent influenced by the degree of compaction, and the ordinary methods of silage making can be divided into:-

- (a) Warm Fermentation process:- mature or wilted herbage is packed in layers, each layer being allowed to heat to the required temperature before the next layer is built on. In stack silage, due to the difficulties in achieving sufficient compaction to eliminate air, high temperatures are often registered with resultant losses in carbohydrates and digestibility.
- (b) Cold Fermentation process:- practised in Northern Europe. The material is chaffed and packed down to eliminate air. However if the mass does not contain sufficient readily available carbohydrates, the rate of acidification may be too low to promote lactic fermentation.
- (c) Low Temperature process:- This method is found to be most suitable for grass. The silage is made in layers, having an interval between each filling to allow the temperature to rise to about 90° F. Consecutive layers consolidate the layer underneath and limit further temperature rise.

Silage making in New Zealand.

Stacking silage is the most common method of making ensilage in New Zealand, though pits are also used. These two methods will be dealt with in this order.

Stack silage. The main practical advantage of stack silage lies in its simplicity. No capital outlay for the silo is necessary and the material can be stacked in any part of the farm, either near where it is to be fed or near the site of harvesting operations. The amount of surplus grass cannot be determined beforehand and stacking provides a method whereby a variable quantity of material can be conserved from year to year. Dibble (1925) states that it is the most suitable method for New Zealand conditions.

Watson (1939) points out that the greatest disadvantage of the stack is the difficulty of compression of the mass and the resultant wastage at the sides. Temperatures are given to reaching relatively high points and the warm fermentation process is usually applied to this type of silage. This rise in temperature causes a depression in digestibility of the resultant product. Woodman and Hanley (1926) found that a temperature of 165° F. in a stack of legume and grass silage gave a product of low digestibility, the protein fraction being most seriously affected.

Coup and his co-workers (1941) made a survey of stack silages in Taranaki, Waikato and Manawatu, finding that one half of the stacks examined showed serious signs of overheating, while 25 % were badly burnt. Not only was the protein content low but its digestibility was seriously depressed. They used the in vitro pepsin soluble method of determining protein digestibility which is rather a dubious method, though Woodman (1930) and other workers have used it with fair success.

Pit silage. Pit silage is also made in New Zealand but there are no figures available to show how much grass is ensiled by the two methods. Pit silos are less common however. The pit is excavated to a depth that is above the

water table and is then filled with the green material. The bottom may be sloped in order to allow for drainage though pits are probably limited to farms where the soil is firm and well drained.

Deem (1925) describes pit silos which are dug into the side of a hill. The topography of the area can be used so that filling can take place at the high end, and leading away from the lower end. Such pits are most satisfactory when lined with concrete. The main disadvantage of the pit is that it may not be possible to locate it in the most advantageous place for filling and emptying.

In comparison with the stack, the pit is more efficient in excluding the air; there is less wastage at the sides, and the maximum temperature is lower, so that the food value can be expected to be higher and the total wastage less. Sill and Sears (1942) made an investigation into the losses in pits. These losses ranged from 20 to 30 per cent of the dry matter. However, small experimental pits holding only two tons were used so that these figures may be overestimates.

A comparison between pit and stack silage was made by Sears (1947). The average losses recorded after 800 tons of material had been ensiled was as follows:-

Table 5 a. Total % Dry Matter losses.

|            | <u>Stack</u> | <u>Pit</u>  |
|------------|--------------|-------------|
| As wastage | 10.8         | 3.3         |
| As exudate | 3.2          | 6.1         |
| Invisible  | 27.4         | 25.3        |
| Total      | <u>41.4</u>  | <u>34.7</u> |

Table 5 b. % Losses of Total Digestible Nutrients.

|                   | <u>Stack</u> | <u>Pit</u> |
|-------------------|--------------|------------|
| Dry Matter        | 50.9         | 41.9       |
| Crude Protein     | 72.8         | 61.3       |
| Crude Fibre       | 33.5         | 18.3       |
| N-free Extract    | 58.8         | 55.0       |
| Total org. Matter | 60.0         | 46.8       |
| Ash               | 49.2         | 47.1       |

As the current methods of silage making involve such high losses of feeding value, it is necessary to examine in some detail the improved methods of making silage which reduce these losses, to see if they have any application to New Zealand dairy farming conditions.

Improved methods of making ensilage.

Several methods have been used for improving ensilage making especially to meet the requirements of conserving young grass without undue loss. The methods can be divided into three groups:- physical and mechanical devices, fermentation, and direct acidification.

Compressing by mechanical devices has not been very successful, but it is used to a limited extent in making cold fermentation silage. Sterilization by the use of carbon dioxide, carbon disulphide, sulphur dioxide, formic acid, formaldehyde, common salt or steam requires special equipment involving expense, and results have shown very little improvement over the usual methods.

Stimulation of lactic acid production has been attempted by inoculation with bacterial cultures. However, normally the fresh crop has an extensive microflora, and in consequence inoculation with bacterial cultures has never really been successful.

While it is perfectly feasible to ensile high carbohydrate crops successfully because the acids produced at the expense of the sugars and starch act as a preservative agent, it is more difficult to ensile a protein-rich, high moisture content crop by the same method, without undue loss. In the

case of crops with low starch and sugar content, the development of the organic acids in sufficient amount to act as a preservative agent is prevented. Thus some fermentable material should be added to ensiled young grass.

Molasses has been used with much success (Watson (1939)), while potatoes have been tried. Unless the latter are thoroughly mixed with the material the lactic acid fermentation may only be stimulated in patches. Ordinary whey can be added as a substitute for molasses. Excellent silage can be made by the use of dry or concentrated whey either alone or inoculated with lactic acid bacteria. Allen and his coworkers (1937) found no greater losses in silages made with whey than silages made with either molasses or by the A.I.V. method.

The reason for a dominance of a lactic acid fermentation under optimum conditions is that these organisms can withstand and continue their activities under more acid conditions than the other types. If the acidity of the mass can be raised rapidly by external means, then only lactic acid fermentation can progress. A.I. Virtanen in Finland has patented the so-called A.I.V. solution consisting of five parts concentrated hydrochloric acid mixed with one part of concentrated sulphuric acid and diluted with five parts of water. (Virtanen (1933)). Watson (1937) conducted seven accurate trials at Jealott's Hill with silage made by different methods. The dry matter losses for the A.I.V. method, the ordinary method, and the molasses method were 17.7, 18.2, and 16.1 respectively, while the losses of protein were 3.8, 5.7, and 5.4 respectively. These results were at variance with those obtained by Virtanen (1937), whose work indicated that A.I.V. silage does not suffer a loss greater than 8 % of the dry matter, and in most cases the loss is nearer 3 %.

The successful improved methods of silage making offer possibilities of reducing losses in feeding value of conserved pasture and producing a resultant product which is capable of supporting high butterfat production. Sears and Sill (1941) show that the feeding value of ordinary New Zealand silage is

low, having a starch equivalent of about 40 to 45 and a crude protein content of from 10 to 12 per cent. Such feed is only suitable as a maintenance ration for dairy cows but there is a great need in New Zealand for a milk-producing feed for summer feeding.

Therefore these improved methods of silage making should have some application on dairy farms. <sup>GOODBANK</sup> Sears (1947), in New Zealand, used acid in pit silos and lowered the losses. However, the resultant product was so unpalatable to dairy cattle that they refused to eat it. This difficulty has been also found by English workers (Watson (1939)), and the labour involved in applying acid, neutralizing the silage before feeding, and the high cost of acid in New Zealand, would probably prevent the adoption of this method, however effective it was in reducing losses. The A.I.V. process has found but little support in either <sup>2 Britain</sup> England (Moore (1942)) or America (Le Clure (1937)) but it is used quite extensively in Northern Europe.

The addition of carbohydrate to immature grass so that losses, especially protein losses, are reduced would appear to have possibilities in New Zealand. Whey, a by-product of the Dairy Industry, could be utilized for this purpose, but it would be necessary to dry it first, which would add to its cost. <sup>Sill</sup> Sears (1942) added molasses to 2-ton silos, finding that it had no effect in reducing losses. This appears at first to be contrary to the results found by Watson (1939) in England, but the material that Sears used was relatively mature and probably had a high carbohydrate content already. In other experiments with very immature material only 30 lb of molasses were added per ton of green matter, while 50 to 60 lb are usually considered adequate to reduce the losses (Whyte (1939)).

The use of carbohydrate materials has not been properly tested under New Zealand conditions. Further work should be carried out in which whey paste, molasses, acid and the ordinary methods of silage making should be compared under properly controlled conditions.

### Other possible methods of conservation.

Grass drying has recently become quite popular in Britain. It is being organised on a co-operative basis by the Milk Marketing Board. It provides the most efficient method we know for conserving surplus pasture; the only possible loss, given proper drying, is mechanical during the actual process. Watson (1939) has shown that the loss in dry matter does not exceed 5 per cent while Woodman, Bee and Griffith (1936) have shown that there is no depression in digestibility. Although technically an efficient process, it is doubtful if it would prove economical under New Zealand dairy farming conditions.

Mow drying, a process of mechanically blowing cold air through partially field-cured grass, is not likely to have much application in New Zealand, as the apparatus requires extensive buildings, the labour requirements are high, the nutritive value of the resultant material is only of the same quality as excellent hay, and mould growth is common. The method is still being developed and may have application on the small farm in Europe. (For a review of the work on this method, see Grinstead (1947)).

### The effect of conservation on pasture production.

It is well known that a pasture deteriorates if it is cut year after year for hay or silage. This may often happen when a paddock is inaccessible to the herd because of faulty farm layout. By closing a paddock for conservation, the return of nutrients, so important in the soil fertility cycle, is prevented. The nutrients lie idle in the stack or pit and are often not returned to the paddock from whence they came. Clover, which is the basis of high production pasture, will tend to be suppressed, for it is a plant demanding light. It would be relevant to mention here that the improved strain of clover, New Zealand no.1 white clover, is more shade-enduring and it is not so likely to be suppressed. Pastures tend to be opened up

after cutting, which leads to the ingress of weeds. Although these factors tend to lower the future production of pasture, it must be borne in mind that the output of dry matter will be higher when cut for hay or silage than when grazed, though the quality may deteriorate somewhat. This may be unimportant however when only maintenance feed is required for winter feeding.

Silage-making has the advantage in that it is usually cut at an earlier stage of growth than hay so that the pasture is less likely to be opened up and the clovers are unlikely to be suppressed to any marked degree. Also, as silage is cut early, the paddock has more time in which to recover before the dry summer months. Paddocks closed for hay and cured after mid-December when the crop is in an advanced stage of maturity will not be able to recover rapidly because of the onset of dry weather. It is well known that once a pasture plant has accomplished flowering it does not return quickly to the vigorous production of vegetative growth, and this process will not be assisted by a low incidence of rain. However, in areas where paspalum contributes to a large extent to the production of a pasture, hay-making is more successful in this respect, as paspalum is a more drought-resisting plant than ryegrass.

Silage has a less deleterious effect on pasture productivity than hay and the fact that the area made into silage each year has been declining may be looked upon with some concern.

We may conclude that although the losses involved in making hay and silage are considerable there are methods by which we can reduce these losses but they may not be economically efficient. However in order to obtain efficient utilization of pasture it is necessary to conserve pasture until such time as other methods are developed sufficiently to take its place.

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B. ALTERING THE REQUIREMENTS OF THE HERD TO FIT MORE CLOSELY THE CURVE OF PASTURE GROWTH.

We shall discuss below the ways in which it is possible to alter the requirements of the herd for pasture so that these requirements more closely fit the curve of pasture production.

On dairy farms where seasonal factory supply is practised, the highest requirements of the herd almost coincide with the flush of pasture growth - (See Figure 1). The higher the level of output of the herd, the more nearly do the herd requirements fit the curve of pasture production. On town milk supply farms however the requirements of the herd remain relatively constant throughout the year because of all-the-year-round-calving. In consequence, the surplus of pasture during the spring will be greater so that the pasture utilization problem becomes more difficult. In Britain, the highest requirements of the dairy herd fall during the winter period which makes the use of grass for milk production complex and emphasis is being placed on reducing the losses in conservation by making silage and artificially drying grass.

If the stocking rate of a dairy farm is raised, pasture utilization can be expected to be more efficient as the surplus in the spring is reduced. This may account for the relationship between high stocking rate and high output of butterfat per acre found by Fawcett (1929). However, if no special provision is made for feeding the herd during periods of deficient pasture growth - winter and the late summer - the yield of butterfat per cow may be so reduced that the output per acre of butterfat may be lowered.

The probable importance of proper feeding during the winter and its relationship to output of butterfat in New Zealand has been pointed out by Hamilton (1944) who finds a positive correlation ( $r = + .77$ ) between the area cut for hay and silage in one year and dairy production in the following season (see Figure 14).

Further work in New Zealand, at Ruakura and in the Manawatu (Lees,

McMeekan and Wallace (1948)), and Campbell and Flux (1948) shows that widely different levels of nutrition during the dry period affect the production of cows during their subsequent lactation. Thus at Ruakura the difference in butterfat production between two groups of cows fed at high and low planes of nutrition prior to calving were 26 lb, 63 lb and 60 lb per cow in the first, second and third years of the experiment, respectively. The corresponding differences in the Manawatu experiment were 23 lb, 28 lb and 25 lb. The differences in the two levels of feeding were probably greater than is found in practice.

Another trial conducted in the Manawatu (Riddet et al. (1942)), showed that a subnormal plane of nutrition during the summer months depressed both the milk yield and the content of solids-not-fat in the milk. This latter constituent is important from the cheese-manufacture point of view. Thus a high stocking rate would tend to give a lower plane of feeding during the periods of pasture deficit - winter and late summer. Thus it is important that, in raising the stocking rate, there should be some practice of providing feed during these periods so that the output of butterfat per cow is not depressed to the extent that total production is reduced.

The practice of making hay and silage has been discussed in the preceding pages. In this section we shall give some consideration to the practice of adjustment of the stocking rate and cropping as methods of providing feed for stock during the periods when there is a shortage of pasture.

### ADJUSTMENT OF STOCKING RATE.

In some localities it is possible to winter stock off the farm and so obtain a better utilization of the flush pasture growth. The Romney Marsh sheep-fattening pastures are a good example of how adjustment of stock numbers can aid in giving efficient utilization. Wethers to be fattened are run on surrounding downland country during the winter and are brought down onto the Marsh pastures in the spring. As these wethers fatten they are removed from the pasture so that the numbers of stock are adjusted to fit the fluctuating growth of the pasture.

The practice of wintering dairy cows off the farm is a common one in New Zealand. The applicability of the method depends on the availability of run-off land and the cost of such winter grazing. The system not only allows more efficient utilization but prevents overgrazing and pugging in the winter so that pasture deterioration from these causes is prevented.

### CROPPING.

By growing arable crops for feeding to the herd during periods of deficit, the demands of the herd for pasture during these times may be reduced so that sufficient stock may be carried to utilize more efficiently the flushes of pasture growth. On many New Zealand dairy farms this method is combined with conservation practices.

Another example from English farming may be cited here to illustrate this point. On the bullock-fattening pastures on the East coast of Northumberland store bullocks are brought in to feed off the autumn flush of grass. They are stall-fed during the winter on mainly arable crops, viz., turnips, swedes, oat-straw and oats, together with a certain amount of 'seeds' hay. They are turned out in the early summer on the flush of pasture and are removed as they fatten. Thus the requirements for pasture are equated with pasture growth, giving efficient utilization.

The crops grown in New Zealand for dairy cows are soft turnips, rape,

chou moellier, kale, cabbage, maize, and Japanese millet which are used for summer feeding, while crops suitable for winter feeding are swedes, mangels, sugar beet and pumpkins.

There is a considerable area of grassland on dairy farms which needs renovating and often it is convenient to plough and sow an arable crop before reseeding. Usually it is undesirable to attempt to sow down grass in the spring because of weed competition and severe checks imposed by the dry summer weather. Thus a piece of land sown for a winter arable crop may be out of pasture for two seasons. However, a pasture ploughed in the spring and sown for a summer crop will only be up for one season, for it can be re-sown in the autumn.

Now this has considerable bearing on the comparative yields per acre of crops and pastures. Such a comparison is shown in table 6.

Table 6. The comparative yields in terms of starch equivalent per acre of crops and pastures.

| Feed.              | Green matter per acre.<br>(in tons) | S.E. Value. | lb S.E.<br>per acre. |
|--------------------|-------------------------------------|-------------|----------------------|
| (excellent         | 30                                  | 13          | 8736                 |
| Pasture (very good | 20                                  | 13          | 5824                 |
| (poor              | 10                                  | 9           | 2016                 |
| Soft turnips       | 20                                  | 44          | 1971)                |
| Green maize        | 30                                  | 8           | 5376) Summer         |
| Chou Moellier      | 15                                  | 12          | 4032)                |
| Swedes (good)      | 45                                  | 7           | 7056)                |
| Mangels (good)     | 60                                  | 7           | 9408) Winter         |
| Sugar beet (good)  | 30                                  | 15          | 10080)               |

Although the winter arable crops outyield pasture, it is doubtful if this would be the case when considered over two seasons.

Cropping requires additional labour and capital. The crops are subject to disease and weed infestation which may make them unreliable. Their full utilization is often difficult, especially winter crops on soils where pugging is a serious problem. These disadvantages must be balanced against the advantage of obtaining a fuller utilization of pasture.

C. ALTERING THE CURVE OF PASTURE PRODUCTION  
TO FIT THE REQUIREMENTS OF THE HERD.

Although New Zealand has a climate eminently suitable for all-the-year-round production, there are two periods of low productivity, - winter and late summer. If these two gaps can be bridged, not only may we expect a higher production of grass but, because the requirements of the dairy herd will follow more closely the production of grass, we shall obtain more efficient utilization of pasture.

Seasonal variation in productivity of pasture is largely dependent upon the plant's external environmental conditions over which the dairy farmer has very little control. However, it is possible to alter the moisture content of the soil by irrigation and so maintain pasture production through the summer dry period. Irrigation has proved valuable in Central Otago (Calder (1940)), but it has not yet been tried on the dairy farms of the North Island of New Zealand. Experiments are now in progress at the Soil Fertility Research Station at Hamilton on overhead irrigation of pasture but no results have yet been published.

To obtain a seasonal spread of production in conformity with herd requirements, advantage can be taken of the different seasonal characteristics of the various pasture species and strains. These characteristics can be brought to the fullest expression by proper pasture management.

It is also possible to store in the field pasture which has grown in one period, for consumption during another. It is not possible to store the early summer flush in this manner as the pasture tends to continue growing and its quality will deteriorate. However, the autumn flush of pasture may be stored in situ, where it will continue to grow only slowly, and will not tend to deteriorate in quality, as growth will be vegetative. McIlroy and Bartrum (1940) have shown that the nutritive value of this autumn saved pasture is high. This aspect will be discussed after dealing with the use

of various species and strains to obtain a better spread of pasture production.

### The Ryegrasses.

The ryegrasses have probably contributed more to the high grassland productivity of New Zealand pasture than any other imported grass species. Among the economically important characteristics of the ryegrasses is the ability to produce during the winter and early spring. It is this characteristic which is exploited in order to assist in spreading the seasonal production of pasture.

There are four ryegrasses of agronomic importance in New Zealand:- perennial, Italian, short-rotation and Western Wolths, from which pedigree strains have been produced. A comparison of the seasonal production of perennial, short-rotation and Italian ryegrasses during the first 18 months after autumn sowing is shown in table 7. The figures refer to the dry matter production of ryegrass only in a ryegrass/white clover pasture. (Corkill 1949).

Table 7. Perennial, Italian and short-rotation ryegrass production. (in lb dry matter per acre of ryegrass).

| Species        | Winter <sup>x</sup> | Spring | Summer | Autumn | Winter |
|----------------|---------------------|--------|--------|--------|--------|
| Perennial      | 369                 | 2283   | 2150   | 1774   | 853    |
| Short-rotation | 953                 | 2881   | 2450   | 1374   | 1545   |
| Italian        | 1206                | 2984   | 1760   | 515    | 1074   |

x = 2 months only.

Although perennial ryegrass has a high winter yield in comparison with other permanent pasture species, its yield is much lower than that of the shorter lived ryegrasses. Under the high fertility conditions at Palmerston North, its winter production is about 25 per cent of the maximum spring production, whilst the relative figure for short-rotation ryegrass is about 50 per cent. Italian ryegrass shows a seasonal spread of production

similar to short-rotation ryegrass except that it produces less in the autumn.

Short-rotation ryegrass and Italian ryegrass can be used for increasing the winter productivity of permanent pastures though their persistency is low and only with careful management can these useful species be maintained in the sward. They are of more use in temporary pastures with red clover to provide summer feeding as well. Corkill (1949) in trials at Palmerston North presents evidence that the pedigree strains of Italian ryegrass are more persistent than the certified commercial strain. Survival counts made on these two strains in replicated plots of individual plants show that in the second year 83 per cent of the plants of the pedigree strain survived while only 5 per cent of the commercial strain remained. Thus it is important that the pedigree strains are used in temporary pasture seed mixtures. Short-rotation ryegrass is intermediate between Italian and perennial ryegrass in persistency but its persistency can be altered by management. Under continuous grazing, short-rotation ryegrass may be little better than an annual but under a lenient system of grazing combined with high soil fertility it approximates to a perennial. Levy and Sears (1949) subjected a complex mixture containing short-rotation ryegrass to different grazings:-

1. Close and continuous (at 1 in. continuously)
2. Sheep rotationally grazing (up to 3 - 4 in., down to 1 in.)
3. Dairy rotationally grazing (up to 8 - 10 in., down to 2 in.)

The botanical analysis on a dry weight basis is shown in table <sup>8</sup>.

The table shows "the failure of the short-rotation ryegrass under close and continuous grazing, and its dominant position in the sward (at that time of year) when under rotational grazing with long spells between grazings."

Table 8 . The Botanical composition of a pasture after being subject to three different grazings as at 1:10:47.

|                           | 1<br>Continuous<br>Grazing | 2<br>Short spell<br>Rotational<br>Grazing | 3<br>Long spell<br>Rotational<br>Grazing |
|---------------------------|----------------------------|---|--|
| Perennial ryegrass... ..  | 43.3                       | 41.6                                      | 31.1                                     |
| Short-rotation ryegrass.. | 2.9                        | 21.7                                      | 40.2                                     |
| Timothy.. ... ..          | 6.8                        | 1.2                                       | -  |
| Cocksfoot ... ..          | 1.0                        | 3.2                                       | -  |
| Other grasses ... ..      | -                          | 4.0                                       | 0.7                                      |
| White clover. ... ..      | 42.4                       | 24.3                                      | 23.3                                     |
| Red clover... ..          | 2.8                        | 2.8                                       | 4.2                                      |
| Other species ... ..      | 0.8                        | 1.2                                       | 0.5                                      |

Western Wolths ryegrass is an annual variety of Italian ryegrass characterized by an even greater winter production than other ryegrasses. The object of using this strain is to obtain a flush of pasture growth for the first six months after autumn sowing. The present strains of Western Wolths are not persistent enough to carry production into the spring. More persistent strains should be developed.

#### The Clovers.

The clovers are principally summer growing pasture plants. The strain-investigational work of Levy and Davies (1929) produced lines of white clover based on Type 1 ecotype which have been selected for extended seasonal growth. However the red clovers are most suited to late summer production. There are two varieties of red clover used in seeds mixtures in New Zealand: broad red clover, which is a double cut variety, and Montgomery red clover, which is a single cut variety. The pedigree strain of Montgomery red clover is more persistent than the strain which was imported 20 years ago. Montgomery red clover is used in conjunction with short-rotation ryegrass for a special-purpose pasture providing winter and late summer feed.

### Special-purpose pastures.

A special-purpose pasture is a pasture that is designed to supply feed at a certain time of the year. To do this, a planned seeds mixture must be sown and the pasture must be correctly grazed and managed. Levy and Sears (1948) recommend the inclusion of short-rotation ryegrass and Montgomery red clover in permanent pasture mixtures, which under lax grazing management should provide feed in both winter and late summer, thus extending the productive period of the paddock. The importance of lax long-spell rotational grazing in order to give maximum yield over the dry summer period is illustrated by the following table.

Table 9 . Showing the effect of three different grazings on the botanical composition and the yield of a pasture, during the period 8th Dec. 1947 to 22nd March 1948

|  | 1                     | 2                                    | 3                                   |
|--|-----------------------|--------------------------------------|-------------------------------------|
|  | Continuous<br>Grazing | Short spell<br>Rotational<br>Grazing | Long spell<br>Rotational<br>Grazing |
| <u>% Composition</u>                                       |                       |                                      |                                     |
| Ryegrasses   | 37.3                  | 48.8                                 | 20.4                                |
| Timothy  | -                     | 0.5                                  | Trace                               |
| Cocksfoot  | 0.6                   | 1.0                                  | 0.8                                 |
| Other grasses  | 1.6                   | 3.5                                  | Trace                               |
| White clover   | 54.7                  | 31.8                                 | 21.4                                |
| Red clover   | 5.1                   | 12.1                                 | 55.3                                |
| Other species  | 0.7                   | 2.3                                  | 2.1                                 |
| <u>Yield for period</u><br>(in lbs dry<br>matter per acre) | 2900                  | 3400                                 | 5100                                |

Under close and continuous grazing the sward is stabilized at perennial ryegrass and white clover which yields relatively poorly through the dry summer period. However long-spell rotational grazing encourages the red clover which produces abundantly during that period.

Levy and Sears (1948) also suggest seeds mixtures for ultra-special-purpose pastures of a semi-permanent nature. Such a seeds mixture contains short-rotation ryegrass, perennial ryegrass, Montgomery red, broad red and white clover. This pasture should be leniently grazed during November and

December to give the red clover an opportunity to grow and a chance for the short-rotation ryegrass to seed. There will be a feed of red clover mixed with ryegrass roughage for the herd during the summer until mid-March, when it should be cleaned up to give the short-rotation ryegrass seedlings a chance to establish. After this the pasture is spelled for winter grazing and early spring feed which will be produced mainly by the ryegrasses.

These writers also suggest a similar mixture containing paspalum for use in the Northern dairying areas which requires similar management. Another mixture of a temporary nature consisting of Western Wolths ryegrass, perennial ryegrass and broad red clover is suggested. During its first winter it would provide a bulk of feed, due to the Western Wolths ryegrass; an early crop of silage could be taken during the early spring, followed by a spell to allow the development of the red clover which comes away for the late summer grazing.

Davies (1944) gives examples of seeds mixtures for both summer and winter production for English conditions. Like Levy and Sears he bases mixtures on late flowering red clover to provide feed for the summer gap, but suggests Aberystwyth strains of Timothy and meadow fescue for winter growth. These species are also summer producers.

A method of providing pasture during the summer which is gaining favour in England is the sowing of new pastures in the spring. The young grass provides nutritious feed during the months of July and August. This method of sowing is unpopular in New Zealand because of serious weed competition.

#### Pampas grass.

Pampas grass may be cited as an example of a special-purpose pasture, for it provides feed for both winter and summer. Lynch and Osborn (1948), from the results of a survey, consider that it grows satisfactorily in all the main dairying areas but is only of minor importance in the Manawatu.

With a few exceptions, the warmer, higher rainfall districts of the North Island of New Zealand are the areas where pampas is considered a useful plant.

The young plantation is often difficult to establish and is not ready for grazing usually until 18 months afterwards. Unfortunately it has a low nutritive value (Shorland and Brooker (1935) and Coup and Dunlop (1945)) but it is very palatable. The fact that it is only a maintenance food is not important when it is required for winter feeding prior to calving though it is unsuitable for summer milk production unless supplemented.

#### Autumn- or Winter-saved pasture.

Autumn- or winter-saved pasture is grass which is grown during the autumn flush period and held in 'cold storage' in the field during the winter for use in the late winter and early spring period. It can be seen from Figure 1 that the herd calves down about a month to six weeks before active pasture growth commences in the spring. This interval depends upon the season. Although the gaps can be filled by using hay and silage, usually these feeds are not adequate production rations and we need to look elsewhere to find a ration suitable for supporting high butterfat production during this period. Requirements can be met by the use of autumn-saved grass in conjunction with hay and silage.

The time of closing varies, - with the time at which it is to be used, the condition of the pasture, and the district. The aim is to have a leafy sward of about 9 inches high (Lees (1948)). If the herbage is allowed to grow too long it will rot at the base, become unpalatable and waste. Also long winter-saved pasture tends to encourage prairie grass, cocksfoot and Yorkshire fog while it suppresses clover.

#### CONCLUSION.

The use of special-purpose pastures combined with suitable management practices appears to have the greatest possibilities in the equation of pro-

duction of grass with herd requirements. Making hay and silage involves considerable losses and the improved methods of conservation hold out but little hope of reducing these losses and increasing the quality of the product. Also the closing of paddocks for conservation probably causes deterioration of the sward and loss of future production. Making hay and silage and feeding it out accounts for a considerable proportion of the labour required to produce butterfat, while cropping is known to be costly, but this last may fit into a general scheme of pasture renovation.

Adjustment of stocking rate is a satisfactory method of equating requirements and pasture production for the individual farmer. From a national point of view it is undesirable, for it is hoped that the land now used for off-wintering cows may be utilized to better advantage in the future.

The species used in special-purpose pastures demand high fertility conditions. Until the level of fertility of a farm has been raised by judicious management and manuring to a level high enough to support these strains and to produce out-of-season grass, it will be necessary for farmers to continue to make hay and silage, to crop, and to winter cattle off the farm. Even then these practices are likely to continue, but to a more limited extent. The first step in equating herd requirements and pasture production is to raise the level of fertility of the soil.

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THE UTILIZATION OF PASTURE  
IN RELATION TO  
ITS FUTURE PRODUCTION.

Up to now the discussion has been centred round the losses that are experienced when a pasture is subjected to grazing. The utilization of a pasture will have a profound effect on its future rate of production, seeing that a pasture is a biotic climax, an equilibrium that is evolved between the plant community on the one hand and the animal grazing it on the other.

An alteration in the grazing factor will bring about an alteration in the structure of the plant community.

Throughout this thesis the effect that utilization has on the future production of the pasture is considered, but there are three important points that will be discussed in the following pages. They are:-

(a) The effect of overgrazing the pasture in the winter, and undergrazing it in the summer. This is the direct result of an inefficient pasture utilization.

(b) The severity or closeness of grazing to which the pasture is subjected. In order that complete pasture utilization might be obtained, a paddock should be grazed down hard. This will have an effect on its production which will be discussed.

(c) The effect that efficiency of utilization has on that of

SHOWING THE INFLUENCE OF METHOD OF GRAZING TOGETHER  
 WITH MANURING ON THE BOTANICAL COMPOSITION OF A  
 "TUMBLE-DOWN" SWARD AFTER TWO YEARS TREATMENT  
 JULY 1933

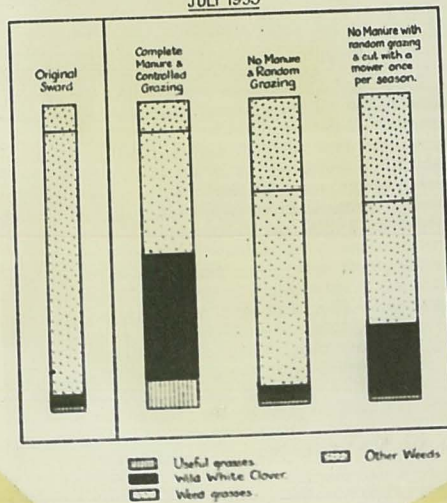


Figure 9. THE BOTANICAL COMPOSITION OF A PREVIOUSLY UNIFORM SWARD AFTER THREE YEARS OF DIFFERENTIAL TREATMENT.

rotational grazing as a method of increasing pasture productivity.

(a) The effect of overgrazing in the winter and undergrazing in the summer.

If measures are not taken to equate the production of pasture with herd requirements, then the pasture will be undergrazed during the summer and overgrazed during the winter. Jones (1933) at Jealott's Hill, England, carried out the following experiment in which he subjected a newly sown clover sward to the following treatments among which was the treatment mentioned above.

1. Hard spring grazing in order to punish the ryegrasses.
2. Lenient spring grazing to encourage ryegrass which then had a shading effect on the light-demanding clovers.
3. Rotational grazing, where the stock numbers were adjusted to the feed supply. The pasture was given about a month between grazings.
4. Undergrazing in the summer and overgrazing in the winter.

The trial was carried out over a period of three years. In Figure 9 the effect of these treatments on the botanical composition is shown diagrammatically.

Hard spring grazing suppressed ryegrass and encouraged a clover-dominant sward. With a spring rest, the ryegrass was encouraged and it suppressed the clovers. Rotational grazing with adjustment of stock numbers gave a well-balanced ryegrass/white clover sward, while undergrazing in the summer and overgrazing in the winter showed a decrease in both ryegrasses and white clover with an increase in weeds and weed grasses.

A perennial plant is most susceptible to the influence of defoliation in the early stage of its active growth period (Donald (1946)). Thus hard winter and early spring grazing weakens the early growing ryegrasses. The light-demanding clovers are suppressed during the summer by undergrazing as they cannot compete with the shade-demanding plants such as Yorkshire fog or bent.

Levy (1940) reports that overgrazing during the winter in New Zealand

tends to open up the pasture which leads to a crop of *Ranunculus* species, *Cirsium lanceolatum* or *Mentha pulegium* in the following spring. There is a weakening effect on the sward as a result of shading when a paddock is closed up for conservation, or undergrazed. The light-demanding white clover and perennial ryegrass tend to be eliminated at the expense of shade-demanding plants - cocksfoot, timothy, Yorkshire fog and paspalum. After cutting a paddock, the pasture is opened up and weeds may invade the sward. Undergrazing in the summer or summer conservation tends to reduce those plants which contribute most to the spread and yield of pasture. Thus inefficient pasture utilization so affects the botanical composition of the sward that the problem of utilization becomes progressively more difficult as the spread of production is reduced. Solving utilization problems by making hay and silage has the same effect.

The New Zealand dairy farmer tends to have a high stocking rate so that the flush spring pasture is utilized more efficiently. On most farms, this involves heavy overstocking in the winter. An increase in pasture weeds may be expected and a decrease in the ryegrass content of the sward which will lower winter pasture production so that utilization problems may be expected to become more serious.

Understocking during the summer results in a 'clumpy' pasture. These clumps contain the mineral nutrients which would have been returned to the soil in the form of stock manure if the herbage had been grazed. Now farm animals only retain a small proportion of the nutrients they consume. Levy and Sears (1948) give some figures on the percentage retention of nutrients by various classes of stock. Although the milking cow retains more than other classes of stock, as shown in the following table, 75 per cent of the nitrogen and 90 per cent of the ash constituents are returned to the soil.

Table . Percentage of nutrients retained by animals.

|                 | Nitrogen |      |       | Ash constituents |              |
|-----------------|----------|------|-------|------------------|--------------|
|                 | Retained | Dung | Urine | Retained         | Dung & Urine |
| Milking cow     | 25       | 18   | 57    | 10               | 90           |
| Fattening sheep | 4        | 17   | 79    | 4                | 76           |
| Fattening pig   | 15       | 21   | 64    | 5                | 96           |

Levy and Sears also demonstrated the value of returned nutrients by converting them into equivalents of artificial manure. Thus when a pasture producing 14,000 lb of dry matter per acre annually is fully utilized by sheep, the equivalent of 24 cwt of sulphate of ammonia,  $16\frac{1}{2}$  cwt of potash,  $2\frac{1}{2}$  cwt of calcium carbonate and 6 cwt of superphosphate are returned to the soil in one year.

Stock manure contains plant nutrients in a very readily available form. On reaching the soil they can be used immediately for further pasture production. Thus in a grazed paddock there is a constant turnover of nutrients and it becomes necessary to think of fertility in terms of rate of turnover as well as in terms of the inherent fertility of the soil.

Levy (1942) points out that the more feed that is produced, the greater will be the residues that are returned. As we must think of fertility in terms of rate of turnover of nutrients, it is important that the herbage grown should be fully utilized so that the nutrients contained in it can be used again. Roughage that has been neglected by stock may take months or even years to rot down and become incorporated in the soil. "The nutrients in herbage which is eaten re-enter the soil fertility cycle within 24 hours, and it is this quick turn-round of fertility that explains the high production possible under an efficiently controlled grazing and full utilization plan."

Nutrients removed in hay and silage will be idle in the stack for a period before they are returned to the soil. Conservation as well as poor utilization will have the effect of lowering the rate of turn-over of nutrients and may be expected to lower the yield of pasture.

Undergrazing in the summer is likely to have a deleterious effect on both yield and spread of pasture production. On the other hand, it may be that pasture yield is reduced by overgrazing during the summer.

(b) The severity or closeness of grazing.

Previously it was pointed out that if the dairy herd was forced to clean up each paddock before moving to the next the pasture would be efficiently utilized but because the cow would have difficulty in meeting her feed requirements under such conditions the butterfat production would fall. To this we may add that if a pasture is grazed too closely the yield of herbage may be reduced also.

Stapledon (1926) cut cocksfoot plants seven times during the pasture season at ground level and at two inches above ground level. In comparing the yields of these two treatments, he found that the latter out-yielded the former by 20 per cent. Further work at Aberystwyth (Stapledon and Milton (1934)) showed that when cocksfoot was cut at six inches and at ground level, the more lenient treatment out-yielded the control by 30 per cent. Similar results have been obtained by several workers including Graber and Deem (1931), Harrison (1931), Roberts and Hunt (1936), Tortensson (1938), and Edmunds (1949), working with different species under varying climatic conditions. Broadly speaking, within the range of cutting treatments applied, it appears that the yield of pasture varies inversely with the severity of defoliation.

The reason for this is clear. The succeeding crop of herbage is synthesised by the leaves of the plant. If these leaves are completely removed between each grazing, new leaves have to be produced at the expense of underground reserves before synthesis can proceed. By severe defoliation, root reserves are diminished, weakening the plant and reducing the yield.

In these experiments, the plants were defoliated by cutting which may be much more severe than grazing. A plant with a prostrate habit of growth will have leaves lying so close to the ground that they will be inaccessible to the grazing animal. Hard grazing may not reduce the yield as much as these exper-

iments would indicate.

(c) The effect that efficiency of utilization has on the efficiency of rotational grazing as a method of increasing pasture productivity.

Over the past two decades, the trend in pasture management in New Zealand has been towards closer farm subdivision and rotational grazing. It has been advocated by various New Zealand agricultural authorities including Wild (1928), Woodcock (1929), Connell (1931) and Hudson (1933) on the basis of two main advantages. Firstly the pasture is more efficiently utilized, and secondly a greater yield of nutrients is obtained per acre.

The work of Woodman and Colleagues (1926) (1928) (1931) (1932) showed that pasture cut frequently provided a highly digestible protein-rich concentrate. As the interval between cuts lengthened, the yield of pasture increased but it had a wider nutritive ratio and a slightly lower digestibility. Such feed they considered was better balanced in respect of carbohydrates and protein to meet the requirements of dairy cows.

Earlier, Stapledon and his co-workers (1924) at Aberystwyth found that yield of pasture was decreased by increased frequency of cutting, but that the more frequent cutting yielded a more leafy herbage with a higher nutritive value. They considered that a balance should be struck between yield and nutritive value which would be attained by rotational grazing.

The work of Jones (1933) (already described), showed that by rotational grazing the botanical composition of the pasture is stabilized at a mixture of ryegrass and white clover in desirable proportions.

Theoretically rotational grazing should provide an increased yield of nutrients. Woodman and Norman (1932) stressed the point that the results of their mowing trials were only applicable in practice if, at each grazing, the herbage was efficiently and uniformly utilized. The work of Moore, Barrie and Kipps (1946) at Canberra, Australia, emphasises the fact that unless there is reasonably efficient utilization of pasture, no increased

yields can be expected from rotational grazing. Richardson, Trumble and Shapter (1932) in Australia had found similar results to those of Stapledon with *Phalaris tuberosa* so that theoretically rotational grazing should increase pasture yield. Moore and his co-workers compared continuous, four-weekly and eight-weekly rotational grazing with sheep on a pasture mixture containing *Phalaris tuberosa*, subterranean clover, lucerne and cocksfoot. There was no difference in yield either in terms of herbage produced, live-weight gain, or wool produced.

Under the conditions of study, the sheep requirements far exceeded the production of the pasture through most of the year, whatever system of grazing was practised. Unless the sheep numbers are adjusted in the spring flush (which is not possible under practical sheep farming conditions in Australia) the percentage of that grown which is eaten by the sheep is very small (between 9 and 35 per cent), so that the effect which the animal can have on the pasture output is inappreciable. They conclude that unless the stock requirements can be adjusted so that the rate of consumption of the pasture is of the same order as its rate of growth (e.g. efficient utilization), no increases can be expected from rotational as compared with continuous grazing.

It is probably for this reason that disappointing results have been obtained by Sprague (1929), Hodgson et al (1934), Hein and Cook (1937), Woodward et al (1938), Black and Clark (1942) and Ahlgren (1944) in the U.S.A., when comparing rotational and continuous grazing. The failure of rotational to increase production in the U.S.A. and Australia is due to the poor utilization which is intensified by extreme fluctuations of pasture production.

Although pasture production does not fluctuate so widely in New Zealand, utilization is often not as efficient as it could be. Thus rotational grazing as a method of increasing the yield of nutrients under farm conditions may not be as successful as some overseas experimental work would indicate. It is surprising that there are no reports of replicated comparisons in New

Zealand between continuous and rotational grazing, yet the practice is widely advocated. When such an experiment is carried out, it would be interesting to compare rotational with efficient utilization, with rotational grazing with inefficient utilization.

We may conclude that inefficient utilization of pasture leads to a reduced yield and a reduced seasonal spread of production. Complete utilization obtained by very close grazing may also reduce the yield, though probably not as much as defoliation experiments would indicate. The efficiency of <sup>ROTATIONAL GRAZING</sup> utilization as a method of increasing the yield of pasture is reduced by inefficient pasture utilization.

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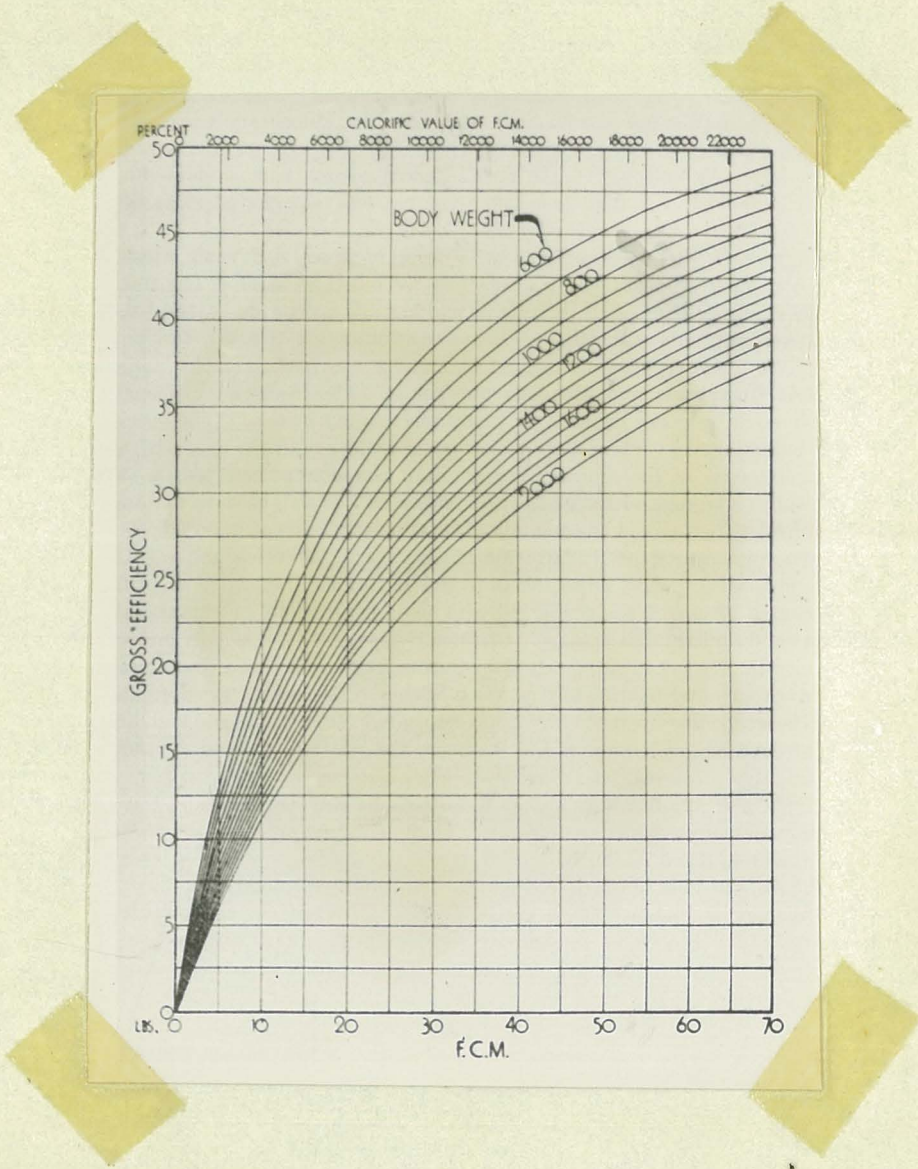


Figure 10. SHOWING THE RELATIONSHIP BETWEEN DAIRY MERIT <sup>GROSS EFFICIENCY</sup>  
AND OUTPUT OF MILK.

THE UTILIZATION OF THE FEED CONSUMED FROM PASTURE

- BY THE DAIRY COW. -

The output of butterfat, cheese or market milk from a New Zealand dairy farm depends mainly upon the production of pasture, the efficiency with which that pasture is utilized and the efficiency of food utilization for production by the herd. It is this latter aspect which will be discussed here. Obviously it will be impossible to discuss, in any detail, all the factors which affect food conversion, but those which are closely associated with pasture utilization and pastoral dairying will be noted in some detail.

The efficiency of food utilization for milk production depends upon the dairy merit of the cow. Brody (1945) defines dairy merit as "the biological efficiency of milk production as measured by the percentage of T.D.N. energy which is converted into milk (F.C.M.) energy." This definition may be represented by the equation:-

$$\text{Dairy merit} = \frac{\text{Milk energy production}}{\text{TDN energy consumption}} = \frac{340 \times \text{lb FCM produced}}{1814 \times \text{lb TDN consumed}} "$$

Dairy merit depends largely on the level of production. As the output of milk rises, the dairy merit increases but at a decreasing rate in accordance with the law of diminishing returns. (See Figure 10.) Therefore there is a theoretical maximum dairy merit which Brody considers to be approximately 50 per cent.

Broadly, the three main ways of increasing the cow's level of production are breeding, feeding and management.

BREEDING.

Space does not permit a detailed discussion of the methods which are used to raise the average genetic level of the herds throughout New Zealand. Two aspects of breeding in relation to dairy merit will be discussed. (a) The effect which low producers have on the average dairy merit of the herd, and

(b) the best breed for utilizing grass feed.

(a) The effect which low producers have on the average dairy merit of the herd.

It may well be that the low producing cows of a herd eat more than they need to meet their requirements for maintenance and production under free-intake grazing conditions, thus lowering the average dairy merit of the herd. Hancock's (1949) observations on the grazing habits of dairy cows tend to confirm this view, but until experimenters can evolve an efficient method of determining intake, this point remains plausible but not proven. Under the original Hoehnheim system an attempt was made to ration stock on pasture by giving the milkers first access to a clean paddock while the dry stock followed on behind to clear up that which remained. A similar system of division of the milking herd into high and low producers might be feasible on New Zealand dairy farms if the labour supply was more abundant. However, before this system could be advocated, a measurement of pasture intake with cows producing at different levels under free grazing conditions would be necessary to determine the possible quantitative value of such a system.

(b) The best breed for utilizing grass feed.

There is often considerable speculation and debate on the breed of dairy cows most suited to utilize grass efficiently. Let us consider two extreme breeds of cattle - the Jersey, with a low body weight but secreting milk with a high test, and the Friesian, a heavy cow with a low test.

Let us first consider the effect that body size may have on the dairy merit. Brody (1945) finds that both maintenance cost and milk energy production vary with  $W^{0.7}$ , where  $W$  is the body weight. Thus the dairy merit of a cow is independent of body size. Although resting maintenance needs vary with  $W^{0.7}$ , the energy cost of moving the body during grazing varies directly with body weight,  $W^{1.0}$ . However Brody argues that the voluntary activities of animals decline with increasing body weight so that the total maintenance varies with  $W^{0.7}$ . This is supported by the work of Southcombe

(1947) who observed that Jerseys grazed longer and walked further than Friesians

Small cows may have a higher dairy merit than large ones. The breeder tends to evaluate the performance of his individual cows by their absolute production rather than by dairy merit. It is only those small cows which produce as much as larger ones that are retained in the herd. But if a small cow produce as much as a large one, her maintenance requirement will be lower and in consequence she will have a higher dairy merit. (Brody (1945)). Although this unintentional selection may be true within a breed, it is unlikely to have a large bearing between breeds.

In New Zealand, the average production of butterfat in Jersey and Friesian herds containing at least 75 per cent of pedigree cows under the group herd-testing scheme was 298 and 295 lb respectively during the 1946-47 season (Ward (1948)). The average butterfat tests of the two groups were 5.3 and 3.6 per cent respectively. Assuming the average Jersey weighed 900 lb and the Friesian 1250 lb, it was possible to estimate the average dairy merit of these two breeds by converting the productions to 4 per cent fat-corrected milks using Brody's table (p.861). The dairy merits of the Jerseys and Friesians were 25 and 26 per cent respectively. In view of this and Brody's work it would appear that the dairy merits of the two breeds are approximately equal. Thus the output of energy from a given amount of feed would be the same whether it was consumed by Jerseys or Friesians.

In New Zealand, milk is used for three main purposes, viz. market milk, butter and cheese. Now the relative economies of the Jersey and the Friesian for utilizing grass consumed depend upon the use to which the milk is put. In table <sup>10</sup>, the yield of market-milk milk, butterfat and cheese from milks of varying tests but having the equivalent energy content of 10,000 lb of 4 per cent milk is demonstrated, and in this table the conversion of butterfat to cheese was performed by using McDowall's (1948) conversion factors:-

Table 10. Yields from milks of varying tests.

| Test<br>% | Market milk<br>lb | Butterfat<br>lb | Cheese<br>lb |
|-----------|-------------------|-----------------|--------------|
| 3.0       | 11750             | 352             | 990          |
| 3.5       | 10820             | 378             | 1000         |
| 4.0       | 10000             | 400             | 1016         |
| 4.5       | 9300              | 418             | 1017         |
| 5.0       | 8700              | 435             | 1023         |
| 5.5       | 8160              | 448             | 1037         |
| 6.0       | 7670              | 462             | 1054         |

From Table it will be seen that the high testing milks yield the greatest quantity of butterfat. Thus the Jersey is more efficient in utilizing pasture feed for butterfat production than the Friesian, assuming that the average dairy merits of the two breeds are the same. This is supported by Fawcett's survey work (1932) in the Waikato and Taranaki districts. He found a close relationship between high herd test and high output of butterfat per acre. The Friesian will be more efficient when the milk is sold for town milk supply, where the payment is on a gallonage basis. The Jersey may have a slight advantage over the Friesian for the production of milk for cheese manufacture.

These conclusions are born out by practice. The Jersey predominates in butterfat producing areas while both Jerseys and Friesians are found in Taranaki where milk is used mainly for cheese production. Friesians are the most popular breed for town milk supply.

An argument often raised in favour of the Jersey is that it is believed that the smaller animal is better adapted to sparse grazing conditions.

The Friesian breed was evolved under the high plane of nutrition conditions of the lush lowland pastures of North Friesland and requires the very best nutrition in order to express its potential performance. (McMeekan (1943)). By contrast the Jersey was evolved as a peasant's breed and by reason of its small size is specially adapted to sparse grazing conditions. This assumes that

pasture conditions are such that a cow is just able to consume enough grass to meet the maintenance and production requirements of a Jersey cow. This consumption will not be sufficient to meet the higher maintenance and production requirements of a Friesian. The Friesian, unable to obtain her requirements, will not express her potential performance.

Further evidence of the adaptability of small animals to low nutritive conditions comes from the ecology of sheep breeds in Britain. On the rough grazing land of the Welsh mountains, the small, hardy Welsh Mountain breed is found. In the foot-hills we find the larger Kerry, Radnor Forest and Clun breeds, while the heavy Shropshire is located on the lowland pastures. A similar ecological succession of sheep breeds is found in Scotland. In the mountains there is the Black Face, in the foot-hills the Cheviot and in the lowlands the Border-Lieicester-Cheviot cross. An explanation of this adaptability phenomenon is given by Hagedoorne (1946) who states that "while one sheep weighing a hundred pounds has only one head and one set of legs, two sheep, weighing a hundred pounds together, have two heads and two sets of legs, so that they can be in two different places to hunt the scanty herbs, and for this reason, in conditions where the sheep of fifty pounds can just live, a hundred-pound sheep must necessarily starve."

There can be little doubt that under sparse grazing conditions, the small Jersey will be able to survive and produce more efficiently, but whether the degree of sparseness on New Zealand dairy farms is such that the Jersey has this advantage over the Friesian is unknown. During periods of pasture scarcity supplementary feeds are usually fed to the herd so that the Friesian should be able to maintain her consumption rate. It may well be that under sparse grazing conditions the Friesian increases her grazing time and so meets her requirements. Grazing behaviour and intake studies are needed to throw light on this hypothesis of adaptability.

#### FEEDING.

The efficiency with which grass is converted to milk is affected by

feeding as well as by the genetical make-up of the dairy cow consuming that feed. In this section, we will discuss the relationship between plane of feeding and grass feed utilization, and later this will be related to rate of stocking which is important from the point of view of pasture utilization.

#### Food utilization and plane of nutrition.

Armsby (1930) reviews the literature up to that date on the effect of plane of nutrition on digestibility. These data show that as the level of feeding rises, the digestibility of the feed decreases. More recent work by Watson (1935-40) in Canada, with steers fed at 5 different levels with various feeds, shows similar results. However the differences in digestibility at different planes of feeding were not very great, while in some cases, especially with roughages, these differences did not occur. In several cases the digestibility was actually depressed by feeding at low levels but this he believed was not due to plane of feeding per se, but to the abnormal feeding habits of the animals under starvation conditions (i.e., these steers bolted their food). Generally one would expect that digestibility decreases with increasing plane of nutrition because of a relatively more rapid transit of food through the digestive tract and in part to the consequent lessened extent of bacterial action.

The work of Forbes (1928 and 1930), and Mitchell (1932) has shown that the net energy of a feed for steers decreases with increasing plane of nutrition. Not only was the digestibility depressed but heat production due to specific dynamic action increased. Weigner and Ghonium found similar results with rabbits. Brody and Proctor (1933), investigating mathematically these data mentioned above, found that increasing the plane of nutrition tends to reduce the net energy value per unit of food in accordance with the law of diminishing returns.

Although the decreasing efficiency of feeding value with increasing plane of nutrition has been shown with dry animals, it is still unknown whether this

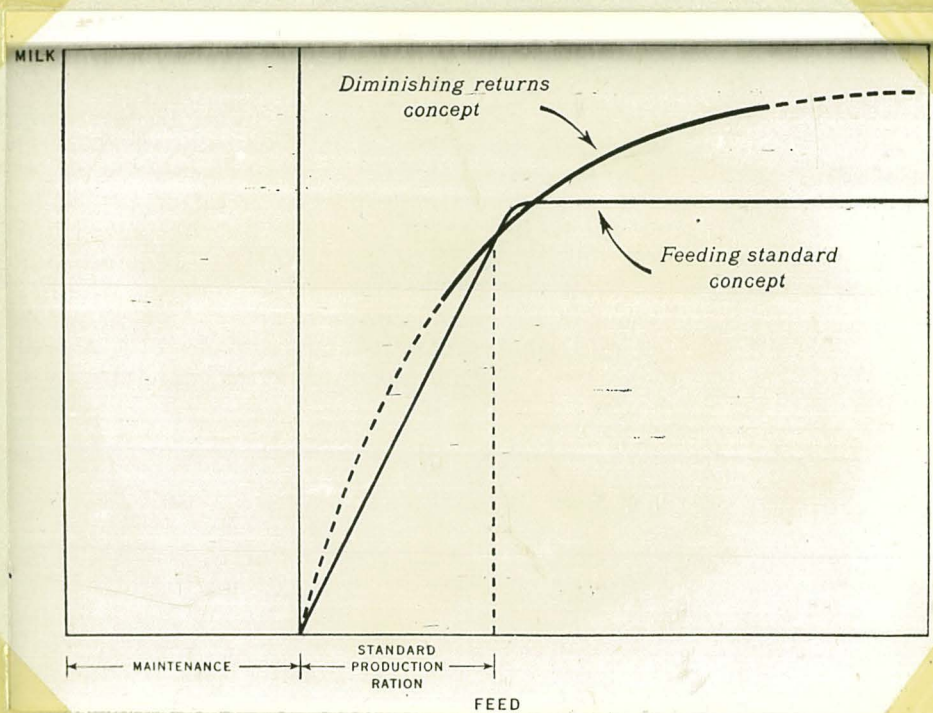


Figure 11. TWO CONCEPTS OF PRODUCTION RESPONSE TO INCREASED FEEDING.

decrease would occur with animals having a high feed requirement.

The energetic efficiency of the entire milk producing mechanism may also decline with increasing lactation rate above a certain level. Brody (1945) illustrates this point by analogy with a motor car. Thus there is a decline in energetic efficiency of a car with increased driving speeds above 30 m.p.h.

Jensen et al. (1942) recorded the yields of milk and the consumption of feed of 346 individual cows over a period of three years, fed on roughage and concentrates at six levels. There was a constant stepping up of production with every increase in grain allowance but the additional milk produced for each additional unit of feed decreased. Previously, in the absence of experimental evidence, it had been widely held that milk production increased in proportion to the increased production ration fed until the level set by the feeding standard was reached, after which there was only a slight increase. The two concepts, the diminishing returns concept, and the feeding standard concept are shown in Figure 11.

Jensen et al fitted to these data the experimental curve given by the Spillman diminishing returns equation, (Spillman (1933)), which had been used to describe the law of diminishing returns as it applies to the use of fertilizers on crops. Brody (1945) points out that the satisfactory fit of this curve proves nothing as the range of data is so narrow that a linear or parabolic equation would probably fit equally as well. However as the theory is probably sound, the fitting of the equation of the principle of diminishing increments is reasonable.

In summary we may conclude that it is probable that as the level of feeding increases, the net energetic efficiency<sup>i</sup> of milk production decreases. This point will be discussed in relation to stocking rate.

$$^i \text{ Net energetic efficiency} = \frac{\text{Energy in milk produced}}{\text{Energy required for milk production}}$$

### Stocking rate.

One of the main problems that a dairy farmer has to solve is the number of stock his farm will carry in order to yield the maximum in butterfat, cheese or market milk per acre. If he overstocks, not only ~~will~~<sup>may</sup> he obtain a low per cow production through underfeeding, but due to overgrazing his pasture production may decline. By undergrazing he may obtain a higher output per cow, but the utilization of his pastures will tend to be less efficient and the sward may deteriorate.

Fawcett (1929), in a survey of dairy farms in the Waikato and Taranaki, found a close relationship between high stocking rate and high butterfat production per acre. A less close relationship was found between high production per cow and high butterfat production per acre. Also Hancock (1949), at Ruakura, New Zealand, carried out an experiment where identical twin pairs of cows were split three ways over the following treatments:-

- (1) one acre per cow
- (2) one acre per cow plus concentrate feeding
- (3) six-tenths of an acre per cow.

In the first year of this experiment, the cows under treatment (3) yielded less per cow than those under treatments (1) and (2) but they produced approximately 100 lb more butterfat per acre than those on treatment (1) and approximately the same amount as those on treatment (2). Therefore it would appear from the work of Fawcett and Hancock that high stocking rate is associated with high per-acre production on the New Zealand dairy farm.

There are three possible reasons for this relationship.

- (a) The grass consumed is more efficiently utilized for production
- (b) A high stocking rate leads to a greater pasture production
- (c) The pasture is better utilized under a high stocking rate.

High stocking rate leads to a lower plane of feeding which may give a better utilization of the grass feed consumed and this aspect will be dis-

cussed below.

Mitchell (1949) recalculated Jensen's data for cows typical of those in New Zealand. He assumed that the dairy merit of the average New Zealand dairy cow was the same as those used by Jensen. As the ration of the New Zealand cow is not divided into maintenance and production, he made his calculations on the basis of gross efficiency expressed as T.D.N. per lb of butterfat rather than net energetic efficiency as was used by Jensen. To make this calculation he used Brody's (1945) figures for maintenance requirement, output of energy in relation to body weight, and for the conversion of 4 per cent milk to milk with tests of 3.5 per cent, 4.5 per cent, 5.0 per cent and 5.5 per cent which are representative of those found in New Zealand.

The results of Mitchell's calculation can be seen in table II.

Table II. Estimates for dairy cows of Gross Efficiency of feed utilization per pound of butterfat produced.  
(T.D.N. per lb of butterfat)

| Annual butterfat<br>production<br>per cow | 800 lb<br>live weight |             |             | 900 lb<br>live weight | 1,150 lb<br>live weight |
|---|-----------------------|-------------|-------------|-----------------------|-------------------------|
|   | 4.5<br>test           | 5.0<br>test | 5.5<br>test | 4.0<br>test           | 3.5<br>test             |
| 180                                       | 20.36                 | 20.03       | 19.78       | 21.81                 | 24.83                   |
| 200                                       | 19.29                 | 18.92       | 18.64       | 20.60                 | 23.28                   |
| 220                                       | 18.50                 | 18.09       | 17.78       | 19.70                 | 22.07                   |
| 240                                       | 17.95                 | 17.51       | 17.14       | 18.98                 | 21.13                   |
| 260                                       | 17.72                 | 17.14       | 16.72       | 18.67                 | 20.44                   |
| 280                                       | 17.70                 | 17.02       | 16.50       | 18.53                 | 19.96                   |
| 300                                       | 18.00                 | 17.12       | 16.49       | 18.63                 | 19.67                   |
| 320                                       | 18.78                 | 17.56       | 16.62       | 19.12                 | 19.54                   |
| 340                                       | 20.46                 | 18.53       | 17.34       | 20.18                 | 19.68                   |

From table it will be seen that as the total production of butterfat rises, due to the increased level of feeding, the quantity of total digestible nutrients required to produce an extra pound of butterfat is such that the overall benefit gained from the greater spread of non-productive maintenance is progressively reduced and finally eliminated. Above this point every extra pound of butterfat becomes increasingly expensive in terms of total

digestible nutrients required.

Mitchell concludes that the level of maximum efficient production of the average New Zealand Jersey cow, assuming that the cow has approximately the same dairy merit as those cows studied by Jensen, is about 280 lb of butterfat per lactation. As the Dominion average stands at about 220 lb of butterfat, it would appear that on many farms there is too low a stocking rate which leads to overfeeding and a consequent poor utilization of the grass consumed.

Although it seems likely that the principle of diminishing returns does operate for level of feeding in relation to butterfat production, it is uncertain that the slope or shape of the curve found by Jensen represents that which would be obtained from a representative sample of New Zealand cows. Thus, although there is probably a point of maximum gross efficiency, there is not sufficient evidence to indicate the location of that point. Further, by raising the dairy merit, the level of production, at which maximum gross efficiency is attained, is raised.

The main criticism of the application of the law of diminishing returns in relation to feeding level to New Zealand dairy farming conditions is that there are periods of high and low levels of feeding throughout the year on nearly all farms while Jensen obtained his data under feeding conditions which were level throughout lactation so that his results are hardly applicable to New Zealand conditions.

Although better utilization of the feed consumed may play a part in giving a high output of butterfat per acre under a high stocking rate, it is more likely that the relationship is due to a better utilization of pasture, though a higher pasture production may be a factor, but this would seem to be doubtful.

#### MANAGEMENT.

Finally there are many management factors which affect the production of the dairy cow and so in turn affect the efficiency with which pasture feed is

utilized.

Recently considerable interest has been focussed on the shed management of the herd during milking. Gentleness of handling, udder massaging, order of milking and speed of milking have been stressed but these effects on production will not be enlarged upon. New Zealand dairy farming is characterised by low labour requirements and so it is of some significance that Ward (1948) has found that non-stripping does not lower production of butterfat. Higher production can be obtained by milking three times a day but this would not be economical in New Zealand.

Calving date probably affects production. Herds are usually calved four to six weeks prior to beginning of rapid pasture production so that early production is maintained by post-calving lactational stimulus using body reserves while the later production is supported by the flush of pasture growth. It is widely held that later calving reduces the herd production.

Under pastoral dairying conditions, the dairy cow is more prone to the effects of climatic conditions than when stall-fed. It is very noticeable that many New Zealand dairy farms are devoid of shade and shelter and the hot summer weather may lower butterfat production. Thus the summer drop in production may be partially due to direct climatic effects.

Disease accounts for a considerable loss of production each year. Perhaps Mastitis and contagious abortion are the most serious although metabolic diseases associated with flush pasture growth and the onset of lactation - milk fever, ketosis and grass staggers - cause loss of production, while bloat is a serious problem.

#### CONCLUSION.

We may conclude that under free-intake grazing conditions, the low producers of the herd may consume more grass than is required to meet their requirements and in consequence lower the average dairy merit of the herd. In terms of dairy merit there appears to be no difference between the Jersey

and the Friesian, but the efficiency with which food is converted to product depends upon the use to which the milk is put. Theoretically the Jersey is better adapted to sparse grazing conditions but whether the conditions are such in New Zealand to give the Jersey this advantage over the Friesian remains open to speculation, unsupported by any data.

The efficiency of food conversion varies inversely with the plane of feeding but because of the fluctuating nature of pasture growth and the consequent periods of pasture surplus and deficit, it is doubtful if it is the proximate cause of the relationship between high stocking rate and high output of butterfat per acre.

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METHODS OF MEASURING INTAKE  
OF GRAZING DAIRY COWS.

A better understanding of the question of the best utilization of a pasture and a given pasture feed would be obtained if a more satisfactory method could be developed for estimating the amount of the intake of both dry matter and specific nutrients by the grazing animal.

Various techniques have been evolved, but they are still only in the developmental stage at the present time. However, the progress that has already been made will be discussed in the following pages.

A knowledge of the amount of intake of dairy cows would make it possible to estimate the losses which occur on the pasture during utilization. At present no accurate data are available which give any indication of the extent of these losses, but by making some comparisons between pasture production, when it is measured by accepted agronomic methods, and the quantity of grass which is consumed by the herd during grazing, a reasonable estimate of the losses would be obtained.

Unfortunately we know very little about the various factors which may have an effect on the intake of dairy cows on pasture. A study of the various effects of different climates, different pasture conditions, the grazing pattern of the cow or the herd, and the varying requirements of the herd would be extremely interesting. Thus a low solids-not-fat content of the milk during the dry summer period may be due to a low plane of nutrition. The lowered intake may not be due solely to the inadequacy of pasture production but the depressing effect

of hot weather on intake or the low palatability of the herbage at that time.

Although overseas research work on the physiological efficiency of milk secretion can be applied to New Zealand free-intake grazing conditions, definite conclusions cannot be drawn until the consumption of pasture can be measured.

Further, in experiments concerning high and low plane feeding on pasture, the intake of the dairy cows can only be altered by grazing cows on different areas of pasture. One group of cows may be on half the area of the other group but this does not mean that they are obtaining half the feed, for the group of cows on the smaller area will utilize the pasture more efficiently. Also the fact of a different stocking rate will cause a reaction in the plant community which will affect the pasture production. Under sparse grazing conditions some cows may eat more than their fair share of feed. Thus some will be grossly underfed while others may be quite well fed. Under all experiments with dairy cows on pasture, the use of a method of measuring intake will add greatly to the value of the results that can be obtained.

#### CLIPPING METHOD.

The clipping method of determining the intake of grazing animals depends on estimating the grass present in a paddock, and subtracting from this the amount present after the stock have grazed it. Woodward (1936) used this method to estimate the intake of two dairy cows. He divided a small paddock into two halves. One half was grazed for 2 to 4 days, while the other remained uncut until the grazing period was completed. Then both were cut with a mower, the difference between the two cuttings being the amount which the cows consumed. Dry matter determinations and chemical analysis give estimates of the intake of nutrients.

Garrigus and Rusk (1939) compared the clipping method with the method they developed for estimating the intake of a grazing steer. The steer's average daily consumption on good pasture was only 83 per cent of the calcu-

lated maintenance requirement as estimated by the clipping method. Their new method was used simultaneously with the old method, on the same steer, grazing the same pasture, during the same period. By this method the calculated consumption was 192 per cent of the maintenance requirement of the steer. They listed a number of sources of error which they considered tended to depress the estimate of intake by the clipping method:-

1. Lawn mowers, which are normally used for clipping, will cut closer to the ground on the grazed plots than on the ungrazed plots, causing an under-estimating of the intake.
2. Animals often graze below the level at which the mower will cut.
3. The method takes no account of the growth of grass during the grazing.
4. In Woodward's method the conditions under which the animals grazed were far from normal for there was no shade, shelter or company. The grazing pattern may have been upset.
5. The determination of the forage not grazed is hindered by the droppings of the experimental animals and the trampling down of grass.

We may conclude that the clipping method is open to large experimental errors which tend to lower the estimate of intake.

PLUCKING METHOD.

The plucking method of estimating intake has been developed by the Grasslands Division, Palmerston North, New Zealand (unpublished data). Sample areas are protected from grazing in the paddock and plucked by hand to simulate grazing so that after the stock have been removed the areas cannot be distinguished from the remainder of the paddock. The amount plucked represents that which has been consumed. Not only is this method subject to biased errors, but it involves a considerable amount of manual work.

ERIZIAN METHOD.

This method is also somewhat laborious. It was developed by Erizian (1932) working in Germany. The grazing animal is weighed before and after a

grazing period. During grazing the excrements are collected and weighed by attendants using buckets. The insensible loss during the grazing period is calculated from pre-determined constants. From these data the weight of green food consumed can be calculated.

The accuracy of the method largely depends on the accuracy of these constants for estimating insensible loss. They are determined by weighing an animal before and after it has performed some activity of grazing, i.e., grazing, walking or lying down. The loss due to grazing is determined by placing the animal in a crate with a piece of sod and allowing it to graze for a definite period. It is doubtful if such a method actually measures the insensible loss under grazing conditions.

Another disadvantage of Erizian's method is that it only measures the weight of green material consumed.

In order to find the intake of dry matter, a representative sample of the pasture which the animal grazes would have to be found. This would be difficult as the animal is selective in its grazing habits and the dry matter content of the herbage varies from plant to plant and from time to time during the day.

DIGESTIBILITY METHOD.

The digestibility method was developed by Garrigus (1933) at Illinois to determine the dry matter intake of grazing steers. The weight of dry matter defecated and the digestibility of the feed is ascertained and from these data the intake of dry matter is calculated. Thus if the weight of dry matter defecated is x lb and the digestibility coefficient of the dry matter of the grass is d, the intake of dry matter is  $x(100 - d)$ . The problem therefore divides itself into determining the output of faecal dry matter and calculating the digestibility of the grass consumed.

The determination of the amount of faecal dry matter over a given period.

The simplest method is for attendants to catch the dung in a bucket. This

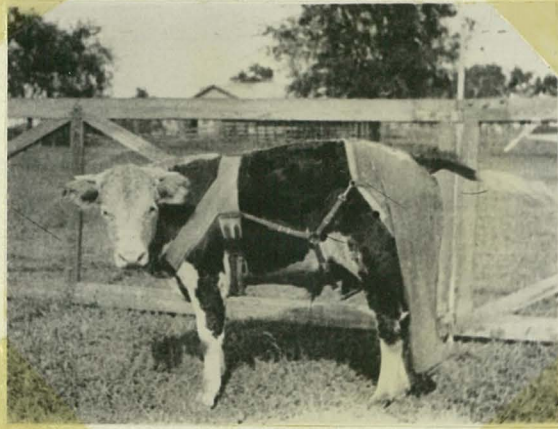


Figure 12. AN APPARATUS FOR COLLECTING DUNG EXCRETED BY A BULLOCK.

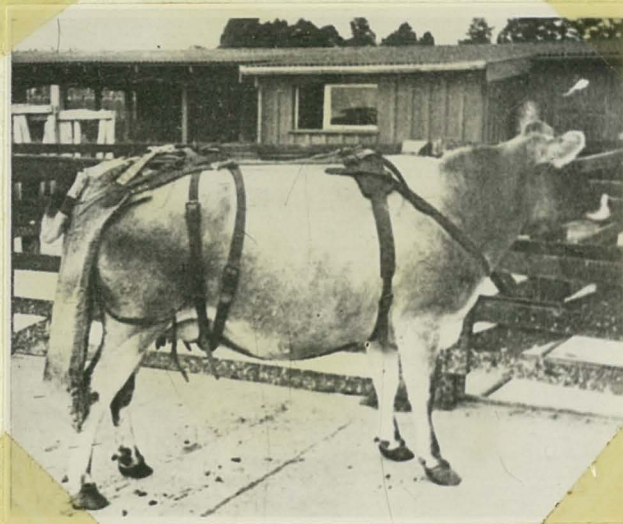


Figure 13. AN APPARATUS FOR COLLECTING DUNG EXCRETED BY A COW.

is weighed and sampled for dry matter analysis. Garrigus and Rusk (1939) harnessed steers with waterproof bags to collect the faeces. See Figure 12. In some cases these bags caused soreness of the tail but in the authors' opinion the grazing pattern of the animals was not upset. Woodman and his colleagues (1937) used a similar method with sheep. Ballinger and Dunlop (1946) have developed an apparatus which can be fitted to a cow so that the dung falls into a bag but the urine is separated from the dung and falls to the ground. See Figure 13. This apparatus caused soreness unless considerable care was taken to keep the cow clean.

These methods are laborious and the presence of attendants or the harnessing of the animal may upset the grazing pattern. In consequence a reference-substance technique for determining faecal dry matter output has been developed.

Lancaster (1949) has measured the dry matter excreted over a given period by using chromium sesquioxide as a reference substance. Twice a day at milking time each cow is dosed with a gelatin capsule containing 10 grams of chromium sesquioxide. At the same time a sample of faeces is taken by hand from the rectum of the cow. Each 'grab' sample is kept separately and is dried at 100 Centigrade, milled and analysed for Chromium sesquioxide. The dry matter excretion for each half daily period is calculated from its concentration in the 'grab' samples. Lancaster in an experiment with stall-fed animals fed on fixed rations of freshly cut pasture found that faecal dry matter excreted, calculated from the chromium sesquioxide in the grab samples, was in the order of 8% higher than the faecal dry matter found by direct measurement.

Barnicoat (1945) compared the use of chromium sesquioxide used as an inert reference substance for determining digestibility with the standard method. He found that the recovery of chromium sesquioxide in the faeces is lower than expected and this affords an explanation of Lancaster's high

results. Thus animals fed for ten-day periods showed that only about 80 per cent of the amount ingested appeared during the appropriate ten-day collection period. Barnicoat did not consider that the substance had been absorbed for if this had happened acute poisoning would have resulted. He suggests that chromium sesquioxide is held up in the folds of the intestine. Similar results have been found by Gallup and Kulhman (1931) and Druce and Willcox (1949). Before this method could be used to estimate faecal output accurately, some method of correction for the holding up of chromium in the alimentary tract would have to be devised.

Barnicoat also points out that there are large day to day fluctuations in the ratio of chromium sesquioxide to faecal dry matter. Thus this reference-substance method would only be applicable for estimating the intake over long periods. However the method offers great possibilities for simplifying the technique of determination of faeces output.

#### DETERMINING THE DIGESTIBILITY.

Garrigus and Rusk (1939) carried out digestion trials prior to estimating the intake from the weight of faeces excreted and the digestibility. Freshly cut pasture was fed to stalled-steers over an eight-day digestion period to determine the digestibility of the dry matter. After a five-day preliminary period on pasture, these same steers were harnessed for faeces collection over an eight-day consumption period. The digestibilities, determined over the stall-feeding period, are used to calculate the intake from the faeces dry matter excreted during the following consumption period. There are two main criticisms of this method.

(a) The material which is cut and fed to the steers during the digestion period may not be representative of that which the animal consumes. As the digestion period takes place before the consumption period, it may well be that the herbage fed during the digestion period has a higher digestibility than the more mature herbage that is grazed some days later.

(b) In the 27 experiments, the steers consumed on the average only 65 per cent as much dry matter during the digestion period as they did when on the grazing trial. Now it has been shown that digestibility is affected by level of feeding. Honchamp and Koch (1920) fed sheep a ration of clover hay at three levels, finding that as the level of feeding increased the digestibility of the dry matter decreased. Watson et al (1935) fed four steers with hay at four levels of feeding but the differences in digestibility between the highest and lowest level was only .5 per cent. The differences in plane of nutrition of the steers during the digestion and the consumption periods may be a source of error, but it is unlikely to be very large.

Woodman and his colleagues (1937) determined the dry matter intake of grazing sheep by a method similar to that developed by Garrigus. However they divided the experimental sheep into two groups. While one group was grazing the other group was undergoing a digestion trial. Although this method avoids errors due to differences in digestibility caused by differences in stage of maturity, it assumes that the sheep on the digestion trial digest the dry matter to the same extent as those grazing. In order to avoid such errors, inert reference substances can be used to estimate digestibility.

#### THE USE OF INERT REFERENCE SUBSTANCES.

Gallup, Hobbs and Briggs (1945) suggested that digestion coefficients could be calculated and feed intake determined for grazing animals if some 'tracer' material could be found. Such a substance must occur naturally in the feed yet be neither digested nor absorbed by the animal. These workers tested the applicability of the silica-ratio method to digestion trials conducted with steers on pasture, and steers and sheep in stalls, by finding the percentage recovery in the faeces of ingested silica. The average excretion of feed silica in the faeces was 10 per cent, 36 per cent and 7 per cent higher than the calculated intake with stall-fed steers, grazing steers and stall-fed sheep respectively. These findings were explained by the probable contamination of the faeces with

dirt under stall feeding conditions and by the ingestion of dirt by grazing steers. Thus silica does not appear to be of much value for determining the digestibility under grazing conditions.

Ellis, Maynard and Matrone (1946) find that lignin in a ration of timothy hay, beet pulp and concentrates is not digested by steers when estimated by the method they developed. The same finding has been reported with a mixed ration fed to sheep (Swift (1947)), clover-timothy hay (Forbes (1946)) and Korean lespedeza hay cut at four stages of maturity (Corbin (1947)).

Forbes (1948) carried out grazing trials with six Hereford steers on Kentucky bluegrass. The steers were divided into two groups. While one group was confined to digestion stalls where freshly clipped bluegrass was fed, the other group was permitted to graze but was harnessed with apparatus for dung collection. A paddock was divided into three sections - A, B and C. Sections A and B were grazed alternately by the steers while section C was clipped for pasture to feed to the steers on the digestion trial. The results of four trials are published. The steers which were in the digestion stalls during the first trial were on the pasture during the second trial while in the third they returned to the stalls, and so on.

From the digestion trials it was found that the average recovery of lignin was 102 per cent  $\pm 7$ . "If it is assumed that the lignin in the faeces represents all the lignin in the forage, the feed intake can be calculated. For example, if three pounds of lignin are excreted during a collection period, and the average lignin content of the forage for that period is 3 per cent, the dry matter intake for the period will be 100 lb."

Forbes calculated the intake of the grazing steers by three methods:-

(a) The lignin ratio method (just described)

(b) The Garrigus method. The digestibility of the clipped feed is determined prior to the grazing trial with the same animals as are used during the consumption period.

(c) The simultaneous digestion trial method. A digestion trial and a grazing trial are run concurrently.

The comparison of the three methods is shown in table 12.

Table 12. Comparison of dry matter intakes (lb./day) calculated by three methods for steers grazing on bluegrass.

| Trial | A<br>Lignin<br>ratio<br>method | B<br>Garrigus method |                   | C<br>Simultaneous<br>digestion trial<br>method |
|-------|--------------------------------|----------------------|-------------------|--|
|       |                                |                      |                   |  |
| 1     | 14.9                           | 11.4 <sup>b</sup>    |                   | 14.6   |
| 2     | 14.0                           | 16.0 <sup>a</sup>    | 12.8 <sup>b</sup> | 14.6   |
| 3     | 12.2                           | 19.8 <sup>a</sup>    | 14.0 <sup>b</sup> | 15.5   |
| 4     | 13.3                           | 15.8 <sup>a</sup>    | 12.1 <sup>b</sup> | 13.9   |

<sup>a</sup> indicates comparison with preceding digestion trial

<sup>b</sup> indicates comparison with following digestion trial

The table shows a good agreement of the simultaneous digestion trial method with the lignin ratio method in three cases out of four. This would seem to indicate that the former method gives dependable results. However the results by the Garrigus method do not agree with the results estimated by the other two methods because of the differences in stage of maturity of the grass when grazed and when fed in the digestion stalls.

The lignin ratio method may be considered as fairly satisfactory for estimating dry matter intakes but perhaps its chief advantage is that it is possible to estimate the digestibility of any specific nutrient under grazing conditions. Thus if  $y$  is the percentage digestibility of a specific nutrient  $n$ , then

$$y = 100 - 100 \frac{x}{z} \cdot \frac{\%n \text{ in faeces}}{\%n \text{ in feed}}$$

where  $x$  and  $z$  are the percentages of lignin in the feed and faeces respectively.

However by using the lignin ratio method the herbage sampled is assumed to be similar in composition to that eaten by the grazing method. It is well known that animals are selective in their grazing habits. Stapledon

and Jones (1927) have shown that sheep prefer leaf to stem. This is well illustrated by Table .

Table . Percentage of leaf to total stem and leaf.

|                | Clovers | Perennial ryegrass | Other grasses |
|----------------|---------|--------------------|---------------|
| Before grazing | 58.4    | 27.3               | 60.0          |
| After grazing  | 54.5    | 14.1               | 49.0          |
| Actually eaten | 60.0    | 51.2               | 73.8          |

This source of error may not be great when a pasture is fully utilized but under practical pasture management conditions the grazing animal probably selects a more digestible feed than samples of the pasture would indicate. A method of determining digestibility is needed which does not require the analysis of the feed.

#### FECAL NITROGEN METHOD.

Lancaster (1947) finds that the indigestible protein per 100 grams of pasture dry matter ingested is constant at 4.5, from the results of 85 pasture digestibility trials conducted at three research centres in New Zealand. The output of dry matter can be calculated from the chromium sesquioxide method while the intake of dry matter can be calculated from the nitrogen percentage in the faeces. Lancaster's work is supported by Gallup and Briggs (1948) who find that the fecal nitrogen excreted per 100 grams of dry matter intake is relatively constant when steers were fed on prairie hay with a low protein content. Forbes (1949) finds that the fecal nitrogen excreted per 100 grams of dry matter intake rises as the protein content of the ration increases and considers that the total fecal nitrogen varies too widely to be of practical use in determining intake. However Lancaster finds that his method gives an estimate of intake of a single animal over a period of 14 days to within 15 per cent.

There is a paucity of data on the digestibility studies with grass fed to

dairy cows. As more data becomes available the accuracy of Lancaster's method under different pasture conditions may be shown. The use of fecal nitrogen offers great possibilities for estimating intake.

We may conclude that the reference substance technique for measuring output of fecal dry matter and the use of the lignin ratio, or the fecal nitrogen, hold out great possibilities for estimating indirectly the intake of dairy cows on pastures. Further work will show the relative accuracies of the methods. Although absolute results may not be obtained, these estimates of intake may be useful for comparative work.

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RECAPITULATION.

1. In attempting to raise the level of human nutrition throughout the world, emphasis will be placed on increasing livestock products which are excellent sources of protective foods. Intensive livestock production from grass is practised in New Zealand and the approach to grassland farming of the New Zealand dairy farmer might well be copied in other countries where the climate is suitable for high pasture growth, especially in Great Britain. High output of butterfat per acre in New Zealand depends upon high pasture production, efficient pasture utilization and efficient utilization of the feed consumed by the dairy cow. Pasture utilization may be a weak link in the chain of production on the New Zealand dairy farms, and evidence is presented that large losses of feed may occur through utilization.
2. Some of the main factors which affect the quality of pasture are discussed in brief to act as a fundamental background to the thesis. Special emphasis is placed on the relation of stage of maturity of the herbage and its feeding value which is important for obtaining the greatest yield of nutrients from pasture.
3. Another fundamental aspect which is discussed is the grazing behaviour of dairy cows. A picture is given of the general behaviour pattern while variations in this pattern due to the genetic make-up of the cow, seasonal and climatic factors and condition of the pasture are discussed.
4. Losses through pasture utilization by grazing are due to there being surplus pasture above herd requirements which, because it is not eaten, continues to grow, losing both its nutritive value and palatability. Clumps in pasture are evidence of poor utilization, but these may also develop as a result of impalatability caused by dung and urine or other factors under conditions of efficient utilization. On the dairy farm closer subdivision,

giving greater flexibility in grazing management, enables paddocks to be cut out of a system of rotational grazing for conservation. Under wet conditions there may also be losses through trampling, which may be reduced by draining and grazing management.

5. Several factors are described which may prohibit utilization of pasture because of damage either to the cows themselves or to their products. Taints in cream due to clover and weeds, especially landcress, are discussed. Poisonous weeds in the sward, and bloat, may also prevent utilization. Cobalt and copper deficiencies are also discussed for they have prevented the utilization of huge areas of grassland in New Zealand.

6. Basically, the solution of the problem of pasture utilization lies in the equation of pasture production and herd requirements. Conservation, the method practised most commonly for using pasture efficiently in New Zealand, involves losses in feeding value to the extent of 40 - 60 per cent of the dry matter. Improved methods of making hay and silage reduce these losses but their added costs are likely to prove uneconomic. Further, conservation adversely affects both the production and seasonal spread of pasture. Thus the adapted adage, "the more you make hay, the more you may."

The adjustment of stock numbers to balance the pasture production is practised by New Zealand dairy farmers, by wintering the herd off the farm on second-class country. Although the pastures are more efficiently utilized, the winter grazed country will deteriorate, which is undesirable from a land-utilization point of view. Cropping is an aid in equating herd requirements and pasture production but it may be uneconomical due to the machinery and labour required. Special-purpose pastures combined with the use of autumn-saved grass probably provide the best line of approach to the solution of the problem of pasture utilization.

7. The utilization of pasture affects its future production. Both inefficient utilization and over-efficient utilization may reduce pasture production.

The efficiency of rotational grazing as a method of increasing the yield of pasture is reduced when herd requirements and pasture production are not equated.

8. In discussion of the conversion of grass feed consumed by the cow into milk, it was shown that the efficiency of conversion in terms of energy was the same for the Jersey and the Friesian. The efficiency of the breeds depended on the use to which the milk was put. Thus the Friesian was more efficient when the milk was sold as market milk on a gallonage basis, while the Jersey was more efficient when the milk was used for butter-making. There was but little difference between the two breeds when the milk was used for cheese-making. Again, the Jersey is theoretically better adapted to sparse grazing conditions than the Friesian, but there is no data available to show that the Jersey has this advantage under grazing conditions in New Zealand.

The evidence that decreased food utilization resulted from increased levels of feeding was discussed in relation to stocking rate. It was concluded that there was not sufficient evidence to show that this phenomenon accounted for the relationship between high stocking rate and high output per acre.

9. Further experimental work on pasture utilization demands a knowledge of the intake from pasture by grazing animals. The methods of measuring intake which have been developed were discussed. The indirect digestibility method holds out possibilities, using the inert-reference-substance-technique for determining the dry matter excreted and either the lignin ratio method, where the feed is fully utilized, or the fecal nitrogen method for determining the digestibility.

10. In conclusion the writer wishes to emphasize the importance of pasture utilization in obtaining a high output per acre from dairy farms, and the need for further research to find out the losses which occur through utilization on the New Zealand dairy farm, and the efficiency of the various methods for overcoming them.

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