SHEEP NUTRITION AND MANAGEMENT

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SUMMARY

Against the current background of requirements of New Zealand's export markets and their future potential the following main themes are discussed:

(a) The nutrition of the ewe after weaning and during mating, during pregnancy and while suckling.

(b) The nutrition of weaned lambs and hoggets, and the failure of young sheep to make satisfactory rates of liveweight gain up to the two-tooth stage.

(c) Feed requirements of the grazing sheep and the factors influencing them.

(d) The effect of nutrition on wool quantity and quality, particularly with reference to efficiency of such production.

(e) Nutritional requirements of various classes of sheep end products, especially the production of wool and wethers versus fat lamb production.

(f) The desirability of increasing sheep stocking rates on various classes of land, and the managerial and nutritional problems involved in such a policy.

INTRODUCTION

It is not possible in the space available to present a comprehensive, well-documented review of research into the influence of nutrition on sheep production, an influence that is so profound as to permeate all aspects of production. The best such review of recent years is that prepared by Schinckel (1963). Reviews of a more practical type, and pertaining to North Island conditions, have been given by Wallace (1960) and Clarke (1959a), the latter applying particularly to hill country. In this paper some of the knowledge of significance to the task of increasing sheep production in this country will be discussed and an endeavour made to point out where knowledge is lacking. This will be very much a personal point of view, and there will not be space to deal with certain whole sections of the field such as lamb mortality, trace elements, and the interactions of cattle and sheep.

One general observation must first be made, namely, that increased sheep production through nutrition will be achieved most rapidly by an increase in total pasture and crop production and in the amount of conserved fodder.

Such considerations involve soils, plants and fertilizers as well as animals, together with an economic atmosphere favourable to financial investment in farm improvement. This paper then will deal solely with the utilization of the feed grown. At the very outset mention should be made of one factor which confounds and complicates the whole approach to better nutrition. This is the influence of stocking rate or carrying capacity. It would be easy to point out the benefits of good nutrition, giving sheep in excellent condition, high fleece weights and rapid lamb growth rates. But what must be attained is not so much good nutrition as high efficiency of conversion of feed to lamb and wool and this high efficiency can, in most cases, be obtained only by sub-optimal nutrition.

EWE NUTRITION

In view of the high proportion of breeding ewes in New Zealand, their nutrition is obviously of great importance. This may be dealt with in the three main phases of the annual cycle — the post weaning and mating period, the winter pregnancy period, and the lambing to weaning period.

Nutrition After Weaning and During Mating

Nutrition during this period decides to a major degree the reproductive performance of the ewe. The long-established practice of flushing is widely accepted by sheep farmers. The literature records many experiments purporting to show that improved levels of nutrition before and during mating cause corresponding improvements in lambing percentage brought about primarily by increased numbers of twins. It will be sufficient to concentrate upon the recent work which may cause some modification of these theories. From the work of Wallace (1961b) and Coop (1962) it is now known that the liveweight of the ewe at mating has a major determining influence on fecundity and fertility — the higher the liveweight the greater the percentage of twins and the lower the percentage of barren ewes. Secondly there is a specific flushing effect (Coop, unpub.). In ewes of the same liveweight at conception, those which are or have been gaining weight will have more twins than those merely maintaining liveweight, which in turn will have more than those losing liveweight. These two factors seem to be of about equal importance. The customary treatment is to flush for about three weeks

before the rams are turned out with the ewes and for a further three weeks during mating. This is rather expensive of good feed and in many places in many seasons the amount of feed is just not available (Hulet *et al.*, 1962). It is clearly necessary to determine what is the optimum time and duration of flushing. This is being studied at Lincoln College, and the first tentative results suggest that twinning rate at lambing is already largely determined by the time the rams are put with the ewes.

Between weaning and the month of April, ewes attain their highest rate of wool growth. Deliberate starvation during this period in order to reduce ewes to a condition where they will respond to flushing, as was suggested by the old theory and now proven to be incorrect, has a very marked effect on fleece weight. Between extreme groups up to 1½ lb difference in fleece weight has been measured.

In a bounteous summer or in an understocked situation ewes should be kept in good condition after weaning and then flushed. In drought or in an overstocked situation the best management is not quite so clear cut. Given a limited amount of feed, it still is better to semi-starve the ewes immediately following weaning and then to flush them if possible with the feed that is saved during the semi-starvation period. What must be avoided at all costs is for the ewes to be losing condition immediately before mating.

Lambing percentage can vary by up to 10 to 20% as between good conditioned and poor conditioned ewes or between flushed and unflushed ewes, so it is clearly of some importance to take advantage of this, especially if it can be obtained at low cost. Several questions, however, remain unanswered:

(1) Is it possible to obtain the response by stimulating the ewe nutritionally for a short period at some critical phase of the cycle and so obtain all the benefits from a few days of good feeding instead of several weeks?

(2) What is the biochemical and physiological reason for the higher twinning rate in good conditioned and flushed ewes?

(3) What are the economics of flushing with hay or concentrates in seasons when pasture flushing is impracticable? This will depend a good deal on whether one can obtain a response from a short, sharp flushing period instead of the customary 6 weeks.

Apart from flushing, there is no nutritional need for good feed in the late summer and early autumn and the question

therefore arises as to what is the effect on ovum implantation and embryo survival of a substantial lowering of the level of nutrition at the end of mating, or after the first 3 weeks of mating, or indeed possibly almost as soon as the rams go out. Work at Reading by Allen (pers. comm.) suggests that nutrition post conception is of little significance and it is known that in pigs it appears to have little effect on litter size. There are many managerial advantages to be obtained by lowering the level of nutrition early in the autumn so as to conserve autumn grass for use in late pregnancy, so this is also a matter for investigation.

The trouble with these studies is that large numbers of sheep are required. To get the most out of the experiments the ewes should be slaughtered and hormone assays made. Wisconsin workers (Bellows *et al.*, 1963) have attempted to elucidate the mechanism of flushing by such methods but the results have been disappointing because of inadequate sheep numbers. Conversely, work at Lincoln College could be criticized because assays have not been made and lambing performance of large numbers of ewes has been the sole criterion.

Nutrition of the Pregnant Ewe

The main problem here is one of exercising strict rationing procedures to avoid on the one hand too generous feeding, wastage of food and abnormally high lamb birth weights, and on the other low birth weights and pregnancy toxaemia. Twenty years ago pregnancy toxaemia was one of the main causes of mortality but now is of considerably less significance because of an understanding of the principles involved in feeding in-lamb ewes. However, if both carrying capacity and twinning rate continue to rise the problem will remain. Basically, the foetus or foetuses make most of their growth and cause greatest nutritional demand only in the last 3 to 6 weeks of pregnancy. The ewe during this period should be on a rising plane of nutrition both quantitatively and qualitatively, and with forethought this is not difficult to achieve.

In the interests of high carrying capacity and conservation of feed for this critical pre-lambing period, it is possible to take advantage of the undoubted resilience of the ewe by putting her on to a sub-maintenance diet immediately after conception so that she loses weight during the late autumn and early winter but regains it just before lambing and gives birth to average sized lambs. It is

necessary, therefore, to compromise between feeding the ewe well and feeding her only adequately.

Recent theories of the causes of pregnancy toxaemia owe much to the work of Reid and Hinds (1962). They have shown that the initial biochemical lesion is probably hypoglycaemia followed by increased cortisol output, adrenal hyperactivity and increased blood ketones. Using blood ketone level as a precise measure of energy status. Reid has shown that by the last 2 to 3 weeks of pregnancy the energy requirement of a single-bearing ewe is nearly 50% above maintenance while that of a twin-bearing ewe is 75% above maintenance. Of course, the ewe has some control over her requirements by reducing the birth weight of her lambs and hence the energy requirement of the foetuses.

It must not be forgotten that wool growth rate is at its lowest in winter and is further reduced by the demands of pregnancy and lactation. This leads to a thinning of the wool fibre and even to a complete break or shedding which reduces not only fleece weight but also fleece quality. Again a compromise is necessary. A high carrying capacity, which is made possible by a strict or severe rationing system, causes this deterioration in wool weight and quality but gives greater production per acre.

Nutrition of the Suckling Ewe and Lamb

The subject of neonatal lamb mortality is of much importance. The level of mortality is higher in the very large and the very small lambs at birth, and birthweight is influenced by the nutrition of the in-lamb ewe in late pregnancy. Attention must also be drawn to the excellent work of Alexander (1962) who has measured heat production of newborn lambs under various environmental conditions. Heat loss is relatively high in small lambs owing to their high surface-to-volume ratio and their reserves of fat are rapidly used up. In bad weather such lambs rapidly perish unless they have sufficient strength to get up and drink.

Several studies have shown that milk production of the ewe and growth rate of the lamb are most affected by immediate level of nutrition (Barnicoat *et al.*, 1949; Coop, 1950). Although the broad principles of feeding from lambing to weaning are reasonably well known, there are many things yet to be learned. This whole period is one ripe for thorough investigation. Conflicting ideas may be argued. The writer concurs with

those who consider that milk production of the ewe is very important and that New Zealand breeds of sheep are notably deficient in this respect, especially by comparison with U.K. sheep. But, on the other hand, with the demand for light lamb slaughtered at 8 to 12 weeks of age, early weaning techniques, clover-dominant pastures for early weaned lambs, and high carrying capacity, one can increasingly regard the ewe merely as an incubator capable of getting one and preferably two reasonably healthy lambs to about 6 weeks of age. Nevertheless, not very much is known about the nutrition of the young lamb and especially the young twin lamb.

In his study of lamb growth in the U.K., Spedding (pers. comm.) has shown that milk production is important, first, because of its direct effect on lamb growth rate, secondly, because the lamb which gets plenty of milk eats less grass, and, lastly, because worm infestation of the lamb is inversely related to milk consumption so that parasitism is unimportant in single suckling lambs.

Twin-bearing ewes are known to give 30 to 40% more milk than single-bearing ones, due, it is thought, to the fact that a single lamb does not drink all the milk the ewe can produce and so limits the lactation of the ewe. This may not be the only explanation, otherwise single lambs would grow at a more uniform rate. This is certainly not true even within a flock, still less between local Romney lambs and some of the U.K. lambs which grow at phenomenal rates. What exactly is the interaction between the lamb and its dam's milk supply? The nutritional factors which influence the lactation curve and persistence of lactation also remain obscure. At lambing time many enlightened farmers use the rotational shedding system. In many circumstances, this means a considerable fall in nutrition during the first one to three days of lactation. What effect does this have? Is it possible to devise some system of management which limits milk production for single-bearing ewes during the first month, but creates greater persistency for the third month, and should there be a different system again for twin-bearing ewes?

Management techniques such as rotational and creep grazing or drenching with anthelmintics have generally shown no great advantage over set-stocking except in exceptional circumstances, such as exceedingly high carrying capacities (Wallace, 1963). One of the things that has been learned from the demand for the very light weight

lamb is that carrying capacity can be increased by early drafting, and another that lambs can be weaned at very early ages if this is either necessary or desirable, which it is with high carrying capacity. At Lincoln College, lambs have regularly been weaned at 8 to 10 weeks of age, and at times 6 weeks of age, when the lambs weigh between 30 and 40 lb liveweight, without any obvious disadvantage. Such techniques suggest that it is necessary to know more about the nutrition of such young, weaned lambs as distinct from those normally weaned at 12 to 16 weeks of age. In this connection the high rates of gain obtained by McLean's lambs at Lincoln College (1964) on clover and to a lesser extent on lucerne is of great interest, as are the rates of gain of lambs at Manutuke on clover pastures (Sinclair *et al.*, 1956).

WEANED LAMBS AND HOGGETS

The problem of so-called ill-thrift has dominated research on weaned lambs.

Clarke's (1959b) work has defined an important type of ill-thrift as one of inappetence or, as he calls it, starvation in the midst of plenty. To define a problem is the first essential step, but there follows a long, tedious and often disappointing struggle to find the cause. Although a solution to this seems as remote as ever, some extremely important results are coming forth concerning metabolism in the rumen, to which reference will be made later. The use of selenium for what was another form of ill-thrift has had startling results (Hartley, 1961) and is widely adopted. So much work has been done in ill-thrift and mineral deficiencies that it is impossible of review in the space available here.

Important though the problem of ill-thrift is, it must be emphasized that 90% of the failure of weaned lams to give a satisfactory growth rate is due to a shortage of sufficient feed and especially sufficient feed of adequate quality. On large tracts of New Zealand hill country and most high country, lambs weigh about 45 to 50 lb at weaning, and yet more than 12 months later, when mated as two-tooths, they weigh only 70 to 80 lb. Further, in the 7 months from weaning to the following spring, many of these lambs make virtually no liveweight gain at all. These lambs and hoggets are perfectly healthy, they do not know what ill-thrift is, and apparently they do not know what good feed is either. Oversowing and topdressing provide the first answer but

in many cases this is not the only answer needed. Supplementary feeding and especially the economics of supplements for hill hoggets is worthy of further study. The lamb may well be much more sensitive than the ewe to wind, rain and the winter generally, on account of its higher surface-volume ratio, so that some new management technique to minimize this may be necessary.

On New Zealand hill country, where most of the ewe replacements are reared, the rearing of good hoggets is the primary nutritional problem — well before such things as barrenness, much of which follows from poor hogget rearing. It needs to be emphasized that the growing hogget should produce 40 to 50 lb of liveweight gain plus 10 lb of wool in the year following weaning and this cannot be done on pasture whose digestibility is only 60%. Much interesting and important fundamental work is now in progress both here and overseas on the relationship between food digestibility, rate of passage, voluntary intake, rumen development and volatile fatty acid production. Its application to the adequate nutrition of hoggets is clear. As digestibility of pasture improves from, for example, 60% to 80%, there is not merely just this much more food absorbed, important though that is. More important still is that voluntary intake is significantly increased and the ratio of volatile fatty acids becomes more favourable. There is, therefore, a snowballing effect. The margin of nutrients available for liveweight gain over and above those necessary for maintenance may increase severalfold. This merely highlights the fact that, if reasonably rapid liveweight gain is to be promoted, the pasture must be of reasonably high quality and that what is good enough for ewe maintenance is very far from good enough for hoggets.

For eight out of every twelve months the ewe is virtually at maintenance level and there is really no great reason why the quality of the feed should be higher than maintenance quality. But the growing lamb and hogget is altogether a different proposition requiring the highest possible quality of feed from birth until it reaches 100 lb liveweight. Yet the same pastures are used for both purposes and reliance is placed on pasture management to bridge the gap. It may well be that it will be found necessary to provide a different type of pasture entirely for the weaned lamb — such as the clover pastures on which such high rates of growth have been obtained at Manutuke, Lincoln College and Palmerston North (Rae *et al.*, 1961; McLean, 1964).

FEED REQUIREMENTS

The fundamental feed requirements of sheep when fed in pens are now known with sufficient accuracy and receive support from Blaxter's (1962) calorimetric approach, but what is certainly not known with any clarity is the feed requirement of grazing sheep under the various grazing conditions existing in the country. It may be argued that since grazing sheep are not hand-fed or individually rationed, the exact feed requirements are merely of academic interest. But this is not so. The stage has been reached in animal husbandry where the criterion of productive efficiency is efficiency of conversion of feed to meat and wool. The denominator is the feed intake required to achieve a certain level of production and this denominator must be capable of calculation from such easily measured things as liveweight and liveweight gain.

The 50 to 100% increase in maintenance feed requirement recorded for grazing cattle by Wallace (1961a) and for sheep by Lambourne (1961), and by Coop and Hill (1962), is still the subject of debate. Assuming it to be correct for sheep in the specific conditions at Lincoln College, one can only guess the added grazing cost for sheep under all the other conditions such as summer drought, wet cold winter, steep hill country and the 5 acres per sheep high country. And if it is proved to be correct, how can management systems be devised to minimize the grazing energy cost? Lambourne first showed that maintenance energy requirements can be reduced by increasing the availability of feed and decreasing grazing time, and this has been confirmed at Lincoln College.

Blaxter, the leading exponent of energy metabolism in the U.K., has resolutely opposed the idea of the energy cost of actual grazing being nearly as large as has been claimed. Recently he has shown that heat loss from sheep is greatly increased by wind even in sheep carrying appreciable fleeces (Blaxter, 1963). For example, in a wind of 10 m.p.h. the critical temperature of a sheep is 57°F for an 8 cm fleece, increasing to 79°F for a 4 cm fleece and to 90°F for a newly shorn sheep. Calculation from Blaxter's estimates of grazing energy plus heat loss due to wind estimated from wind velocities and temperatures at Lincoln College would bring the maintenance requirement very close to the value observed at Lincoln. Coop and Drew (1963) have also shown that the maintenance requirement of newly shorn sheep in the autumn is 40% above that of woolly sheep when both are fed in pens.

The point of all this is that there is an extensive and important field of investigation here in New Zealand on the effect of climate, fleece length and grazing on the feed requirements and efficiency of sheep. Time of shearing and multiple shearing are obviously implicated. In this connection it has recently been shown by the Hill Farming Research Organisation (pers. comm.) that sheep can be wintered on the Scottish hills with less of the customary liveweight loss if provided with shelter from the wind.

Another aspect of feed requirement and efficiency is liveweight. Liveweight has become one of the fundamental factors in animal production, and any comparison of per sheep productivity must be related to liveweight. One can expect fleece weight and milk production to increase with bodyweight but there is no clear reason why, in aged ewes already sexually mature, those which are heavy should produce more twins than those which are lighter. This may be merely of academic interest. But what is of practical interest is to know how efficiency varies with liveweight because, if an optimum exists, one can obviously aim to achieve that liveweight. The solution is not simple, because feed requirements increase with liveweight at much the same rate as do fleece weight, growth rate and twinning and some compromise is obviously necessary. The picture is clearer with young sheep where barrenness is very sensitive to liveweight.

As the concept of efficiency of feed conversion rather than individual production per sheep gains hold in the sheep industry, so will a knowledge of the fundamental feed requirements and the factors affecting them be of increasing importance. The most important tool in this field of study is the animal calorimeter, a rather costly tool, but one which the sheep industry can hardly afford to forgo for much longer.

NUTRITION AND WOOL

Our knowledge of wool growth and efficiency of wool production owes much to Australian workers. Almost all of their work has been carried out with Merino sheep and while much of this is fundamental and applicable to all sheep it is worth recalling that the Romney is a rather different sheep. It has a reaction to light rhythm and temperature which, in terms of wool growth, is different from the Merino and the heritability of wool characters is also

different. Generally repetition of other people's work is considered to denote sterility of thought, but the Australian work is of such importance to an understanding of wool production that it should be repeated with Romneys to ensure that the knowledge is applicable to our conditions.

Many experiments have demonstrated how sensitive wool growth is to current energy intake or nutritional level. Marston (1948) and also Ferguson (1958) have shown it to be almost proportional to intake but with a slight diminishing return as intake increases. Wool continues to grow even though the animal may be losing weight, for energy stored in the animal can subsequently be utilized to release nutrients for wool growth in times of energy shortage. On the other hand, wool growth is fairly insensitive to protein intake down to levels of 7 to 8% crude protein in the feed. Wool contains an abnormally high proportion of the sulphur-containing amino acid cystine, but, according to Ferguson, only if this acid or proteins are administered in the abomasum or lower in the digestive tract where it escapes fermentation is there any sulphur response. It is then used with high efficiency giving a 30% recovery in wool and higher sulphur content of the wool. In practice, however, the action of the ruminal microorganism so alters the nitrogen and sulphur of the food amino acids that nitrogen and sulphur supplementation *per os* is ineffective in increasing wool growth. The nitrogen and sulphur contents of New Zealand pastures, especially in those topdressed with superphosphate, are such that they are highly unlikely to be limiting factors — instead total energy intake is by far the most important. The situation could be different on untopdressed high country where pasture responses to sulphur are common.

In New Zealand sheep there is a very large seasonal fluctuation in rate of wool growth. In dry sheep the rate in winter is probably only one-third of the maximum rate in summer. In ewes this winter decline is aggravated by pregnancy and lambing so that the ratio is about 1:5 (Coop, 1953). Several questions arise from this observation. Would it pay to feed sheep especially well in summer to exploit the naturally high growth potential then, or would it be better to feed them better in the winter to produce a more even fibre and one free from tenderness and break? We do not know. Where wethers are run for wool production and finally slaughtered for mutton, it would be uneconomic from the wool production point of view to slaughter them later than the autumn.

Schinckel and Short (1961) have shown that under-nutrition of the ewe produces a lamb which at birth has a reduced number of follicles and a low S/P ratio. Post-natal nutrition affects the rate at which the follicles mature and commence to produce wool fibre but has no permanent effect on the number which mature. Pre-natal nutrition, however, does affect the ultimate number maturing. At maturity sheep out of ewes poorly fed both pre- and post-natally had a 20% lower mature fleece production than those born out of well-fed ewes. This is for Merinos. Field trials with Corriedales in New Zealand (Coop and Clark, 1955) and Merinos in Australia (Donald and Allden, 1959) have failed to confirm any permanent effect on mature fleece weight but these trials referred to differential nutrition applied post-natally only. As New Zealand breeding flocks are born mainly on hill country where nutrition is not good, it is just possible that a permanent wool growth depressing effect is produced.

It would be profitable, in the writer's view, to conduct fairly large-scale wool growth efficiency tests, not only between breeds but also within breeds to determine whether more efficient strains of Romneys and Corriedales exist. If wool growing becomes of greater significance in the wool and meat complex, it will obviously be necessary to know something about these differences in efficiency. Australian workers have shown that Merino, Polwarth, Corriedale and Lincoln all produce clean scoured wool with equal efficiency but the trials were on a small scale and could bear repetition (Daly and Carter, 1955). At Lincoln College it has been shown that there are considerable differences in the efficiency of individual Corriedale sheep.

Another aspect of wool efficiency which has not been studied is the influence of age. It is known that fleece weight reaches a maximum at the four-tooth stage and then steadily declines. But to what extent is this decline real and significant, and to what extent is it a reflection of higher twinning rate and milk production and lower intake? The two- and four-tooths are still growing and have more or less reached their maximum skin area. It is also important to know the fundamental biochemical or physiological reasons why old sheep produce less wool, especially as many believe that it would be desirable to keep more old sheep because the latter have higher lambing percentages. Measuring efficiency would demonstrate just how good or bad the old ewe is. If she is bad, then it might be wise to

keep a younger flock, growing the young sheep well so that they will reach a liveweight equivalent to the old sheep and then have the same lambing percentage as the old sheep. This would also fit in with the demand for more mutton.

Lastly, speciality wools such as, for example, paperfelts, have not been exploited. Here breeding is very important but so too is nutrition and it could be that there is a place for a different type of management to meet specific requirements.

WOOL AND WETHERS VERSUS FAT LAMBS

Predictions of prices and markets are not noted for their reliability but, taking things as they are now, the prospects are for unlimited wool markets, increasing and perhaps unlimited mutton markets, and a slowly expanding lamb market. This raises the question of turning the clock back by increasing the national wether flock at the expense of ewes and fat lambs.

Using the data which have been assembled from local intake studies, it is calculated that a wether requires 70% of the annual feed required by a ewe plus single lamb taking that lamb to 28 lb carcass weight. On current wool and lamb values, the ewe returns 20% more money than the wether per unit of food intake and, further, the ewe plus lamb feed requirement fits more closely seasonal grass growth. The above calculation takes no cognisance of many of the virtues of wethers such as lower replacement cost, higher carcass value, lower mortality and lower labour costs, but even so it would be difficult to justify any marked swing towards wethers. Not until wether mutton prices appreciate relative to fat lamb prices would it appear profitable to change to wethers, but that situation may arise within several years and in certain areas it may have arisen now.

In anticipation that such a situation may eventuate it appears that it would be profitable to acquire the knowledge of how to run wethers as efficiently as ewes are now managed in the seasonal pattern of pasture production and then to make a comparison of wethers versus ewes. It would be necessary to use young wethers because these will be at the peak of their wool-producing life, but it will also be necessary to kill them while the carcass quality is high.

LAMB CARCASS WEIGHT AND QUALITY

The major determinant of export lamb weight and quality is breeding, but nutrition and management also play some part. Rapidly grown lambs have better quality than slower ones. High carrying capacity and high lambing percentage make the light-weight lean lamb a better proposition than the 36 lb carcass. Just as the demand for rapidly grown, very lean beef in the U.K. has led to the discovery that the larger late maturing breeds such as the Friesian are more efficient than the traditional beef breeds, so too with sheep the assessment of lamb in the years to come may be based more on efficiency of meat production than on quality of the meat produced. This will require a reappraisal of breeding and management systems. In this connection the time is probably overdue when the N.Z. Meat Producers Board, the meat trading companies and the scientists got together to pool their knowledge and attempt to decide the direction New Zealand research should take to meet changing market needs. Scientists involved in sheep production research cannot claim to have expert knowledge of the U.K. lamb market, the lamb markets which it is hoped to develop in other countries, and the future markets for mutton, although some are no doubt not satisfied that local production is geared to meet these changing markets. On the other hand it is possible that the Meat Board and trading companies are less aware than the scientists of the fundamental factors which govern the efficiency of conversion of grass to meat, factors which are of great practical significance because they are so fundamental.

CARRYING CAPACITY

The quickest way to increase sheep production would be an immediate increase in sheep numbers. Many experiments both in New Zealand by D. E. K. Walker (1954) at Ruakura, Clarke (1962) at Whatawhata, Suckling (1962) at Te Awa and S. D. Walker (1962) at Winchmore, and also overseas by the Grassland Research Institute in England and the C.S.I.R.O. at Canberra have demonstrated that increased production per acre can be achieved by increasing the carrying capacity. Examining individual performance of the sheep and starting from a very low carrying capacity, it is clear that performance improves at first with increased stocking as that stocking gives greater pasture control and then it declines as the feed available

per sheep declines. Body weight, fleece weight, lambing percentage and lamb growth rate all decline in this final phase. But these are more than offset by the greater number of sheep carried and the greater utilization of the pasture grown. Not until the increasing carrying capacity depresses the pasture production with deterioration of the sward or until the decreasing individual performance reaches a critical stage when ewe and lamb mortality increases is a situation of real overstocking reached. Clearly, then, there must be an optimum carrying capacity just short of overstocking.

Most farmers are reluctant to approach this point and one can partly sympathize with their point of view. Because individual production per sheep declines, net financial return is not proportional to stock carried but increases at a lower rate according to a law of diminishing returns. The labour required increases. A tendency exists to overemphasize the drought years rather than the good years. There is not any doubt that it is considerably more worrying to be stocked near to the limit.

How, then, can a move towards a higher carrying capacity be encouraged? Several management techniques such as early weaning, fodder conservation, and knowledge of when nutrition is critical and when it is not, are available. Demonstration on a sizeable scale would help. Another help would be some measure for farmers as to when they are under- or overstocked. Such a measure could well be fleece weight. Since wool grows continuously and is not resorbed, it acts as a measure of the general level of nutrition and as an integrator of all the ups and downs of seasonal nutrition. It would clearly be profitable to determine this optimum fleece weight. High average annual fleece weight (say, 11 lb) may merely be an index of poor pasture utilization. On the other hand, low average fleece weight (say, about 7 lb) would indicate extremely poor nutrition. But within these limits it should be possible to ascertain the optimum level so that farmers may deduce for themselves whether or not over the years they are under- or overstocked. Clearly any figure set for fleece weight would need to be interpreted correctly to allow for the exceptionally good or bad year, and a separate figure would probably be needed for the hard hill country and the high country where the sheep are much smaller in size.

On the poorer and low carrying capacity country where pasture quality is not good, it is more difficult than on good

country to judge carrying capacity. If the fleece weight is 8 lb and lambing percentage 80%, one hesitates to put on more sheep. In this connection the observations of Eadie (pers. comm.) in the Scottish Hill Farming Research Organization may be of significance. He has been measuring pasture digestibility and voluntary intake on some hill pasture, and obtained evidence that voluntary intake was limited not by availability of feed but by the digestibility of it. This means that the stocking rate was below the maximum and that more sheep could be carried without affecting individual intake and production. Quality and not quantity of pasture was therefore the limiting factor.

The problems associated with a very high carrying capacity need further study. In particular, it is necessary to know how to avoid the two main obstacles — the summer drought and the cold wet winter followed by a late spring. It can be taken as axiomatic that if the farm is correctly stocked it will be overstocked in some years and in some particular seasons, and it is towards this problem of surviving these periods of overstocking that attention should be directed.

Fodder conservation is one of the really vital factors. With barns full of hay one can face the future with confidence of surviving the worst that can happen. There is no longer any necessity to stock down to what can be carried through a drought but instead to stock up to what can be carried in a good season. To do this correctly requires 1½ years' fodder in reserve. Lucerne is undoubtedly the best species for this purpose, but not the only one.

During the droughts in Canterbury several years ago, it was learned that the poor roughages such as pea straw, ryegrass straw and oat straw, previously wasted, could be used to keep sheep alive, and these have now become a routine part of summer management on the Lincoln College Research Farm to permit saving all of the lucerne hay for the more critical winter period. Improvement of such very poor roughages by treatment with molasses or urea has so far been unsuccessful. Another thought is whether it is possible to minimize liveweight loss in a drought by cutting out grazing altogether. If grazing is energetically costly, then it might be better to starve the sheep in a shed than to allow them to spend energy searching over wide areas for the very sparse grazing. These are merely some observations to suggest that it is essential to explore new techniques to meet these situations.

The hill country will have to carry many more stock than at present if the rate of increase is to be maintained. The limitation to carrying capacity, apart from the amount of grass grown, is the quality of the herbage which current hill country management provides. Over large areas sheep never reach a reasonably mature size, they start having lambs at 70 to 80 lb liveweight, and thereafter have little chance of putting on condition. If they could only attain 90 to 100 lb as two-tooths, they could perhaps stand the fact that they will not grow any bigger. A satisfactory solution to the grass-grub problem is also urgently required if more stock are to be carried. A means of fodder conservation or supplementary feeding on hill country is also necessary, especially in the form of hay which can be stored for use either in the drought or the winter.

CONCLUSION

It will be clear that it has been necessary to omit many important phases of nutrition and management. Perhaps it is worth just listing some of them: the place of cattle on the sheep farm; the importance of selenium and possibly other as yet unidentified trace elements; ram management; the potentialities of non-castration and the Russian method of castration; the cause of excessive wearing of teeth; control of rabbits and grass-grub; the use of hormones for stimulation of rate of growth.

Rather than look at all of the many problems in a rather piecemeal fashion the object has been to discuss a small number of main themes, emphasizing the following:

(1) The great importance of carrying capacity and the need to develop techniques which will ensure that a high carrying capacity policy can be maintained with almost absolute safety.

(2) The need for greater study, both in management and in the fundamental physiology of the rumen, of the young growing animal from birth to 80 to 100 lb liveweight so that, having got it to that liveweight, its undoubted resilience can overcome the consequences of pregnancy, lactation and a high carrying capacity.

(3) Definition of feed requirements and the factors affecting requirements and voluntary intake in grazing sheep with a view to increasing efficiency of conversion.

(4) A study of wool growth in the Romney sheep;

(5) A need to stimulate research in certain fields in anticipation of future market trends.

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DISCUSSION

DR G. R. MOULE: *Could seasonal changes in wool growth be more useful than annual fleece weight as an indicator of over-stocking? If so the dyebanding technique may be worth considering.*

PROFESSOR I. E. COOP: I do not think so. Seasonal changes in wool growth in New Zealand sheep are quite marked even under conditions of constant level of intake. What is needed is not something which measures the short-term fluctuations in feed supply but something which integrates all these fluctuations. In fact, I would prefer to move in the opposite direction, namely, to use a three-year sliding average of fleece weight since drought or overstocking often

has more influence on the fleece weight in the subsequent year rather than the current year.

Q: *Does the intake of the newly shorn sheep increase when quality and digestibility of feed is low? If so, does digestibility of feed, which normally controls intake, change?*

PROFESSOR COOP: Digestibility certainly would not change. I do not believe that digestibility is the sole factor governing voluntary intake. It is my experience that increased energy requirement such as in lactation or in newly shorn sheep also influences intake, provided the feed is sufficiently available for the sheep to obtain the increased intake.

DR MANIKA TOMASZEWSKA: It is my experience that intake of sheep in outdoor pens increases considerably after shearing, even on low quality hay. The digestibility of the same ration does not vary between shorn and unshorn sheep.

G. L. BANFIELD: *Can Professor Coop reconcile the fact that although hoggets and two-tooths require high protein feed, hogget ill-thrift can be corrected by switching them from short, nutritious pasture to semi-mature pasture?*

PROFESSOR COOP: I did not say that they require high protein feed but rather high digestibility feed. Pasture of high digestibility often has a high protein level but it is digestibility rather than protein which is important. The hogget ill-thrift is something quite different; it is a specific case of inappetance caused by some unknown factor in very rapidly growing young grass in the autumn only, and principally in the North Island.

Q: *How soon does Professor Coop think one can cut down on the amount of feed given ewes following mating to enable feed to be saved for winter?*

PROFESSOR COOP: This is something which we need to know. There is little information on this point. My own belief is that the level can be reduced almost immediately after conception which in practice can be taken as meaning when 70 to 80% of the ewes have been tupped.

Q: *Is there a risk that in combining a shearing in the autumn with reduced intake to save pasture for the winter, a sub-maintenance diet may be produced?*

PROFESSOR COOP: There is certainly this risk, and one which must be taken into account in assessing the value of multiple shearing.

Q: *Does Professor Coop's figure of 90 to 100 lb liveweight as a desirable minimum for the breeding ewe vary between breeds?*

PROFESSOR COOP: It would be reasonable to expect that it would be lower than this for the smaller breeds such as the Merino, and higher for the Romney. We have evidence that the figure can be lower if the ewe is mated late in the breeding cycle, for example, in June rather than in March.

Q: *Is the traditional running of cattle on sheep properties still good practice from the sheep's point of view, and if so, how successful are farmers in determining the optimum proportion of these two species?*

PROFESSOR COOP: There is very little information on these two points. All that can be said is that cattle are necessary for pasture control in many but certainly not all parts of the country. The optimum ratio is mostly guesswork and must be subject to considerable error.

Q: *Could Professor Coop say what period of starvation is necessary to produce a distinct "break" in the fleece?*

PROFESSOR COOP: It is not possible to be at all definite on this subject, since break is influenced by time of the year, stage of pregnancy, lactation, and the degree and duration of the period of under-nutrition. It is usually associated with the high nutritional demands of late pregnancy and early lactation coinciding with the time when the natural wool growth rate is at its maximum.

I. M. CAIRNEY: *Professor Coop stressed good hogget nutrition and high carrying capacity. Does he consider high D.M. silage could have any place in such a system in New Zealand?*

PROFESSOR COOP: Although sheep can and will eat silage, sheep farmers are very reluctant to make any form of silage. They prefer to conserve excess growth either as hay, as paddock roughage, or as increased liveweight of their sheep. High D.M. silage would be helpful, but I am inclined to agree that silage is not a practical proposition on the great majority of sheep farms.