A REPORT ON AN EXAMINATION OF THE RELATIVE DIGESTIBILITY AND NUTRITIVE VALUE OF THE FIVE FOLLOWING FORAGES, WHEN FED TO CATTLE IN TRINIDAD.

1. BAMBOO GRASS - Paspalum fasciculatum.
2. PARA GRASS - Brachiaria mutica (Stapf).
3. GUINEA GRASS - Panicum maximum.
4. GUATEMALA GRASS - Tripsacum laxum.
5. SWEET POTATO VINES- Ipomea batatas.

by

E. S. CAPSTICK, B.A., (Cantab).

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INTRODUCTION.

There is an old English saying, with regard to livestock, that "half the breeding goes in at the mouth". Its significance is obvious, on consideration of the fact that any attempt in livestock improvement, of a permanent nature, must depend upon a sound system of animal nutrition. Only with the comparatively recent advances, in the knowledge of this science, has marked development in any system of livestock improvement and consequently animal production been possible.

Livestock improvement and mixed farming become increasingly important features in Colonial Agricultural Policy. In relation to the problem of food production, their importance, with the advent of the war, becomes magnified since considerations of human nutrition must necessarily be concerned to an even greater extent, with those of animal nutrition.

In this respect it is obviously desirable to become independant of imported feeding stuffs, though such an aim is not always possible.. Permanent or only seasonal lack of home grown feeding stuffs, to supply stock requirements, is a problem which confronts many countries. It is, however, only by a knowledge of the nutritive values of more home grown or easily obtainable feeding stuffs, that a country is enabled to obtain the maximum production from them, in addition to assessing her independence of imported ones. Such a knowledge, it is felt, would be desirable in Trinidad.

Cattle in Trinidad are kept for three main purposes:- work, milk-production and the dung they provide. On sugar estates, this last is one of the chief reasons for the maintenance of a dairy herd. To achieve this end, the soiling method of livestock rationing is adopted, green herbage being cut and fed to the cattle in pens or stalls in the case of dairy herds.

The roughage supplied to the animals varies with the season of the year. In the wetter months this comprises the cultivated perennial grass crops, such as Elephant Grass and those examined in this thesis, or mixed grasses from the cane field traces. In the dry season, these are replaced by cane-tops and Uba Cane which is sometimes grown particularly as a reserve, to

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tide over a lengthy dry season, should other roughages fail.

Throughout the year the peasant cattle owners rely upon what can be cut or (if not) grazed from roadsides or waste patches of land, the use of concentrates being rare.

Though scarce, where present, the pastures are used more as a means of exercise or additional grazing and are not generally relied upon as a supply of roughage.

Home produced or locally obtainable concentrates comprise chiefly Maize, Cottonseed and Coconut meals and molasses. While these are utilised as far as possible, addition of protein-rich concentrates to dairy herd rations is very often necessary, if required feeding standards for milk-production are to be met. To achieve this, reliance has been placed on imports, mainly of linseed or soya bean meals.

There is at present practically no accurate knowledge of the nutritive values of feeding stuffs when fed to cattle in Trinidad and, as far as is known, except for two previous digestibility experiments, and the present one, little attempt has been made to determine any or to verify the standards upon which rations are based. Such a system of rationing, therefore, it is felt, leaves much to be desired. While it is admitted that rations based upon the most accurate feeding standards and nutritive values can at best be little more than an approximation, it is however thought that this should be no excuse for the use of less accurate values which only tend to increase the error in question.

In the larger dairies, a successful breeding programme has been established and a high standard of milk-production reached. With the addition of imported concentrates, to supply the deficiencies of those already available, it has been possible to maintain this standard. The progress made in such a venture cannot but be acclaimed but, while it has been assumed, very often in all probability quite rightly, that the imported feeds are essential to maintain certain standards, it would appear that a certain risk is entailed. With uncertain knowledge of the feeding values of local feeds, too much reliance has inevitably been placed on imported ones. Should supplies of these be cut short or their prices be raised unduly, this uncertain knowledge will only increase the consequent difficulties.

The first essential in livestock rationing is to maintain the animals. A knowledge of the nutritive values of the feeding stuffs which are used for that purpose is needed, in Trinidad, and should form the logical basis to a wider knowledge of the nutritive values of all rations, fed for any purpose. In addition, if there is to be any progress, in the direction of further utilisation of home grown feeds with increased production from them, a start must be made with the perennial fodder crops. There is ample evidence to show that under proper management, they have a high nutritive value. However, as yet, insufficient attention is paid to this aspect by cattle owners in Trinidad and it is felt that, as utilised at present, the potential feeding value of these fodders is not always fully realised.

In general, it is thought, that in comparison to the high standard attained in livestock improvement, the nutritional aspects of the problem have been rather neglected. Therefore any contribution that can be made to alleviate this situation, may be of value to every class of cattle owner.

The Object of the Experiment.

The object of these experiment was to determine the digestibility and nutritive value, as a basis for comparison of the following forages, when fed to cattle in Trinidad.

1. Bamboo Grass - Paspulum fasciculatum.
2. Para Grass - Brachiaria mutica (Stapf).
3. Guinea Grass - Panicum maximum.
4. Guatemala Grass - Tripsacum laxum.
5. Sweet Potato Vine - Ipomea batatas.

Though some time has elapsed since then the experiment may be said to be a continuation of the series, initiated by Maule, J.P. (1930) with work on Uba Cane, Cane-tops and Elephant Grass. This was followed with work by Hobbs, R.E.T. (1931) on Savannah

Grass and Coconut meal.

Outline of the Experiment.

In planning the digestibility trials the method employed was that adopted by the above two workers. This, as Maule (1930) states, depended largely upon circumstances. It was arranged on the lines of similar trials, carried out, in India, by Warth and Lander (1926), with certain modifications similar to those employed by Maule, in a digestibility trial at Cambridge, in 1929. Details of the actual method of conducting the following trials and of the calculation of nutritive values from the amount of digestible nutrients, by the use of Kellner's (1926) "Production Values", will be given in a later section.

PART I.

(A) A CONSIDERATION OF THE METHODS EMPLOYED IN THE EXPRESSION OF THE NUTRITIVE VALUES OF FEEDING STUFFS, WITH SPECIAL REFERENCE TO KELLNER'S METHOD AND ITS LIMITATIONS.

There are three main ways of expressing the nutritive values of a feeding stuff:-

1. Morrison's (1927) in terms of digestible crude protein and total digestible nutrients.
2. Kellner's (1926) in terms of digestible crude protein and starch equivalent.
3. Armsby's (1928) in terms of digestible protein and net energy (in therms).

Basically the two systems of Armsby and Kellner are similar. They both attempt to achieve the same object and differ only in their method of expression. The fact that the two systems exist, however, tends to result in some confusion in terms. With that in mind, it is felt that some slight digression on the subject is essential, in order that the values derived from this work may be correctly assessed.

Kellner's

Kellner's original values, obtained by his respiration chamber were actually net energy ones. They agree, in so far as the feeds can be compared, fairly closely with those obtained by Armsby, working with his animal calorimeter. Both these sets of values for feeding stuffs are net productive ones and thus directly related to the effect they may be expected to produce.

In order to avoid the use of large numbers to express the net energy values of rations in calories and also to avoid the introduction of unfamiliar terms, Kellner converted his values into what he called Starch Equivalents. This value can be defined as the amount of starch (assumed to be perfectly digested) which has the same net energy value as the feeding stuff.

By using the term Starch Equivalent Kellner was able to express in a single figure what otherwise would have to be expressed in three, i.e. one for carbohydrates, one for fat and one for protein. This advantage has, however, very often led to the use of the term Starch Equivalent to express a value, not meant by Kellner, i.e. Gross Digestibility Energy. This value measures only the gross energy production, in terms of starch, but does not signify what proportion of the energy can be utilised for productive purposes. The distinction is made by calling Kellner's Starch Equivalent, "Production Starch Equivalent", and the others "Maintenance Starch Equivalent". These last are comparable to Armsby's Metabolisable Energy Values.

While it does not affect the values they obtained, it is felt that, at this point some criticism should be made of Maule (1930) and Hobbs (1931), for the use of the term "Total Metabolisable Energy", to express a figure in the calculation of their Starch Equivalent, Such a term as "Total Metabolisable Energy" does not exist. It is also felt, that this figure, from the method by which it was obtained, does not truly represent the Metabolisable Energy value of the feeding stuff which, incidentally, is measured in units of heat not starch.

Kellner also devised a method whereby the Starch Equivalent of a feeding stuff could be calculated, on the basis of its

digestible

digestible composition, by the use of "production values".

As stated previously this method was employed in these trials and as can be seen from the method of calculation the term Starch Equivalent is used, as by Kellner, to denote a net productive value.

Kellner determined his "production values" by feeding the pure digestible constituents of feeding stuffs to an animal, in the respiration chamber. By multiplying the amounts of digestible nutrients in a feeding stuff by these values, he was able to calculate its net productive value. When, however, this calculated value was checked against the one, obtained for the feed by direct use of the respiration chamber, the latter value was always lower than that calculated. In the case of very fibrous materials, the net productive values were found to be less than half those calculated from the content of digestible nutrients. This was due to the fact that, when determining his "production values", Kellner fed the (digestible) constituents of feeding stuffs in a pure finely divided form, entailing little or no energy expenditure in mastication and digestion. To obviate this he determined and tabulated correction factors, to be used in calculations, for each type of feeding stuff.

Digestible nutrients in some feeds therefore-pound for pound - have a lower energy value than others. This is a significant fact since it would seem that generally and particularly in the case of coarse fodders, as dealt with in this thesis, total digestible nutrients in a feed are not an accurate basis for comparison. Further, it could be assumed that digestible nutrients in a feeding stuff, containing little fibre, may then be twice as valuable as the same quantity in a feeding stuff, rich in fibre.

The disadvantages of using terms of digestible nutrients, as a measure of nutritive value, have been outlined. There remain the possibilities of expression in terms of either Net Energy or Starch Equivalent. To calculate the former, it is necessary to use Kellner's "production values" in their original form, i.e. as heat units, before conversion into terms of starch. Since this

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last step is eliminated and therefore the chances of error made less, it is felt that this method has much to commend it. However, a discussion of the relative advantages and disadvantages of such a course have no place in this thesis, for the following reason. Starch equivalent values form the basis upon which rations are calculated in Great Britain and the Empire including Trinidad, while, in addition to being the accepted ones, they are probably the most easily understood by stock-owners. Before accepting the Starch Equivalent system, however, it must be realised that there are distinct limitations to both expression of nutritive value, in these terms, as well as to the method which has been used to calculate them.

For attempting to express energy values in terms of matter, Kellner has been criticised by many. By so doing, his values become indirect measurements and as such, more liable to error.

In addition his "production values" were based upon a relatively few determinations. While he utilised these values, in their original form, i.e. as heat units, in earlier work, Armsby later showed that they were not accurate for every class of feed. Woodman (1932) states that in recent years it has been found necessary to increase the Starch Equivalent values for coarse fodders by one-fifth, in order to bring them into line with measurements of net energy made by Armsby. These new figures, he states, are in general agreement with his experience.

This step has been taken with values calculated in this thesis and where quoted, with those determined by Maule (1930) and Hobbs (1931), to put them on a comparable basis. The writer is not, however, quite certain of his justification in so doing, in this case.

Kellner's Starch Equivalents also were originally intended to measure the fat-producing value of feeding stuffs, when fed to steers, in store condition, and it was with such animals that all his determinations were made. The fact remains, however, as Wood, T.B. (1937) states - "that they have been widely accepted as

measuring

measuring the real value of feeding stuffs for all kinds of production, not only fat but growth, milk and work. Particularly in the case of milk-production has their meaning been stretched since there is evidence to show that Kellner's Starch Equivalents do not include a sufficiently high value for protein, to make them really accurate, as a measure of milk-producing value. This is due to the fact that when determining the energy production of feeding stuff constituents, Kellner worked on a basis of pure protein alone, without taking into account the value of amino-compounds, also present in the feeding stuff.

There would then seem to be justification in the severe criticism of Forbes (1937), who states "my feeling in regard to Kellner's method of computation of energy values of feeding stuffs is that it rests upon very slight experimental basis; that it was devised prior to the development of the main point of the revolutionary, newer knowledge of nutrition; and that it affords no scientific basis for recognising the influences of this great body of knowledge. In my opinion, his idea of using correction factors by which to multiply computed energy values to make them agree with results of calorimetric measurements, is a hopelessly awkward and ineffective way of recognising the individuality of feeding stuffs, as determined by the intimate character and nutritive qualities of their proteins, carbohydrates, and constituents of fatty character, their mineral nutrients and their vitamins."

Such a knowledge, while in every way desirable, is quite impossible to determine outside a fully equipped research station. Since however the Starch Equivalent system has become accepted and other values are lacking, those of Kellner must be used for practical purposes. While it is not supposed that Kellner ever intended his method to be so widely applied, it can be said in its favour that upon its rather unstable foundation, to some extent modified, the system of rationing in Great Britain has rested fairly successfully. The fact, however, that results, obtained by the use of Kellner's values, for feeds in Trinidad, may rest upon an even more unstable foundation, must be evident.

(B) THE ASSOCIATIVE EFFECTS OF FEEDING STUFFS IN DIGESTION.

Recently some very important and relevant aspects in the problem of measurement of the nutritive effects of feeds, have been stressed by Mitchell (1937). He points out that the aim of every method developed for the nutritive evaluation of feeds has been to assign to each feed a single value or limited number of values, referring to their different nutritive properties. In the computation of rations, it is assumed that these values are additive and nutritive effect constant. No provision is made for variation in such values, with the level of feeding or through the effect of one feed upon another. Associative effects of feeds in digestion and supplementary effects in metabolism are implicitly derived. Only recently, Mitchell states "has the idea developed, that the conception of constant feed values and the conception that deficiencies of one feed may be corrected by the excess of another, are really incompatible".

It has often been shown that feeds do not behave independently in digestion. Mitchell states that "wastages of foods in digestion are not additive when foods are combined" and that "departure from accurate addition may be slight in some cases but difficult to predict in all".

In connection with Kellner's discoveries with regard to fibrous materials, already mentioned, it would seem reasonable to believe that a bulky fibrous feed impedes the digestion of other feeds, mixed with it. Those feeds, then, with a low digestibility, it might thus be supposed, will lower the digestibility of others. Alternatively, however, feeds of high digestibility might increase the digestibility of one's with lower digestibility. The problem is very complex and by no means solved.

An interesting example is provided from results obtained by Hobbs (1931), at the Imperial College. His object was to determine the digestibility of Savannah Grass and Coconut meal, when fed to cattle. Since it was impossible to feed the Coconut meal alone, he adopted the usual method for determining the value

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of concentrates. This is to feed the concentrate with a roughage whose value is already known, in this case Savannah Grass whose digestibility he had first determined. By assuming the digestibility of the Savannah Grass to remain constant it was possible to calculate the theoretical value for the Coconut meal. As Armsby (1928) states, "it is evident that the determination of the digestibility of a concentrate in this way, is less accurate than that of a feed which can be given by itself. The assumption that the digestibility of the roughage is not changed, is unproved and probably not strictly correct".

Hobb's results bore out this contention. The digestion coefficients for the Coconut meal, so calculated, ranged from -49 to over 200 among the various nutrients. While admitting the possibility of reasonable experimental error, Hobbs points out that such could hardly account for these figures since the digestion coefficients of the combined ration showed no more variation than those of the grass alone.

But one explanation remained, i.e. that the digestibility of the Savannah Grass had been altered by the addition of the concentrate. By this method of calculation which assumes the digestibility of the grass to be constant, any alteration in value would have to be assigned to the concentrate. Since the proportion of concentrate to roughage was small considerable error in the theoretical digestion coefficients of the concentrate would result. Hobbs then attempted to determine to what extent and in what proportion the digestion coefficients for the constituents of Savannah Grass had varied with the addition of the Coconut meal. Unable to use his own, he made the comparison by using digestion coefficients for Coconut meal, obtained by Kellner. While such a comparison is desirable, it must however be obvious, that obtained in this way, it is quite valueless.

Further evidence of this nature is shown by Lander and Dharmani (1925). Using the same method to determine the digestibility of a concentrate., the digestibility of the roughage was so much improved, that, upon calculation, digestion coefficients of over

100 were obtained for several constituents of the concentrate. Warth (1923) also found when conducting feeding experiments with Indian fodders that higher digestibility was associated with a higher proportion of concentrate in the ration and he showed that digestibility increased considerably with the amount of protein present and was related, as far as all ingredients were concerned, to the protein content of the fodder. In this respect Kellner (1926) states that "increase of crude protein tends to aid digestibility of starch which would otherwise pass undigested in the faeces" and also states, "the increase of crude protein in a food causes, not only no depression of digestibility of the other components, but, on the contrary, minimises the depressing effect of large quantities of nitrogen-free substances".

Further evidence on this subject of the associative effects of one feeding stuff upon another is supplied by Mitchell (1937). In particular he quotes the work of Fraps as confirmatory evidence of the effect of protein deficiencies, in the ration, upon energy utilisation. In the light of such evidence, he finds his conclusions expressed in those of Fraps, which are as follows:-

1. "The addition of a proteid feed to an unbalanced ration increases the utilisation of energy of the entire ration. The productive energy of a feed in an unbalanced ration is lower than in a balanced ration. The measurement should be made in a balanced ration since in an unbalanced ration another factor than the productive energy of the feed, is depressing the results.
2. A proteid feed, added to an unbalanced ration, has an effect greater than its own productive energy since it increases the utilisation of other feeds to which it is added".

In brief the following considerations now arise. Rations balanced additively, as at present may be far from balanced inside the cow. Their production value may be greater or less than estimated, but, to what extent, it is difficult to predict.

It has been pointed out that the problem of protein supply, in the rations of Trinidad dairy cows is a doubtful one, especially in view of the uncertain knowledge of feeding stuffs which exists. The above consideration tends merely to increase

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that uncertainty.

Macintosh (1939) has shown conclusively, that provided good quality hay is fed, less protein is needed in the rations of high yielding dairy cows than is recommended by English feeding standards. These to some extent modified, are essentially those laid down by Kellner (1926). Macintosh's findings therefore, it is thought, may be partly due to that error, previously mentioned in connection with Kellner's Starch Equivalent values, as a measure of milk-production. In respect of Macintosh's proviso however, ie. good quality hay, it would however seem that to some extent, his findings may be due to associative effects.

With the existing lack of knowledge of feeding stuff values the query of whether the same might be possible in Trinidad cannot yet be answered. In actual fact, it is believed that, in certain cases with high yielding cows more protein has had to be given, than was thought to be necessary to maintain milk yield, by Trinidad standards.

In the light of the evidence stated, it is a temptation to suggest that the roughage was of inferior quality, in such cases. The above would seem to be an expensive method of production and in itself constitutes a cogent reason for further investigation on Trinidad fodders. While the conception of a production ration being the sum of two parts which supply maintenance first and production afterwards, can no longer be entertained, the desirability of determining which fodders will maintain an animal alone, is obvious. With such a knowledge as a basis, it would then seem reasonable to proceed on the suggestion of Mitchell (1937) whose contention is supported by Forbes (1937), i.e."that in experimental work which presumes to be scientific, the digestibility of the combinations of feeds used must actually be determined, not computed from individual feeds", and put it into practice.

(C) CONSIDERATIONS ON THE RELATIONSHIP BETWEEN PLANE OF NUTRITION AND DIGESTIBILITY.

Another factor, which must not be overlooked is the relationship of the plane of nutrition, upon which an animal has been kept, to the effect which may be expected from any ration.

Armsby (1928) states. "it is somewhat generally believed that the amount of feed necessary for maintenance varies with the plane of nutrition upon which the animal is kept". On a sub-maintenance ration it has been shown that there is a decrease in food utilisation and the animal organism, when kept on such, for a long time, gets by adjustment on a more economical basis. Thus a ration which has been insufficient to sustain live-weight at first, may later be capable of maintaining the animal and later still of increasing that body weight.

"Digestion experiments", Armsby (1928) states, "with a number of animals would indicate that a part of this is due to the more complete digestion of the feed, by the animal on a low nutritive plane, but so far there does not seem to have been a sufficient increase in the degrees with which the feed has been digested, to account for all the increased efficiency in the ration noted".

The above is of importance in respect of the effect which the plane of nutrition may have on feeding standards. Warth (1923) has shown that the maintenance requirements of Indian cattle are rather lower than those given by European and American authorities. Especially is the protein requirement lower, a wider Nutritive Ratio, having been found to be more suitable for animals, not requiring a large production ration. Warth (1927), later quoted in support of this, instances of higher digestion coefficients being obtained by Indian animals than by American ones, for feeding stuffs in which there was no material difference.

The types of fodders, examined in India, have been described by him as of extremely low quality. Nowhere, he feels, do animals have to exist on such poor material. The work of digestion

digestion on such coarse fodders is excessive and some animals would certainly expend more energy on digestion than could be ultimately derived from the feed.

The assumption is, therefore, that in deference to these feeds, the animals' requirements have become lower and a higher digestive capacity has developed.

In the particular respect of crude fibre has the Indian animal been claimed to possess a higher digestive capacity. To verify whether this capacity is inherited and transmitted would seem to be of importance, in Trinidad, where so much Zebu blood predominates, the importance lying in the relationship of this to the feeding standards at present adopted. ?

That the digestibility of a ration is affected by its Nutritive Ratio has been shown by Armsby (1928). It might then be deduced that addition of protein to their ration would in comparison influence the digestive capacity of animals on a lower plane of nutrition, to a greater extent than that of animals, previously existing on a higher plane. However in the case of cross-bred or pure Zebu animals, bred in Trinidad and presumably maintained on a higher plane of nutrition than in India, it is felt that response to a closer Nutritive Ratio would be no greater than in the case of any other local animals treated similarly. Indeed from the scanty evidence available, as will be seen, Trinidad Zebus exhibit no markedly higher digestive capacity, especially in respect of crude fibre, than other local animals.

In general it is felt that the digestive capacity of Trinidad animals is far more likely to be affected by the plane of nutrition, upon which they have been kept and the nutritive ratios, in which their feeds are combined, than by breed characteristics. The animals' digestive powers will be at their maximum when the Nutritive Ratio of their ration is optimum, this point varying with the plane of nutrition upon which the animals have been kept.

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herbivora, these form a considerable protein. All these constituents of the faeces are waste products. "Therefore", as Armsby states, "while they do not represent undigested material it is entirely correct, from a practical standpoint, to deduct them, along with the food which is actually undigested, in determining the digestible nutrients which are of use to the animal. These intestinal waste products which are excreted in the faeces are a part of the cost of digesting the feed as they represent the wear and tear on the digestive organs".

The largest error has been found to occur in calculating the digestibility of ether extract, ash and crude protein.

(a) The Digestion of Ether Extract and Ash.

These are often falsely represented by their coefficients of digestibility owing, in the first case, to the fact, as Morrison (1927) states that, "fat is usually present in feeding stuffs in relatively small quantities, and furthermore ether dissolves not only fat but also such plant compounds as chlorophyll and waxes and such products in the faeces as bile residues".

In the second case, he points out, ash compounds are generally excreted in the faeces and therefore appear to be undigested though they may really have been digested, absorbed and later excreted, after having been used in the body. Thus it follows that in both cases great reliability should not be placed in the digestion coefficients of these compounds.

(b) The Digestion of Crude Protein - Protein Equivalent.

Woodman (1924) in a note on this pointed out that the ordinary digestion coefficient did not give a strictly accurate idea of the actual digestibility of the protein in a foodstuff, the figure obtained by the ordinary method representing a minimum value, due to the presence in the faeces of nitrogenous products (partly protein and partly non-protein) which are excreted into the alimentary canal and are not reabsorbed. He criticised the

method

method, outlined by Pfeiffer, for correcting this so-called apparent protein coefficient of a foodstuff, (by treating the faeces with an acid solution of pepsin to dissolve all the protein compounds, except the true undigested food protein) as not giving a true figure for the actual digestibility of protein, as unless coefficients obtained by the ordinary method were retained, no idea could be obtained as to the availability of t e protein in a foodstuff after ordinary digestion by ruminants.

Both methods are now applied to both feed and faeces, however, for the following reason.

Besides the protein present in a feeding stuff there are present, certain amino-compounds. For general purposes these are classified under the heading of "amides", though actually they are not such. The values obtained for crude protein will thus include these nitrogenous substances while those for pure protein will not.

Macintosh (1939) states, "research work and practical experience indicate that amides have a value for ruminants equal to about half their weight of pure protein and the best measure of the protein supply in a food is therefore the digestible pure protein plus one-half the difference between the percentages of digestible crude and digestible pure protein". This figure is called the "Protein Equivalent" and is in other words the difference between digestible crude and digestible pure protein.

(c) Note on Nitrogen-Free Extract.

Warth (1924) states that "the usual procedures in foodstuff analysis differentiates between crude protein, the residue which has not been attacked by chemical treatment and the nitrogen-free extract which is completely dissolved by chemical means. It is known that in some cases the chemically insoluble crude fibre is digested with greater facility than is the readily soluble nitrogen-free extract". He therefore points out that, in such instances, the chemical procedure has failed to differentiate clearly between digestible and undigestible constituents and he shows this failure

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to be very marked with Indian fodders.

Armsby (1928) also draws attention to this source of error and shows that nitrogen-free extract is far from being composed exclusively of carbohydrates. He further points out the great differences which may occur in the case of roughage, between actual values and those obtained by the normal method of substraction.

(E) LIVE-WEIGHT AS A MEASURE OF NUTRITIVE EFFECT AND THE VALUE OF NITROGEN BALANCE DETERMINATIONS.

In a simple digestion experiment the only criterion of the success or failure of a feed is its effect on live-weight. In this way one would assume that the feed maintained the tissue intregity of the animal, if, over a period, live-weight had remained constant. This assumption however leaves much to be desired.

Lander and Dharmani (1925) point out that it is quite inadequate to weigh an animal on the first and last day of a trial. Retention of faeces and excessive intake and output of water, may entirely mask the true state of an animal's weight. Only by taking a full daily record of live-weight, did they feel that it was possible to obtain an approximately true metabolic picture.

Armsby (1928) shows quite conclusively how misleading live-weight figures are, as a measure of nutritive effect. He points out that if the purpose of the investigation is to study some question relating to the fundamental principles of nutrition, changes of live-weight are of little value as indicators. His reasons are similar to those outlined by Lander and Dharmani above and the fact that from live-weight measurements alone, no knowledge can be obtained of the kind of material lost or gained.

As a measure of the nutritive effect of a feed, the simple digestibility trial thus gives only a limited amount of information. To determine fully the nutritive effect of a feed, a more complete investigation is necessary, involving the use of respiration or calorimeter apparatus. With the aid of such the

investigator

investigator is able to record an exact balance between the energy contained in all the constituent of the food eaten, and the energy given out not only in the faeces and urine but also in the form of gaseous and epidermal excretions.

It has however obviously been quite impossible to apply such a laborious and expensive method of investigation to the vast numbers of feeding stuffs in use. Nevertheless, since there is no excretion of gaseous nitrogen, a determination of the "nitrogen balance" requires simply a determination of the amounts of this element contained in the feed and in the visible excreta. This end is partially attained in a digestion experiment and it is only necessary in addition, to provide for the quantitative collection and analysis of the urine and in very accurate experiments of perspiration and epidermal excrata. The nitrogen content of this last is, however, comparatively very minute and in the absence of any accurate apparatus, is normally ignored.

To determine the nitrogen balance of any animal, on a certain ration, requires then little effort in addition to that expended in the execution of a digestibility trial. The value of so-doing lies in the information which can be gained about the metabolism of the most important ingredient of feeding stuffs, namely protein.

Maynard (1937) states that, "protein requirements which are used in most of the feeding standards at the present time are based upon the results of feeding trials, representing intakes, in rations, considered otherwise satisfactory which were found adequate for keeping the animals in good condition without loss in weight. Scientifically, the maintenance of weight and condition is no certain measure of the integrity of nitrogenous tissue, or of the minimum requirements for this purpose but the rations which prove satisfactory for such maintenance, over extended periods, are considered to supply an amount of protein which is at least adequate".

On consideration, it must be evident that the duration

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of a digestibility trial could hardly be called an "extended period" and during that time the nutritive effect, as indicated by maintenance of weight and condition, may be easily masked.

Lander and Dharmani (1926-8) point out that on a properly balanced ration the body ought not to have recourse to any pronounced utilisation of its tissues. Therefore on a maintenance ration there should be a fairly accurate balance between the total nitrogen in the food and that contained in the urine and dung. They further showed that, in trials on coarse fodders, while reference to the daily weight curve indicated that weight had been more or less maintained and therefore on that evidence alone it might be concluded that the animal was being maintained, the nitrogen balance was distinctly negative. In other trials it was shown that loss in body weight was accompanied by considerable negative balance in all cases.

In the present experiment since it was desirable to discover whether the fodders in question, were balanced for maintenance, it was decided after the first trial, to collect the urine and hence determine the nitrogen balances for as many animals as possible. By so doing it was possible to have a check, as well as become less dependant, upon body weight measurement. It was further prompted by the poor facilities which existed for weighing the animals, this, as a result, being only possible at the beginning and end of each trial. The value of adopting this plan was amply borne out by the results obtained.

The most scarce and the most expensive food ingredient in the tropics and the one which at the same time is most essential for maintenance of bodily vigour as well as for flesh and milk production is the nitrogen-containing fraction of the ration. If this constituent is to be utilised to best advantage the proteid requirements of cattle must be determined and their nitrogen economy studied.

With this in mind workers in India considered it not only expedient to balance the total nitrogen intake against output but also to investigate to some degree the nature of the nitrogenous output and the nitrogenous end-products.

Warth

Warth (1924) has pointed out that the most conspicuous and least known constituents of the group of nitrogenous end-products were creatine and creatinine.

He further shows conclusively that when there is a nitrogen deficiency in the food the animal system exists ? exerts a powerful effort to conserve body nitrogen. This fact is strikingly shown by the total amount of nitrogen excreted as well as by the form in which it is excreted. He quotes the following effect having been obtained at Pusa.

	Total daily N. Excretion.	% N Excreted as (a) Creatine & Creatinine	% N Excreted as (b) Urea
Bullock receiving ample N.ration.	12.6 g.	14	25
Same bullock receiving deficient N ration.	5.9 g.	24	6.4

Further investigation along the above lines would, it is felt, have been of great value in the present experiment. However it would have been quite impossible to impose any further strain on the Chemistry Department above the very heavy one they were already subjected to, during the course of these trials.

(F) NOTE ON MAINTENANCE REQUIREMENTS OF DAIRY CATTLE IN TRINIDAD.

Shannon (1938) states that "the system which has been almost universally adopted in the feeding of dairy cows on a starch equivalent basis works out for maintenance at 6.0 lb. of starch equivalent containing 0.6 lb. protein for 1000 lb. live-weight ...."

This standard is approximately that, recommended by Woodman (1933), for the maintenance requirement of dairy cows in Great Britain.

Woodman's standards are however quoted for animals whose weights are measured in cwts. On the same scale, therefore, for animals whose weights are measured per 100 lb. the following would be be approximately the necessary requirements, per day.

TABLE 1. Maintenance Requirements for Trinidad Dairy Cattle.

LIVE-WEIGHT (lb.)	DRY MATTER (lb.)	S.E. (lb.)	P.E. (lb.)
700	17.5	4.5	0.45
800	19.5	5.0	0.50
900	20.5	5.5	0.55
1000	22.0	6.0	0.60
1100	23.5	6.5	0.65

The nitrogen balance method can be used to measure the actual protein requirements by determining the lowest level of intake which will give the maximum total retention. An attempt was made to apply the above to the few positive balances obtained in this experiment but the figures are variable and rather contradictory. It is felt that a much more detailed investigation, involving a series of daily nitrogen balance determinations is necessary to obtain definite results.

PART II.

DESCRIPTION OF THE DIGESTIBILITY TRIALS OF THE FODDERS EXAMINED.

The digestibility trials which will be described in this section were planned to determine the digestibility of the five local fodders, when fed to cattle.

The experiment was conducted at the Government Stock Farm, St. Joseph and lasted from November 7th. 1939 till February 19th. 1940.

(A) THE FODDERS EXAMINED.

These were examined in the following order:-

Trial 1. Bamboo Grass. Paspulum fasciculatum.
Trial 2. Para Grass. Brachiaria mutica (Stapf).
Trial 3. Guinea Grass. Panicum maximum.
Trial 4. Guatemala Grass. Tripsacum laxum.
Trial 5. Sweet Potato Vines. Ipomea batatas.

The order of trial was dependant upon the availability of each fodder in sufficient quantity.

The Guatemala Grass was grown on the College Farm and the required amounts fetched daily. This also was the case for the Sweet Potato Vines utilised during the preliminary period before the trial proper. This was due to the fact that the supply at the Government Farm was inadequate to meet the necessary requirements for the complete trial. Apart from the above the rest of the fodders were all grown on the Government Farm, where they are normally utilised to a greater or less extent. The essentual features of a good perennial fodder crop can be summarised as follows:-

1. Ease of propagation.
2. High productivity.
3. High nutritive quality.
4. Palatability.
5. Ability to overcome weed competition.

6. Ability to withstand drought.

In respect of the above a note on each of the fodders examined is given with reference to its value and importance in Trinidad.

1. Bamboo Grass. Paspalum fasciculatum.

This grass should not be confused with Panicum fasciculatum (Brown Millet) or Dendrocalamus strutus, a small bamboo with semi-solid stems since both of these are at times referred to by the above common name.

Paspulum fasciculatum is a large extensively creeping perennial. It is stoloniferous, very leafy and flowers rarely.

Widespread in Brisith Guiana and Trinidad, it is also found in the Windward Islands, Mexico and parts of South America.

Its natural habitat is low ground, swamps and the borders of streams. In this respect it should not be confused with "Swamp" Grass with which,in Trinidad, it often grows in association. In Trinidad it can be seen on roadsides, near ditches and streams and is a constituent of many rough grassland areas. As far as is known it is not cultivated, in Trinidad, to any extent. However,where it occurs,it is cut or grazed and thus figures quite prominently as a fodder particularly for peasant cattle.

Spreading rapidly it grows vigorously in a suitable environment. It however hardens rapidly with age and has rather a high proportion of stem to leaf. Due to this last it is probably relished least of all the common fodder grasses in Trinidad, by stock. Experience in the present trials further indicated this contention. The animals under observation took much less readily to it than to the other fodders and on the whole when accustomed to it as a regular diet, eat less.

It could hardly be called drought resistant but due to its habitat often survives the dry season better than other grasses.

On the Government Stock Farm it is to be found quite extensively with several pure stands near the St. Joseph river where

it

it covers the ground with a dense mat. It was from one of these blocks that the material for trial was obtained. The grass was a very even sample about two to three months old. At this stage, however, it was beginning to show distinct signs of hardness. It has not been thought to possess such a high nutritive value as the major fodder grasses used in Trinidad. The results, just obtained, further indicated this to be the case.

2. Para Grass. Brachiaria mutica (Stapf) (Panicum barbinode).

Para Grass is thought to be a native of South America and is widespread throughout the West Indies.

In Trinidad it occurs as a cultivated fodder crop as well as in rough grazings. A tenacious grower, it is stoloniferous and produces stout runners which reach a length of from 15-40 ft. The leaves are short rarely longer than 1 ft. and about 1½ inches wide. Para Grass will under favourable conditions make a dense mass of herbage 3-4 ft. high.

Para Grass thrives best in humid conditions of soil and climate. Its high nutritive value is well recognised by dairy farmers for increasing milk yield and butter fat content. In trials with cultivated fodder crops, conducted by Patterson (1936 and 1938) it has been outstandingly successful. It combines most of the essential features of a good fodder crop and its high dry matter percentage is an important attribute. It can easily be propagated from runners.

It has however several disadvantages. It is a serious weed of arable land. This is mainly due to the practice of soiling as carried out in Trinidad and to improperly made compost. It is a common belief that the nodes of the grass can pass through cattle undigested. Patterson (1938) shows this is not so, in Trinidad. It also exhibits a tendency to flower frequently, this usually being accompanied by loss in herbage production and nutritive quality. Finally it is unable to withstand prolonged dry seasons and under those conditions maintains a sparse and creeping habit. Due to its habit it normally gives a complete smother of weed

growth

growth.

The Para Grass used in the present trials was obtained from several stands growing in association with other grasses in various areas, on the Government Farm. While the grass was all at approximately the same stage of growth and quite pure, this was felt to be undesirable. It was however unavoidable. The grass was little more than two months old but was in flower. About this time, December, many grasses in Trinidad, however, usually flower.

3. Guinea Grass. Panicum maximum.

Guinea Grass is an important forage crop throughout the world at low altitudes. It is believed to be a native of tropical Africa but first achieved prominence in the West Indies. It is found in South Africa and the African colonies where it thrives well. It has a high reputation in Jamaica where it is to be found extensively.

Guinea Grass is a long-lived perennial with short creeping rootstocks, single plants often making clumps, 4 ft. in diameter. The roots are fibrous and form a network near the surface so that the grass is a poor drought resister. The leaves are about 1-3 ft. long, flat and about 1-1½ inches wide. The culms may reach a height of 6-10 ft.

Like Para Grass, Guinea Grass also tends to bloom frequently, following which, the stems become hard and woody. A rapid grower and easily propagated by root divisions or seed, the grass shows a very marked tendency to form clumps. In Malaya, this is overcome by cutting, splitting and removing about two-thirds of the stool every 2-3 years. In Jamaica it is grown as is Para Grass, as permanent pasture where it has proved an excellent fodder, especially for fattening beef cattle. It is palatable, gives high yields and resists weeds well.

In Trinidad it is widely used though it has not such prominence as in Jamaica. Patterson (1938) shows that it is a relatively dry fodder and does not recommend it for a general purpose soilage crop under local conditions.

The

The grass used in the present trials was obtained under similar circumstances to the Para Grass, previously mentioned and warrants the same criticism. It was approximately the same age, also in flower, and the stems were becoming hard.

4. Guatemala Grass. Tripsacum laxum.

Guatemala Grass is a native of Central America but has not until quite recently become known as a fodder crop, in the British West Indies. Grown to a limited extent in Cuba, Puerto Rico and Mexico, as well as in India and Ceylon, the grass is becoming increasingly prominent among cultivated fodder crops.

It is a large grass, the leaves ranging from 1½-2½ ft. in length and from 1½-2½ in breadth. When growing thickly the grass will make a dense mass of herbage 4-5 ft. high and if allowed to continue, will grow considerably higher.

The root system is tough and fibrous, penetrating deeply into the soil and spreads well by means of rhizomes. The grass is thus an excellent drought resister, maintains a high level of productivity throughout the year besides providing almost complete smother of weed growth.

Guatemala Grass is easily propagated by root division from old stools and grows rapidly on most soil-types.

In Trinidad Patterson (1937) recorded the grass as having given the best results of the main fodder crops in the island. Yield of bulk was good with fair quality of forage and few cultural requirements were needed after the establishment period. In 1939 he ranks it highest as being the best general utility grass, although it did not give the highest yield of herbage or nutrient per acre in trial.

Since 1938 however the grass has been subject to fungal attack by "Puccinia polyspora". This may,/if it is spreads, cause marked decrease in the yield of herbage.

In the present trials, the grass was obtained from the College Farm. It was an even sample but about four months old and consequently very coarse. It was also slightly infected with

the

the rust fungus.

5. Sweet Potato Vines. Ipomea batatas.

Sweet Potato Vines are a very useful fodder for cattle. They are extremely palatable to cattle, very nutritious and yield about 8 tons of fodder per acre. They are also valuable in that they can be stored, while it is claimed by some that palatability and nutritive value are not seriously affected by wilting.

The ideal stage for cutting for cattle is about four months old though this may obviously affect the yield of roots. It is however questionable whether the increased value of cattle feed thus obtained will not outweigh any loss in crop. Normally they are fed after harvest but at this stage the nutritive value will be lower, as the stems rapidly become tough and the leaves drop off easily.

In Trinidad they are used to a certain extent though the value of the crop in general has not received the recognition it might. Apart from human consumption both roots and vines can be fed to cattle. As such, it is felt, it can be recommended to cattle owners, particularly peasants, especially on consideration of the high protein content of the vines. The growing of such a crop would seem very desirable in the role of economic food production.

In the present trials, as stated, the vines fed during the preliminary part of the trial were obtained from the College Farm. These were older and considerably tougher than those fed during the trial proper. These last were obtained from the Government Farm and were extremely succulent, being about four months old.

In the preceeding notes on the fodder grasses examined, no mention has been made of yield. Such a quantity is obviously extremely variable as is the quality of the grasses and is dependant upon such factors as season, soil-types, cultivation, manuring and the age and height at which the grass is cut.

All the major fodder grasses in Trinidad possess distinct qualities but, it is felt, these can only be utilised to their

best

best advantage, by stock-feeders, if the grasses most suited to the particular environment are grown and given the attention as a crop which they deserve.

The composition and digestibility of grasses, is materially affected by the proportion of vegetative organs and, in general, leaves and leafy species have a higher feeding value than those containing a large proportion of stem. In general, it is felt that the tendency, in Trinidad, is to feed grasses at too old a stage, when the nutritive quality is lowered. Earlier i.e. in Trinidad at about six to eight weeks old, and higher cutting would be advantageous. In this respect Woodman (1938) points out recent American research which has proved that there is present in grass, particularly quickly-growing grass, some growth factor that passes over into the milk and increases very remarkably its growth promoting properties.

Grass land management and improvement it is felt have not received sufficient attention in Trinidad by stock-owners and the importance of this problem to them cannot be too heavily stressed. A discussion of such problems, with reference to a comparison of the grasses examined with others, would however involve more space than is warranted in this thesis. Patterson (1936-7-8-9), in a series of papers, to all of which reference has been made in compiling this section, has outlined these problems and in experiments has shown the effect of some of the above factors upon the yield and quality of the main Trinidad fodder grasses.

A table has been compiled (See Appendix) in which, as far as is known, all the complete analyses available for the main Trinidad fodders have been stated. This includes where determined by direct experiment, their nutritive values. Reference to this, will indicate the range of variation which may occur in composition and consequently in nutritive value.

The importance of mineral content must be emphasised especially in respect of the associative effects of minerals upon the digestibility of feeding stuffs. While this aspect has not been overlooked, it has been omitted since time available did not

permit

permit analysis of grasses, for these constituents, or a discussion of the subject.

(B) THE EXPERIMENTAL ANIMALS.

TABLE 2. Details of Experimental Animals.

Name of Cow.	Age. Yrs.	Months.	No. of weeks before calving	Initial Weight Lb.	Breeding &c.
1A. TERBANI	5	1	8	1022	Pure Zebu. Used in Trials 1 & 2.
1B. CHERIAH	10	-	-	951	Pure Zebu. Used in Trials 3,4 & 5. Not in calf, as would not hold to service.
2. No.8	4	6	30	760	Pure Sahiwal strain imported from India. In second calf.
3A. SUSY	4	-	8	762	Cross-bred. Zebu x Holstein. Purchased. Exact breeding unknown. Used Trials 1 x 2.
3B. BLACKIE	4	-	-	976	Half-bred. Pure Holstein Bull x Pure Zebu cow. Used in Trials 3,4 & 5.
4. NELLIE	1	6	-	725	Pure Sussex. Not in calf.

N.B. All details are given for animals, as from date of their introduction into experiment.

Since the utility of any results obtained would be primarily concerned in the calculation of rations for dairy cattle, the dairy animal would seem to be the most desirable for experimental purposes. There are, however, several disadvantageous to this course of action.

The dairy cow in general and particularly in the case of the Zebu is a nervous and restless animal, especially when subjected to changes in conditions and treatment. Steers are more adaptable and less temperamental and that is one reason why they are more often chosen for experimental purposes. Nevertheless all animals are subject to such influence. Any sort of excitement is likely to entail increased utilisation of nervous as well as muscular energy

and

and will naturally tend to affect the maintenance requirement, by correspondingly increased food consumption. If true maintenance requirements are then to be determined the animal should be as nearly at rest in every respect, as possible.

Alternatively it may be argued that if experimental conditions are to approximate as closely as possible to normal ones, an animal should expend some energy, over and above that normally utilised during a digestion experiment. While such may be admitted the obvious difficulty arises in assessing, in any way, such a quantity of energy.

Lander (1926) however describes trials with dairy cows in which some daily exercise was given for above reasons and to prevent any stiffness occurring in the animals' joints, due to being kept in confined conditions, over a period. While this last difficulty was encountered by Hobbs (1930) it did not occur in those trials, conducted by Maule (1936) or in the present case. If exercise were to be given, the difficulty would also arise of guaranteeing proper collection of faeces and urine, without harness.

The use of harness, as described by Lander (1926) for a dairy cow, is obviously more complicated than for a steer, especially if urine is to be kept separate from faeces. In addition the cow is bound to become very upset by this and considerable time would be wasted in getting the animal accustomed to the harness.

In the present case the methods employed and animals used were largely dependant upon circumstances. Neither steers nor harness were available and the animals had to be selected from dry cows, in the dairy herd. The choice among those animals available, was further limited by their temperament since quiet and easily handled cows were the primary consideration. In one respect this was fortunate as it would have been quite impossible, as decided after Trial 1, to collect urine satisfactorily with the limited equipment available, had steers been used.

The animals selected, however, soon settled down to experimental conditions and except for occasional lapses on the

part

part of the two cross-breds and the Sussex proved quite adaptable.

In general it is desirable to obtain as uniform a lot of animals as possible as regards age, size and especially the plane of nutrition upon which they have been kept. Except as regards the plane of nutrition upon which they had previously been kept, the animals selected might in the above respects be criticised. Their selection from those animals available, was due to the decision to include one representative of each of the four main breeds kept on the Government Stock Farm. While it was not implied that any one animal was truly representative of its breed, it was felt that if any marked difference in digestive capacity due to breed, was present, it might be exhibited.

Armsby (1928) and Kellner (1926), however, point out that:-

1. "Different breeds of the same species of animal possess an equal digestive power".
2. "Between individual members of the same breed small variations, usually traceable to some slight physical weakness on the part of the animal, may occasionally be noted .... Where differences are not due to serious disease of the stomach or intestine the percentage error seldom exceeds 3-4 % of the ingested organic matter".
3. "The age of the animal does not influence the digestibility of the food".
4. "Alterations in the conditions under which the animals are placed are also without influence upon the digestibility of the food, provided violent excitement or disturbance of health are avoided".

Hence, as Maule (1930) states, "one may conclude that the variability between two animals in regard to breed age and size, should not, provided all are healthy, thriving beasts, have any unfavourable effect upon the accuracy of the results.

It is felt that the age of the animal may not influence the digestibility of the food provided only that the animal is

mature.

mature. In this respect the Sussex heifer, eighteen months old, is subject to criticism. She was however stated to be full grown.

Her digestion coefficients were to a certain extent lower than average, particularly in the case of Guinea Grass. This, however, might partly be explained by the fact that during that trial she came on heat and was thus naturally subject to some nervous stress. Fortunately her other heat periods did not coincide with any other trial. The cow Blackie No. 3B also came on heat after the finish of the Para Grass trial (No.2) and was served.

This difficulty further emphasises the unsuitability of using dairy cows, in a digestion experiment. They obviously cannot be used when in milk and if dry they may come on heat, as in the above two cases. If in calf, the animal metabolism will be affected to an increasing extent with the growth of the foetus and this condition it is felt is obviously undesirable. If therefore dairy cows are to be used it would seem desirable that they should be used only in the early stages of pregnancy.

Maule (1930) encountered difficulty in this respect, one of his animals calving during trial. Before selecting the animals, in the present experiment, this point was noted. Unfortunately a mistake was made in checking their dates of service and two animals, Terbani (No.1A) and Susy (No.2) had to be replaced after the Para Grass trial (No.2), signs of approaching calving becoming evident after it had started.

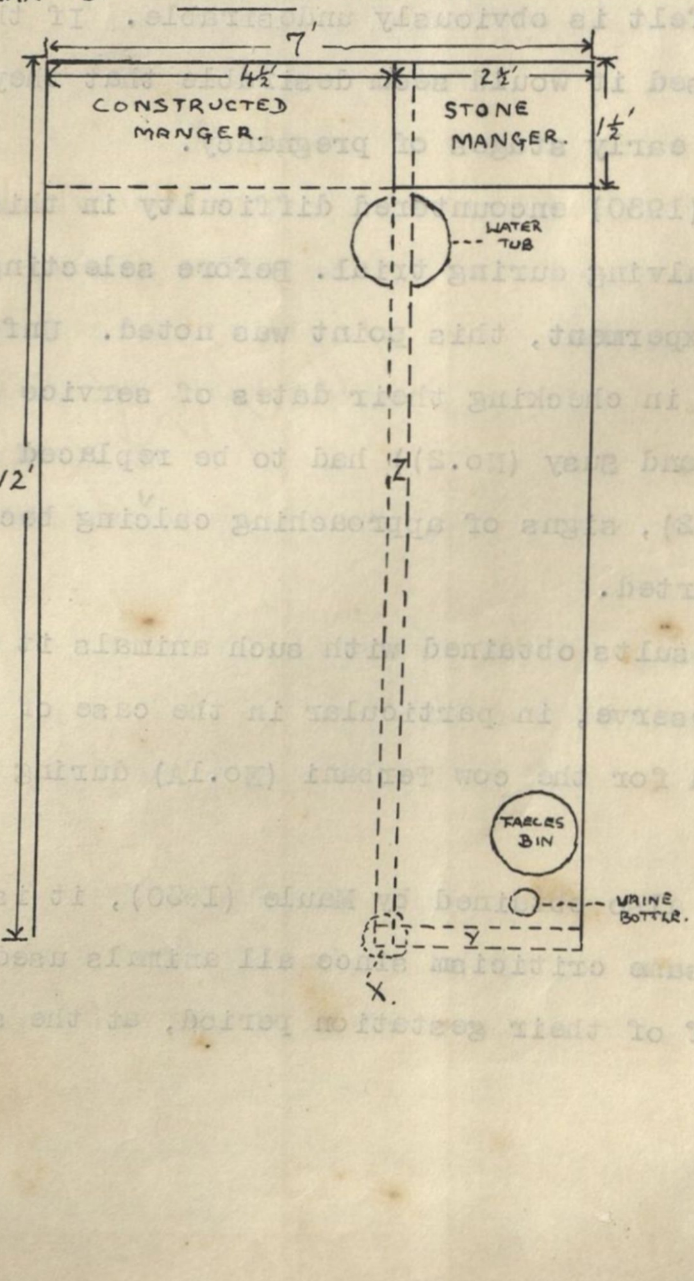
The results obtained with such animals it is felt should be taken with reserve, in particular in the case of the nitrogen balance obtained for the cow Terbani (No.1A) during the Para Grass Trial (No.2).

Those also obtained by Maule (1930), it is felt, are subject to the same criticism since all animals used by him were in the last half of their gestation period, at the start of his experiment.

HOLSTEIN x ZEBU. COW "BLACKIE" No: 3B

ZEBU. COW "CHERIAH". No: 1.B.

PLAN OF THE DIGESTION STALLS.



(C) THE DIGESTION STALLS.

These were not in the true sense digestion stalls but instead consisted simply of four ordinary loose-boxes with concrete floors and wooden partitions, 5 ft. high, between each stall. In the right hand corner of each was a stone manger 2½ ft. x 1½ ft. and 2¼ ft. high. Animals were normally kept in the loose boxes by these wooden bars, fitting into slots. The original measurements of the boxes were 12 ft. long x 7 ft. wide.

For experimental purposes stalls were adapted from the loose boxes, as follows:- A bamboo upright (X) was secured to the cross beam of the roof and to the floor, by means of a cross-piece (Y). This was fixed to the wooden partition on the right hand side of the loose-box. A bamboo pole (Z), the length of the stall was then secured at one end, to the top of the stone manger, 2¼ ft. high and at the other to the bamboo upright (X), at the same height.

On the first day wooden tubs were used for feeding. These were soon dispensed with, as the animals threw a considerable portion of their fodder onto the ground, during feeding. Using these it would have been impossible to make accurate measurements of food consumed. For this purpose wooden mangers were then constructed from the end of the stone ones to the opposite side of the stall, using the concrete floor as a bottom. These mangers were then 4½ ft. wide x 1½ ft. long and were made 1½-2 ft. high. For the cow Blackie (3B) the height of this manger had to be raised to about 2½ ft. and a curved notch made, to allow her to reach the bottom. This was necessary to curb her tendency to put her fore-legs inside the manger.

The construction of these mangers was satisfactory. They would hold a large quantity of fodder and due to their size, it was possible for a boy to get inside and collect completely any uneaten fodder, using a small hand-brush. In addition the animals could reach the fodder easily but to do so had to bend forward and downward and consequently the amount previously thrown out from the wooden tubs was not lost.

The

The animals were tied at the head to the partition on the left-hand side and to the junction of the bamboo pole (Z) and the stone manger, on the right. The position of this bamboo pole (Z) permitted them enough movement to lie down but not to turn round. The bars at the end of the stalls were removed.

The animals were given water in the round wooden tubs, previously mentioned which were placed at the right hand end of the constructed manger, partly under the bamboo pole (Z). The faeces bins and urine bottles were placed in the alley between the pole (Z) and the right hand partition of the stall. This alley was useful in that it gave easy access for feeding and reaching the constructed manger without unduly disturbing the animal. Reference to the diagram and pictures included will clarify the above description.

No bedding was at any time used on the floor since, in an experiment of this nature, it is clearly impossible to do so. During the preliminary period of trial the animals and stalls were washed down daily. During the trial proper this was not done since with the collection of urine from some animals and all faeces, the floor and animals remained clean. Before this begun the stalls, animals and equipment were all cleaned with especial care and the floor during that period was constantly kept clear of dust or any contamination, in event of faeces dropping on it. In the case of those animals from which it was impossible to collect urine the stall floors, after urniation, were immediately swilled and swept out.

Tt was necessary for an electric light to be installed, to enable the collection of faeces and urine, by the night attendants.

(D) METHOD OF FEEDING.

Armsby (1928) states that 1-2 weeks preliminary period and 7-10 more days actual trial are required, in the case of ruminants, in order in the first place to get the animal accustomed to a fixed daily ration and clear its intestines of all other excreta and, in the second place, to collect faeces over a period, long enough to eliminate daily variations in the faeces.

It was only possible to have preliminary and experimental periods of 8 days duration each in the trials conducted by Maule (1930). He however suggests a longer preliminary period to overcome fluctuations in daily amount consumed caused by change in ration. In the present experiment it was therefore decided that trials should consist of a preliminary and experimental period, each lasting 10 days. In the case of Trial 5 - Sweet Potato Vines - it was only possible to have a preliminary period of 7 days duration, due to the necessity for the trial to coincide with the Sweet Potato harvest on the College. In this case however there was no difficulty in getting the animals accustomed to their new diet, as they took readily to the vines. Fluctuations in amounts consumed daily naturally occurred more markedly during all preliminary periods. In every case average daily consumption per head was greater during experimental periods, when the animals had become more accustomed to the particular fodder.

The animals were always permitted to eat as much as they desired. To ensure this 100 lb. of fodder was fed daily during the first four trials and 75 lb. daily of Sweet Potato Vines in the fifth trial to each. In no case did the animals show any inclination to consume as much.

The daily ration was fed on three feeds of 35 lb., 25 lb. and 40 lb. fed respectively at 6.0 a.m., 1.0 p.m. and 6.0 p.m. In the case of the Sweet Potato Vines these amounts were reduced to 25 lb., 20 lb. and 30 lb. respectively. Every evening and morning before feeding, the residue from the previous days feed was collected and the weight deducted, to ascertain the actual

amount

CHAFFING MACHINE

WOODEN SIDES. SWEET POTATO VINES CHAFFED & MIXED.

amount consumed by each cow.

The fodder was cut-fresh daily and was usually brought in about 10-11 a.m. It was kept under cover and not chaffed up all at once, to prevent wilting as much as possible. The 6 a.m. feed and 1 p.m. feeds were chaffed at 6 a.m. and the 6 p.m. feed just before feeding.

Chaffing was essential if representative samples were to be fed and obtained for analysis. To facilitate this, a hand chaffing machine was placed on the concrete, besides the stalls. Around its base, as can be seen from the photograph, wooden sides were built, using the floor as a bottom. Into this the fodder fell on chaffing and by keeping the floor clean, the fodder could be well mixed, without contamination before feeding and sampling.

It must be stated, that a cake of rock-salt was put in each animal's manger. The writer was uncertain whether theoretically this addition to the animal's fodder should have been made. The animals however normally had access to this and when it was at first lacking, showed signs of their want, by licking the stone mangers also the whitewash. This habit ceased when rock-salt was given.

(E) METHOD OF SAMPLING THE FODDER.

This was done daily except in the last morning of each trial. Two representative samples, A and B, were taken from the bulk of each day's fodder, directly after being chaffed and mixed at 6.0 a.m. and before weighing out quantities for the first two feeds. The samples were removed in air-tight jars of about 1 lb. weight, to the Chemistry Department. It is felt that this might be criticised on the ground that the samples did not include any of the fodder, fed during the evening feed. It was however felt to be desirable that the samples should be removed, as fresh as possible, in the morning, to the Chemistry Department. If samples had to be taken from all one day's fodder supply, this would have entailed chaffing the lot at 6.0 p.m. This would have taken a considerable time and the samples would have had to remain in that condition till next morning. It was also noted during preliminary periods, that animals did not take nearly so readily to fodder which had remained chaffed for some time and had wilted slightly.

One difficulty arises out of a consideration of the fodder for analysis, namely the cows selection of it when fed. The representative samples contain stem and leaf of the fodder in correct proportion. When however the cow receives its portion, it will pick over the whole lot, eating all the leaf and succlent portions first and will only go on to the stems, if still unsatisfied. The ideal would seem to be to feed a quantity of fodder, such that both stem and leaf will be eaten, if the animal is to be satisfied. Such a quantity is obviously very variable and in certain cases the animal may prefer to go unsatisfied rather than eat the hard stem. Such a difficulty should not however arise in fodder cut correctly, at a young succlent stage. It occurred to a certain extent however with the Bamboo, Guinea and Guatemala grasses, during this experiment, particularly in the case of the four months old Guatemala Grass. There was a large proportion of tough stem at the base, also some dead leaves. All this material was removed before chaffing since it was regularly refused by the animals during the pre-

Preliminary

preliminary period. If this material had been included in samples for analysis, the discrepancy between that sampled and that eaten might have been quite considerable. The sample analysed might thus be considered as not being truly representative of the grass at that stage of cutting. This is admitted, also the fact that the dead material would probably not have been removed in practice. In practice, however, it is felt the grass ought never to be fed so old. This removal of dead material is probably responsible for the relatively high values obtained for the four months old Guatemala Grass, on consideration of its age and condition.

Moisture determinations were done on the fodder samples by the Chemistry Department, the same morning. After this, the remainders of each of the two samples, A and B were kept separate and oven dried. At the end of each 10 days, all the A samples and all the B samples were bulked into two composite A and B lots and reserved for analysis.

On Sundays all samples, fodder and faeces had to be stored for 24 hours till the following Monday morning. This was to be regretted but was unavoidable.

(F) METHOD OF COLLECTION AND SAMPLING THE FAECES.

The method of collecting the total bulk of faeces, voided by each animal, which was adopted was that employed by Maule (1930). This entails the immediate collection of the faeces, as they are voided, by means of a small bucket, and their transferrance to a bin, of sufficient capacity to hold a day's collection, and sufficiently airtight to avoid more than the minimum moisture losses. The bins used by Maule were however not to be found so four five-gallon paint drums were obtained. These were quite satisfactory. They would hold a day's collection and the lids were equipped with rubber washers, fitting on the rims of the drums and kept down by spring catches. These drums were first cleaned by burning out the paint and scrubbing before use. These drums were also rinsed out each day after weighing and sampling the faeces.

This method calls for constant attendance upon, and observation of, the animals and in consequence, the careful organisation of the labour employed. Maule (1930) states that, "the disadvantages are that it is impossible with a small staff to collect all faeces as voided and proportion will unavoidably fall on the ground and possibly become contaminated or escape collection. Its merit is that the cows need not be trained in the wearing of any elaborate harness, the conditions thus more nearly representing ordinary farm conditions, and, in the case of cows, it is easier to collect the faeces in this way than by the harness method".

In the present experiment the method was found to be quite satisfactory. The size of Maule's staff is uncertain but during the present experiment, as stated, two attendants were present, night and day. The writer has no hesitation in saying that the bulk of faeces lost throughout the whole experiment was infinitesimal and claims as good a collection this way as by the use of harness.

Even if, as Maule states, some did fall to the ground, the quantity lost in this case was very negligible since the attendants were never averse to using their hands for scraping,

if

if necessary to avoid any faeces escaping collection. In this way also, it is felt that the loss would be no greater than that occurring when the sheet type of harness is used and the faeces have sometimes to be scraped down the sheet, into the container. In addition, as already outlined, the concrete floor was always kept clean and consequently, in event of faeces falling, contamination was avoided.

This method of collection though obviously expensive in labour, becomes increasingly simple, as the experiment progresses. The attendants soon noted the fairly regular intervals at which the animals defaecated and urinated and the characteristic preliminary movements of each individual before so doing.

If however any appreciable proportion of the faeces escapes collection, the accuracy of the results will be seriously impaired. If this was the case in Maule's experiment, as his remarks might be taken to indicate, his results are obviously very open to criticism.

The object of collecting the faeces over a period of days is to obtain a representative sample from the total amount collected. The usual method is to retain each day's collection and by a process of preservation prevent the rapid fermentative and putrefactive changes which would normally occur during storage, resulting in alteration in the composition of the faeces.

This preservation of the total bulk of faeces from each animal would have been extremely difficult under the conditions of this experiment as, in addition to the use of some preservative, it would be necessary to keep the faeces in cold storage or alternatively to dry it down rapidly, to prevent decomposition.

In the present trials it was impossible to deal with the faeces in bulk in this way and the method adopted, as by Maule (1930), to obtain a representative sample in normal condition was, at the end of 24 hours, after weighing and thorough mixing, to take two samples of the daily faeces of each animal. The two samples (A and B), each of about 1 lb., were taken in air-tight bottles and after the moisture content had been determined by the

Chemistry Department, they were oven dried for chemical analysis. At the end of the experimental period, as with the fodder samples, all the A subsamples of each animal were thoroughly mixed and ground up and a single representative sample taken, the B subsamples being treated similarly.

During Trials 1 and 2 the fresh faeces were preserved with Toluene, a small quantity being sprinkled on each separate amount voided, after transfer to the bin. The supply of toluene under the present conditions, was however cut short and as an alternative Formalin was used. This preservative has been shown to be satisfactory in such circumstances, by French, R.B. (1930).

By this method Maule (1930), states, "it was considered that:-

(1) The moisture content of the daily subsamples would be accurately determined, the average of the 8 subsamples not having an error of more than 1 %.

(2) Decomposition would be prevented.

(3) The final mixed A and B samples for chemical analysis would represent as fairly as was possible the total bulk of faeces, bearing in mind the great difficulty which would have been experienced in preserving and sampling the total bulk of dung from each animal for each trial period.

The writer, however, felt that there might be some loss of nitrogen during the oven-drying of the faeces. A comparison was therefore made between nitrogen contents of several individual samples when fresh and after being oven-dried.

The difference was found to be very negligible indeed and, in certain cases, the nitrogen values obtained for the oven-dried material were slightly higher than those for the fresh material. This, it was felt, was due to the difficulty entailed in getting a truly representative sample, of the very small size necessary for a nitrogen determination, from such a heterogeneous mass as the fresh faeces.

(G) METHOD OF COLLECTION AND SAMPLING THE URINE.

The desirability of determining the nitrogen balance for each animal has already been outlined. After Trial 1, it was therefore decided to make an attempt at urine collection in the same manner, as employed for the faeces and separate small buckets were obtained for this purpose.

The attempt was not entirely successful. It was never possible to make a collection from all the cows. Collection from the Sussex heifer.. Nellie No 4 was always impossible, due to quite frequent urination when lying down, while collection from the cow Susy No 3A proved so troublesome that the attempt was abandoned. From all other animals it was possible to make a very satisfactory collection, throughout each trial and as with the faeces, collection soon became comparatively simple.

After collection, the urine was immediately weighed and the weight recorded. A portion was then put into a Winchester quart bottle with the addition of some Formalin. One of these bottles was allotted to each animal, from which collection was being made. At 6.0 a.m. each day, the contents of these bottles were well shaken and two samples removed from each in test tubes. These were taken to the Chemistry Department where nitrogen contents were determined that day.

(H) DAILY ROUTINE DURING EXPERIMENTAL RECORDS.

6.0 a.m.	Two day-attendants arrive. Sufficient fodder chaffed up for this feed and the next, mixed thoroughly and sampled. Both feeds weighed and bagged for each animal. Fodder, uneaten by each animal, weighed. 35 lb. fodder (25 lb. Sweet Potato Vines) fed. Water-tubs, emptied, cleaned and refilled. Faeces weighed and sampled. Urine sampled.

Bins

	Bins, buckets and bottles washed and drained.
	Floors swept.
	Two day-attendants then take over collection from night ones. All samples, faeces, urine and fodder removed, by writer, to Chemistry Department.
10.0 a.m.- 10.0 a.m.	Fresh days supply of fodder brought in. Kept under cover.
1.- p.m.	Mid-day ration (chaffed, weighed and bagged at 6.0 a.m.) fed. 25 lb. fodder (20 lb. Sweet Potato Vines).
5.0 p.m. - 6.0 p.m.	Two-night attendants arrive.
	Chaff, bag and weigh 40 lb. fodder (30 lb. Sweet Potato Vines).
	Fodder uneaten by each animal, during day. Weighed.
	Above amount fed.
	Water-tubs, emptied, cleaned and refilled.
	Stalls swept down.
	Two-night attendants then relieve day ones.

This routine was adhered to as closely as possible, throughout all experimental periods and is detailed to clarify any points which may not be fully understood from previous descriptions.

It was arranged, as far as possible, that the bulk of the work should always be done when all four attendants were present - i.e. at 6.0 a.m. and 6.0 p.m. This always ensured adequate attention to the experimental animals.

During preliminary periods only one attendant was employed.

(I) WEIGHING THE ANIMALS.

Since no scale was available, at the Government Farm, it was necessary to send all animals up to the College, in a special cart, used for that purpose.

The inadequacy of live weight as a measure of nutritive effect has been pointed out and this method of weighing while unavoidable, obviously leaves much to be desired, for experimental purposes.

The weights of all animals were taken at the beginning and end of each trial and when possible on the last day of each preliminary period, before the experimental period began. In Trials 3 and 4 the occurrence of Public Holidays prevented this last weight being taken. On consideration of the above points, it was decided to begin the experimental periods, as planned, rather than prolong the preliminary periods till weights could be taken.

(J) CHEMICAL ANALYSIS.

In each trial both fodder and faeces samples were analysed for the following constituents:-

Total Dry matter.
Total Organic Matter.
Total Ash.
Silica-free Ash.
Crude Protein.
Pure Protein.
Ether Extract.
Crude Fibre.
Nitrogen-Free Compounds (by difference).

All moisture determinations and all nitrogen determinations, including those for the daily samples of urine were made by the staff of the Chemistry Department. The remaining analyses were carried

carried out by the writer.

A note on the analytical methods employed in the quantitative determination of the above constituents, is appended.

All samples were oven-dried for twenty-four hours till weight became constant, before analysis. Analyses were always made on duplicate samples.

Estimation of Ash.

This was done by the method normally employed in the Chemistry Department

Estimation of Silica.

After completing the estimation of the ash content of the sample, the ash was washed from the crucible into a small beaker by means of dilute HCl, completing the transferrence with the help of a fine jet of hot water, from a wash bottle. This was then brought to a gentle boil for 2 minutes and then filtered through a small ashless filter paper, washed thoroughly with hot water and dried in a steam oven. The filter paper plus silica was then put back in the crucible and the procedure as for the estimation of ash repeated.

Estimation of Crude Protein.

This involved the estimation of nitrogen content by the Kjeldahl method. To determine percentage of protein, the percentage nitrogen is multiplied by 6.25.

Estimation of Pure Protein.

The method adopted by the Association of Official Agricultural Chemists(1935) involves the precipitation of the proteins by Stutzer's reagent. While its use was desirable, the writer however had no experience of this complicated method. In addition the time available was rather limited. Since however it was desired, if possible, to determine values for the content of Pure Protein, the following less accurate but more rapid method

was

was adopted. This method was one outlined by Woodman for the use of students in a course of practical Chemistry of Foods, during which it was used by the writer.

The procedure is outlined as follows:-
1.5 grams of sample was placed in a 500 cc. beaker and 80 cc. of distilled water added, the content being stirred with a glass rod and brought to a gentle boil. 25 cc. of a solution of Copper Sulphate (containing 60 grams $CuSO_4.5H_2O$ per litre) were then added and the whole brought to a gentle boil again, with continuous stirring. 25 cc. Sodium Hydroxide solution (containing 12.5 grams NaOH per litre) were then added and the process repeated. Further heating was then discontinued and the contents of the beaker allowed to settle and filtered whilst hot, through a folded filter paper of about 5 inches diameter. After the precipitate had been washed completely onto the filter paper, washing was continued with boiling water until the filtrate was free from sulphate. The precipitate was allowed to drain completely and the filter paper and precipitate were then placed in a steam oven to dry. When dry, the nitrogen content was determined by the ordinary Kjeldahl method and the percentage Pure Protein calculated by multiplying the percentage nitrogen by 6.25. The filter papers used, were checked for possible nitrogen content.

Estimation of Ether Extract.

Percentage Ether Extract was determined by extraction with the Soxhlet apparatus.

Estimation of Crude Fibre.

The method employed for the determination of Crude Fibre content was the British Official method (1932).

With feeding stuffs containing 2 percent, or more of oil, it is usual in accurate work, to extract the oil before proceeding to the fibre determination, i.e. to use the residue left in the cartridge after the Soxhlet extraction. In the present case however, this precaution was omitted, the percentage of of oil being very minute.

(K) CALCULATION OF RESULTS.

From the analyses obtained and the total quantities of fodder consumed and faeces voided, the consumption and excretion of each nutrient during the trial period was calculated, and the difference between these, taken to be the amount digested. This expressed as a percentage of the amount consumed is termed the "Digestion Coefficient". This figure is calculated on a dry matter basis since fodder and faeces have varying moisture contents.

Applying the digestion coefficient determined for each nutrient to the amount of it contained in the fresh fodder, the percentage digestibility is obtained.

From the percentages of digestible nutrients the Starch Equivalent for each fodder has been calculated by the method outlined by Kellner (1926) i.e. using his "Production Value" for each nutrient and making the appropriate correction as specified for coarse fodders.

In addition, as previously explained, (See Part I, Section A), the Starch Equivalent values have all been increased by one-fifth.

In this thesis the amounts of digestible crude protein protein and the Protein Equivalents for each fodder have been stated. This last value, as has been pointed out, is the difference between the percentages of crude and pure protein. This difference in the case of fodders is, as can be seen, normally very small. Only in one case, namely Guinea Grass was the difference very marked, this difference being further emphasised by the relatively small crude and pure protein contents of the grass.

The Nutritive Ratio for each fodder has also been quoted. This figure is caluclated by means of the following expression:-

$$N.R. = \frac{(\%\ dig{:}oil \times 2.3) + \%\ dig{:}carbohydrate + \%\ dig{:}fibre}{\%\ dig{:}\ protein}$$

Since the Nutritive Ratio defines the balance of a food or ration, the suitability of a given diet for any specific purpose may be checked by calculating its nutritive ratio. Since it is customary

customary to define requirements in terms of Starch Equivalent and digestible crude protein or Protein Equivalent, the conception of Nutritive Ratio is superfluous, rations designed to supply the correct amounts of Starch Equivalent and protein being automatically balanced. In addition while the Nutritive Ratio calculated for each fodder, by use of the above expression, remains unaltered, all Starch Equivalent values, as stated, have been increased by one-fifth. The Nutritive Ratios then, so expressed, do not therefore truly define the balance of the feed.

All calculations have been made, using figures obtained from duplicate analyses of composite samples of fodder and faeces, as previously mentioned.

In the case of the moisture determinations and the determination of the nitrogen content of the urines, the figure used for calculations has, in each case, has been an average one, the mean of all those samples of either fodder, faeces or each animal's urine, which were analysed daily, during each trial. These average figures were used in order that all calculations should remain on a comparable basis throughout.

In actual fact, variations between calculations of the total nitrogen content of any animal's urine, throughout trial determined by (a) using an average figure, as outlined above; and (b) multiplying the amounts excreted daily by their respective nitrogen contents and taking the sum of these figures; were not found to be very great.

While average nitrogen balance figures so obtained, it is felt, will serve as a check on live-weight measurements, a more detailed investigation, as pointed out, is necessary for the determination of protein requirements.

PART III.

PART III.

THE RESULTS OBTAINED.

TABLE 3. RESULTS OF TRIAL 1. BAMBOO GRASS. *Paspulum fasciculatum*.

Date.	Bamboo Grass Consumed Lb.				Faeces Voided Lb.			
	Zebu	Sahiwal	Holstein	Sussex	Zebu	Sahiwal	Holstein	Sussex
17.11.39	74	51.5	70	66	35	28	40	33
18 "	68	56	64	57	31	27	43	29
19 "	65.5	43	54	48.5	33	27.5	44	28
20 "	67	56	72	53.5	45	27	38	37
21 "	60	44.5	62	51	44	28	50	39
22 "	61	46.5	65	51	38	27	51	35
23 "	60	52.5	63.5	50.5	49	30.5	44.5	38
24 "	61	56	62	65	36	30.5	43	40
25 "	76	63.5	73	48.5	37	32.5	42	32
26 "	76	53	68	54	38	27	40	32
TOTAL	668.5	552.5	653.5	545.0	386.0	285.0	435.5	343.0
					280	270	220	280

TABLE 4. COMPOSITION OF BAMBOO GRASS AND OF FAECES.

	Moisture %	Silica -Free Ash %	Silica %	Crude Protein %	Pure Protein %	Ether Extract %	Crude Fibre %	Nitrogen -Free Extract %
Bamboo Grass	79.20	1.08	1.27	1.31	1.18	0.29	7.19	9.66
Faeces from:-								
1.Zebu	85.00	0.93	2.17	1.16	1.00	0.11	4.80	7.83
2.Sahiwal	81.20	0.74	2.10	1.19	1.19	0.09	5.69	8.99
3.Holstein	85.30	0.80	1.49	1.06	0.98	0.08	4.28	6.99
4.Sussex	83.75	1.13	0.84	1.12	1.08	0.10	4.63	7.43

TABLE 5. DIGESTION COEFFICIENTS OF BAMBOO GRASS.

	Dry Matter	Silica-Free Ash	Crude Protein	Pure Protein	Ether Extract	Crude Fibre	Nitrogen-Free Extract
1.Zebu	52.8	50.7	51.3	51.2	78.2	61.4	53.0
2.Sahiwal	53.4	64.2	54.3	51.8	84.9	62.8	49.6
3.Holstein	52.9	50.6	46.3	44.6	80.9	60.3	51.8
4.Sussex	50.8	-	46.4	42.3	79.1	59.5	51.6
AVERAGE	52.5	55.1	49.6	47.5	80.8	61.0	51.5

TABLE 6. NUTRITIVE VALUE OF 100 lb. BAMBOO GRASS.

TOTAL DRY MATTER Lb.	DIGESTIBLE NUTRIENTS Lb.							
	Crude Protein	Pure Protein	Crude Fibre	Ether Extract	Nitrogen-Free Extract	S.E. Lb.	P.E. Lb.	N.R.
20.80	0.65	0.56	4.39	0.23	4.97	9.47	0.61	1 : 15

CALCULATION OF STARCH EQUIVALENT.

Digestible Crude Protein.	0.65 x 0.94 =	0.61
" Fat	0.23 x 1.91 =	0.44
" Nitrogen-Free Extract	4.97 x 1.00 =	4.97
" Crude Fibre	4.39 x 1.00 =	4.39
TOTAL		10.41
Deduct Total Fibre 7 % x 0.36		2.52
		7.89
+ 1/5 x 7.89 (See Part I.Section A)		1.58
		9.47

N.B. The calculation of Starch Equivalent, in all the following trials have been made as above.

TABLE 7. WEIGHTS OF COWS (LBS.).

1.ZEBU	2.SAHIWAL	3.HOLSTEIN	4.SUSSEX	Date	
1022	760	762	725	6.11.39	Initial weights
1053	737	755	703	15.11.39	Weights at beginning at end of experimental period
1075	741	814	740	27.11.39	

From reference to Table No.5 it will be seen that no figure has been stated, in the case of the Sussex, for silica-free ash. The digestion coefficient in this case was calculated to be over 100.
If also reference is made to Table No.3 it will be seen that, on the average, about 55 to 65 lb. of Bamboo Grass were consumed by animals daily.

On application of the nutritive values calculated it would appear that:-

	D.M.	S.E.	P.E.
55 lb. Bamboo Grass contained	11.6 lb.	5.2 lb.	0.33 lb.
65 lb. " " "	13.7 "	6.1 "	0.52 lb.

The following table shows the weights of all animals at the beginning of the experimental period and their approximate daily maintenance requirements (See Part I. Section F), to the nearest 100 lb., live-weight also approximate average daily consumption.

TABLE 8.

	Live Weight lb.	D.M. lb.	S.E. lb.	P.E. lb.	Lb.Consumed daily approximate.
1.Zebu	1053	23.5	6.5	0.65	65
2.Sahiwal	737	17.5	4.5	0.45	55
3.Holstein	755	19.5	5.0	0.50	65
4.Sussex	703	17.5	4.5	0.45	55

In no case therefore, it would appear, did the ration eaten meet requirements for Dry Matter or protein, except in the case of the Holstein, while the supply of Starch Equivalent would hardly appear to have been sufficient to maintain the Zebu.

On reference to Table No.7, it will be noted that the animals all made gains in live weight, during the experimental period. As stated previous, however, both the Zebu and the Holstein were becoming heavy in calf. The fact that the animals, particularly the above two, appeared to gain weight, on such a ration, notwithstanding foetal growth, might suggest that the values obtained were inaccurate. Alternatively, either live weight was not a true measure of nutritive effect or the standards were incorrect.

The loss in live weight in the cases of the Sahiwal, Holstein and Sussex, during the preliminary period might be accounted for by change in conditions and ration. All animals had previously been receiving grass and a very small quantity of meal. It is however thought to be questionable whether they would pick up as markedly, on such an inadequate ration as the Bamboo Grass was shown to be, as their gain in live weight, during the experimental period, might indicate.

The writer feels, however, that he cannot arrive at any definite conclusion, especially in view of the continual approximation which has to be made, throughout such work.

TABLE 9. RESULTS OF TRIAL 2. PARA GRASS. Brachiaria mutica (stapf).

Date	Para Grass Consumed Lb.				Faeces Voided Lb.			
	Zebu	Sahiwal	Holstein	Sussex	Zebu	Sahiwal	Holstein	Sussex
8.12.39	68	61	72	66.5	40	33	58	48
9 "	71	54	70	59	51	29.5	53.5	43
10 "	68	42	76	67	46	28	54	41
11 "	64	64	80.5	72.5	44	28.5	57.5	46.5
12 "	62	55	81	69	36	28	57	44
13 "	60.5	61.5	72.5	68	41.5	29	55.5	46
14 "	75	62	80	79.5	34	28	51	47.5
15 "	78	74	87	79.5	39	27	46	39.5
16 "	88	61	87	91	31	26	46.5	41.5
17 "	84	52	88	87.5	34	27	46	35
TOTAL	718.5	586.5	794.0	759.5	396.5	285.5	525.0	432.0

TABLE 10. COMPOSITION OF PARA GRASS AND OF FAECES.

	Moisture %	Silica -Free Ash %	Silica %	Crude Protein %	Pure Protein %	Ether Extract %	Crude Fibre %	Nitrogen-Free Extract %
Para Grass	80.10	1.83	0.88	1.88	1.58	0.32	6.78	8.21
Faeces from:-								
1.Zebu	84.35	0.54	1.99	1.06	1.00	0.20	5.54	6.32
2.Sahiwal	81.85	0.58	2.45	1.31	1.26	0.15	6.23	7.43
3.Holstein	86.40	0.63	1.53	1.00	0.96	0.14	4.79	5.51
4.Sussex	86.00	0.53	1.56	1.13	1.02	0.15	4.71	5.92

TABLE 11. DIGESTION COEFFICIENTS OF PARA GRASS.

	Dry Matter	Silica -Free Ash	Crude Protein	Pure Protein	Ether Extract	Crude Fibre	Nitrogen -Free Extract
1.Zebu	56.6	78.3	69.6	65.1	65.6	54.9	58.6
2.Sahiwal	55.8	79.4	66.7	61.4	62.4	55.3	58.9
3.Holstein	54.8	69.4	66.0	59.4	71.3	53.2	56.4
4.Sussex	58.9	77.8	65.8	62.5	72.2	59.4	58.9
AVERAGE	56.5	76.2	67.0	62.1	67.9	55.7	58.2

TABLE 12. NUTRITIVE VALUE OF 100 lb. PARA GRASS.

TOTAL DRY MATTER Lb.	DIGESTIBLE NUTRIENTS Lb.							
	Crude Protein	Pure Protein	Crude Fibre	Ether Extract	Nitro-gen-Free Extract	S.E. Lb.	P.E. Lb.	N.R. Lb.
19.90	1.26	0.98	3.77	0.22	4.78	9.18	1.12	1:7

TABLE 13. NITROGEN BALANCE (Units = Lb.).

	Total Grass Consumed	x 0.30 (% N in Grass) = Total N intake	Total Faeces Voided	% N in Faeces	Total N in Faeces	Total Urine Excreted lb.	% N in Urine	Total N in Urine	Total N output	BALANCE
1.Zebu	718.5	2.156	396.5	0.17	0.674	332.5	0.36	1.197	1.871	+ 0.285
2.Sahiwal	586.5	1.760	283.5	0.21	0.595	266.5	0.35	0.933	1.528	+ 0.232

TABLE 14. WEIGHTS OF COWS (LBS.).

1.ZEBU	2.SAHIWAL	3.HOLSTEIN	4.SUSSEX	Date	
1075	741	814	740	27.11.39	Initial weights
1098	770	838	728	7.12.39	Weights at beginning and end of experimental period
1135	735	807	736	18.12.39	

From reference to Table No. 9, it can be seen that the average daily range of consumption was from 60 to 80 lb. of Para Grass. On application of the nutritive values obtained, it would appear that:-

	D.M.	S.E.	P.E.
60 lb. Para Grass contained.	12 lb.	5.5 lb.	0.67 lb.
70 " " " "	14 "	6.4 "	0.78 "
80 " " " "	16 "	7.4 "	0.90 "

The following table shows the weights of all animals at the beginning of the experimental period and their approximate daily maintenance requirements, to the nearest 100 lb. live weight also approximate average daily consumption.

TABLE 15.

	Live Weight lb.	D.M. lb.	S.E. lb.	P.E. lb.	Lb.Consumed daily approximate
1.Zebu	1098	23.5	6.5	0.65	70
2.Sahiwal	770	19.5	5.0	0.50	60
3.Holstein	838	19.5	5.0	0.50	80
4.Sussex	736	17.5	4.5	0.45	70

In no case were the requirements for Dry Matter supplied but apart from that the rations eaten contained an excess of stated requirements, particularly so in the case of the Sussex.

The results are rather conflicting. The nutrients retained by the Zebu were least in excess of stated requirements, the Starch Equivalent supply being only just possibly adequate. Nevertheless protein supply was apparently adequate despite the animals now advanved stage of pregnancy. Reference to Table No. 13 will show the nitrogen balance in this case to be decidedly positive.

In the case of the Sahiwal while there was apparently a loss in live weight of 45 lb. during the experimental period, the nitrogen balance for this animal was positive, about 10 % of the total nitrogen ingested in each case, being stored in the bodies of both the Zebu and Sahiwal. The apparent excess of requirements for maintenance supplied, and the positive nitrogen balance determined, it is felt, is far more favourable evidence for concluding that the Sahiwal received a maintenance allowance than its apparent loss in weight would be for concluding that it had not.

The Holstein also showed a loss in live weight of 31 lb. Though nutrients supplied were apparently in excess of requirements for maintenance, it must be assumed on this evidence alone that this excess was insufficient for the added requirements due to the animal's condition. This however it is felt is questionable, on condition of the evidence with regard to the Zebu, also in the same condition and especially on consideration of the fact that, in that case, the apparent excess of nutrients was markedly less. Without figures for a nitrogen balance further conclusion is not possible, the reasons for their absence in the case of this Holstein and the Sussex having been already stated.

The relatively slight gain in weight of the Sussex, in view of the large excess of Starch Equivalent and protein, supplied over maintenance would seem remarkable. This animal again lost weight during the preliminary period and seemed to take longer to accustom itself to any change in ration, having the most nervous disposition of any of the animals used and therefore might be

expected

expected to require more to regain condition

TABLE 16. RESULTS OF TRIAL 3. GUINEA GRASS. Panicum maximum.

Date	Guinea Grass Consumed Lb.				Faeces Voided Lb.			
	Zebu	Sahiwal	Holstein	Sussex	Zebu	Sahiwal	Holstein	Sussex
2.1.40	44.5	54.5	61.5	54	37	31	40.5	41
3 "	60	48	63.5	60	34.5	30.5	44.5	44
4 "	60	50	69.5	59.5	33	31.5	48.5	47.5
5 "	62	53	72	68	41	36	51	52
6 "	64	57	93	68	39	29	53	48.5
7 "	71	54	95	51	40	30	54	46.5
8 "	65	73	98	89.5	37	31	51	40
9 "	65	52.5	87.5	70	36.5	32.5	55	42
10 "	78	68	94.5	90	37	36	61.5	59
11 "	74	67.5	89	79	36	38	60	58.5
TOTAL	643.5	577.5	823.5	689.0	371.0	325.5	519.0	479.0

TABLE 17. COMPOSITION OF GUINEA GRASS AND OF FAECES.

	Moisture %	Silica -Free Ash %	Silica %	Crude Protein %	Pure Protein %	Ether Extract %	Crude Fibre %	Nitro -gen-Free Extract %
Guinea Grass	78.55	0.89	2.03	2.13	1.11	0.28	7.45	8.67
Faeces from:-								
1.Zebu	81.30	1.57	2.32	1.25	1.19	0.19	5.62	7.75
2.Sahiwal	79.75	2.10	2.09	1.31	1.23	0.19	6.13	8.43
3.Holstein	83.00	1.48	2.00	1.75	1.06	0.14	5.33	6.30
4.Sussex	83.00	1.67	1.73	1.82	1.09	0.20	5.27	6.31

TABLE 18. DIGESTION COEFFICIENTS OF GUINEA GRASS.

	Dry Matter	Silica -Free Ash	Crude Protein	Pure Protein	Ether Extract	Crude Fibre	Nitrogen -Free Extract
1.Zebu	49.6	-	66.7	38.2	60.0	56.5	49.3
2.Sahiwal	46.8	-	65.4	37.8	61.1	53.6	46.0
3.Holstein	50.0	-	66.5	39.8	67.7	54.9	50.4
4.Sussex	45.0	-	62.3	35.8	52.3	53.9	48.3
AVERAGE	47.9	-	65.3	37.9	60.3	54.7	48.5

TABLE 19. NUTRITIVE VALUE OF 100 lb. GUINEA GRASS.

TOTAL DRY MATTER Lb.	DIGESTIBLE NUTRIENTS Lb.							
	Crude Protein	Pure Protein	Crude Fibre	Ether Extract	Nitro -gen- Free Extract	S.E. Lb	P.E. Lb.	N.R. Lb.
21.45	1.39	0.41	4.02	0.17	4.11	8.69	0.90	1:6

TABLE 20. NITROGEN BALANCE (Units = Lb.).

	Total Grass Con- sumed	x 0.34 (% N in Grass) = Total N in- take	Total Faeces Voided	% N in Faeces	Total N in Faeces	Total Urine Excret -ed lb.	% N in Urine	Total N in Urine	Total N out -put	BALANCE
1.Zebu	643.5	2.188	371.0	0.20	0.742	225.0	0.73	1.643	2.385	- 0.197
2.Sahiwal	577.5	1.964	325.5	0.21	0.684	220.5	0.57	1.257	1.941	+ 0.023
3.Holstein	823.5	2.800	519.0	0.28	1.453	301.0	0.67	2.017	3.470	- 0.670

TABLE 21. WEIGHTS OF COWS (LB.).

1.ZEBU	2.SAHIWAL	3.HOLSTEIN	4.SUSSEX	Date	
951	735	976	736	18.12.39	Weights at beginning and end of whole trial.
951	763	916	727	12.1. 40	

From reference to Table No.16, it will be seen that the average daily range of consumption was from 60 to 80 lb. of Guinea Grass. On application of the nutritive values obtained, it would appear that:-

	D.M.	S.E.	P.E.
60 lb. Guinea Grass contained.	12.8 lb.	5.2 lb.	0.54 lb.
70 " " " "	15.0 "	6.1 "	0.59 "
80 " " " "	19.2 "	7.0 "	0.68 "

The reasons for weighing the animals only at the beginning and end of this trial, as well as in the case of Trial 4, Guatemala Grass, have been outlined. The following table shows the weights of all animals at the beginning of the preliminary period and their approximate daily maintenance requirements, to the nearest 100 lb. live weight, also approximate average daily consumption.

TABLE 22.

	Live Weight lb.	D.M. lb.	S.E. lb.	P.E. lb.	Lb.Consumed daily approximate
1.Zebu	951	22.0	6.0	0.60	60
2.Sahiwal	735	17.5	4.5	0.45	60
3.Holstein	976	20.5	5.5	0.55	80
4.Sussex	736	17.5	4.5	0.45	70

In no case were the requirements for Dry Matter met though the amount, contained in the ration eaten by the Holstein, was almost adequate. Except in the case of the Zebu, it would appear that sufficient quantities of Starch Equivalent and protein were supplied in the rations eaten, with some excess in addition.

On reference to Table No. 21, it will be seen that the weight of the Zebu apparently remained constant throughout the whole trial. The weight of the Sahiwal increased appreciably, that of the Sussex decreased slightly while the Holstein lost weight considerably, over the same period. However, on reference to Table No. 20, it can be seen that the nitrogen balances for the Zebu and Holstein were negative. There would, though, seem to be some connection between the live weight fluctuations and the extent of these balances.

Where the live weight of the Zebu has remained constant, it will be noted that the negative balance is quite appreciable. In the case of the Sahiwal which had apparently gained weight the positive nitrogen balance was comparatively slight while the Holstein not only lost weight considerably but also showed a considerable negative balance of nitrogen.

The Holstein had just been introduced into the experiment at the start of this trial and was, in addition, rather nervous at first. It may be that this was responsible, to some extent, for her performance. It is felt that the nitrogen balances are far more indicative of the effect of the ration, in any case than are the live weight measurements but especially in view of the state of the Guinea Grass examined. No definite explanation can however be given for the discrepancy between the calculated values of the rations consumed and their actual values when fed.

It will be noted that no figures have been given for the digestion coefficients of silica-free ash. The digestion coefficients for this, when calculated were found to be over 100.

TABLE 23. RESULTS OF TRIAL 4. GUATEMALA GRASS. *Tripsacum laxum*.

Date	Guatemala Grass Consumed Lb.				Faeces Voided Lb.			
	Zebu	Sahiwal	Holstein	Sussex	Zebu	Sahiwal	Holstein	Sussex
22.1.40	73	63	87	80	33	18	34	36.5
23 "	69	57	76	74	40	21	37	40
24 "	66	52.5	75	66	34	21	40.5	37
25 "	70	61	81	68.5	32	21	36	34.5
26 "	74	54	65	77	37.5	23	38	33
27 "	71	67	91	77	37	34	38	39
28 "	64.5	58.5	83	76	34	20	44	36
29 "	71	66	73.5	73	36	25	37	39
30 "	65	58	74	66	32	25	38	37
31 "	69.5	60.5	82	71	32.5	22	40	35
TOTAL	693.0	597.5	787.5	728.5	348.0	230.0	382.5	367.0

TABLE 24. COMPOSITION OF GUATEMALA GRASS AND OF FAECES.

	Moisture %	Silica-Free Ash %	Silica %	Crude Protein %	Pure Protein %	Ether Extract %	Crude Fibre %	Nitro-gen-Free Extra-ct %
Guatemala Grass	81.05	0.48	0.90	1.75	1.15	0.71	7.49	7.45
Faeces from:-								
1.Zebu	83.30	0.77	1.58	1.25	1.06	0.62	5.74	6.84
2.Sahiwal	80.45	0.97	1.70	1.44	1.38	0.63	6.25	8.53
3.Holstein	84.35	0.79	1.25	1.44	1.06	0.54	5.54	6.38
4.Sussex	84.15	0.85	0.75	1.56	1.13	0.48	5.86	6.60

TABLE 25. DIGESTION COEFFICIENTS OF GUATEMALA GRASS.

	Dry Matter	Silica -Free Ash	Crude Protein	Pure Protein	Ether Extract	Crude Fibre	Nitro -gen- Free Extract
1.Zebu	55.9	18.4	61.8	52.2	56.4	61.6	54.6
2.Sahiwal	60.3	26.0	62.8	52.0	65.8	67.9	58.2
3.Holstein	62.4	26.0	65.3	56.5	65.4	66.3	63.3
4.Sussex	57.8	13.8	60.8	50.8	65.9	60.5	57.5
AVERAGE	59.1	21.1	62.7	52.9	63.4	64.1	58.4

TABLE 26. NUTRITIVE VALUE OF 100 lb. GUATEMALA GRASS.

TOTAL DRY MATTER Lb.	DIGESTIBLE NUTRIENTS Lb.							
	Crude Protein	Pure Protein	Crude Fibre	Ether Extract	Nitro -gen- Free Extract	S.E.	P.E.	N.R.
18.95	1.10	0.60	4.80	0.45	4.35	10.22	0.85	1:9

TABLE 27. NITROGEN BALANCE (Units = Lb.).

	Total Grass Con- sumed	x 0.28 (% N in Grass) = Total N in- take	Total Faeces Voided	% N in Faeces	Total N in Faeces	Total Urine Excret -ed	% N in Urine	Total N in Urine Lb.	Total N out -put	BALANCE
1.Zebu	693.0	1.940	348.0	0.20	0.696	364.0	0.55	2.002	2.698	- 0.758
2.Sahiwal	597.5	1.673	230.0	0.23	0.529	429.0	0.31	1.330	1.859	- 0.186
3.Holstein	787.5	2.205	382.5	0.23	0.880	441.5	0.35	1.545	2.425	- 0.220

TABLE 28. WEIGHTS OF COWS (LB.).

1.ZEBU	2.SAHIWAL	3.HOLSTEIN	4.SUSSEX	Date	
951	763	916	727	12.1.40	Weights at beginning and end of whole trial.
977	783	850	730	1.2.40	

From reference to Table No.23, it will be seen that the average daily range of consumption was from 60 to 80 lb. of Guatemala Grass. On application of the nutritive values obtained, it could appear that:-

	D.M.	S.E.	P.E.
60 lb. Guatemala Grass contained.	11.4 lb.	6.1 lb.	0.51 lb.
70 " " " "	13.3 "	7.2 "	0.59 "
80 " " " "	15.2 "	8.2 "	0.68 "

Like that for the Guinea Grass the following table shows the weights of all animals at the beginning of the preliminary period and their approximate daily maintenance requirements, to the nearest 100 lb. live weight, also approximate average daily consumption.

TABLE 29.

	Live Weight lb.	D.M. lb.	S.E. lb.	P.E. lb.	Lb. Consumed daily approximate
1.Zebu	951	23.0	6.0	0.60	70
2.Sahiwal	763	19.5	5.0	0.50	60
3.Holstein	916	20.5	5.5	0.55	80
4.Sussex	727	17.5	4.5	0.45	70

Except for Dry Matter, requirements would appear to have been met or mostly exceeded. Reference to Table No. 28 shows that except in the case of the Holstein, there were gains in live weight during the whole of the trial. Again, however, as in the previous set of results for Guinea Grass, the evidence of the nitrogen balances in Table No. 27 is contradictory. In this case there

there seems to be no connection between the live weight fluctuations and the extent of the negative nitrogen balances determined and again no definite explanation can be given for the discrepancy.

TABLE 30. RESULTS OF TRIAL 5. SWEET POTATO VINES. *Ipomea batatas.*

Date	Sweet Potato Vines Consumed Lb.				Faeces Voided Lb.			
	Zebu	Sahiwal	Holstein	Sussex	Zebu	Sahiwal	Holstein	Sussex
10.2.40	59	57.5	65.5	55	26	28	32	25
11 "	66	54.5	68	62.5	30	31	31	27
12 "	61.5	53	66	58	33	27.5	36.5	28.5
13 "	65.5	56.5	67.5	55	36.5	26.5	36	28.5
14 "	67.5	59	71	55	34	28	37	25
15 "	66	59	70	53	33.5	29	33	23.5
16 "	68	58	69.5	54.5	35	29.5	31.5	22
17 "	67	58.5	68	60.5	39	32	34	27
18 "	62	56	72	60.5	36	28	31	24
19 "	69	61.5	68	65	38	36	37	36
TOTAL	651.5	573.5	665.5	579.0	341.0	295.5	339.0	266.5

TABLE 31. COMPOSITION OF SWEET POTATO VINES AND OF FAECES.

	Moisture %	Silica-Free Ash %	Silica %	Crude Protein %	Pure Protein %	Ether Extract %	Crude Fibre %	Nitrogen-Free Extract %
Sweet Potato Vines	78.1	0.70	1.68	2.81	2.15	0.61	5.89	10.21
Faeces from:-								
1.Zebu	82.15	1.73	1.65	1.69	1.38	0.30	7.20	5.28
2.Sahiwal	81.05	1.77	1.47	1.75	1.60	0.33	8.21	5.42
3.Holstein	80.75	1.89	1.62	1.94	1.94	0.36	8.09	5.35
4.Sussex	79.55	2.01	1.74	2.19	2.07	0.39	8.06	6.06

TABLE 32. DIGESTION COEFFICIENTS OF SWEET POTATO VINES.

	Dry Matter	Silica -Free Ash	Crude Protein	Pure Protein	Ether Extract	Crude Fibre	Nitro -gen- Free Extract
1.Zebu	56.76	-	65.79	65.74	87.15	37.33	72.11
2.Sahiwal	55.41	-	67.77	61.64	72.30	35.41	72.11
3.Holstein	55.23	-	64.97	54.08	70.00	32.45	72.65
4.Sussex	57.02	-	61.67	55.62	70.38	39.10	72.14
AVERAGE	56.1	-	65.1	59.3	75.0	36.1	72.3

TABLE 33. NUTRITIVE VALUE OF 100 lb. SWEET POTATO VINES.

TOTAL DRY MATTER Lb.	DIGESTIBLE NUTRIENTS Lb.							
	Crude Protein	Pure Protein	Crude Fibre	Ether Extract	Nitro -gen- Free Extract	S.E. Lb.	P.E. Lb.	N.R. ~~Lb.~~
21.90	1.83	1.27	2.13	0.46	7.38	12.08	1.55	1:6

TABLE 34. NITROGEN BALANCE (Units = Lb.).

	Total Grass Con- sumed	x 0.45 (% N in Grass) = Total N in- take	Total Faeces Voided	% N in Faeces	Total N in Faeces	Total Urine Excret -ed	% N in Urine	Total N in Urine	Total N out -put	BALANCE
1.Zebu	651.5	2.932	341.0	0.27	0.921	310.5	0.65	2.018	2.939	-0.007
2.Sahiwal	573.5	2.581	295.5	0.28	0.839	293.0	0.55	1.612	2.451	+0.130
3.Holstein	665.5	2.995	339.0	0.31	1.051	314.0	0.55	1.727	2.778	+0.217

TABLE 35. WEIGHTS OF COWS (LB.).

1.ZEBU	2.SAHIWAL	3.HOLSTEIN	4.SUSSEX	
977	783	850	730	Initial weights.
979	791	869	732	Weights at beginning and end of experimental period.
963	784	879	750	

From reference to Table No. 30, it will be seen that the average daily range of consumption was from 55 to 65 lb. of Sweet Potato Vines. On application of the nutritive values obtained it would appear that:-

	D.M.	S.E.	P.E.
55 lb. Sweet Potato Vines contained.	12.1 lb.	6.6 lb.	0.85 lb.
65 " " " " "	14.3 "	7.9 "	1.00 "

The following table shows the weights of all animals at the beginning of the experimental period and their approximate maintenance requirements, to the nearest 100 lb. live weight, also approximate average daily consumption.

TABLE 36.

	Live Weight lb.	D.M. lb.	S.E. lb.	P.E. lb.	Lb. Consumed daily approximate
1.Zebu	979	22.0	6.0	0.60	65
2.Sahiwal	783	19.5	5.0	0.50	55
3.Holstein	869	20.5	5.5	0.55	65
4.Sussex	732	17.5	4.5	0.45	55

It can thus be seen that except for Dry Matter, all requirements were apparently exceeded, in the rations consumed. On reference to Table No. 35, it can also be seen that the Zebu and Sahiwal lost weight while the Holstein and Sussex made gains, though in no case were the fluctuations, in live weight, throughout the whole trial, very great.

Reference to Table No. 34 shows that the nitrogen balances of the animals for which the balances were determined were satisfactory. The Zebu showed a slight negative balance but, on consideration of the method of calculation, this cannot be emphasised.

In this trial also, the digestion coefficients for silica-free ash were found to be over 100 and so have not been quoted. This occurrence was also pointed out in Trials 1 and 3. The writer is at a loss to explain this and can only indicate the errors which may occur in the calculation of the digestibility of ash (see Part I Section D.a.).

PART IV. CONSIDERATION OF RESULTS.

(A) COMPARISON OF THE NUTRITIVE VALUES OF THE FODDERS EXAMINED.

From reference to the nutritive values calculated, by the method outlined, it would appear that except for the Bamboo Grass, all fodders were capable of supplying the requirements of Starch Equivalent and protein. In fact these were often in excess of requirements. However, on reference to the individual results of each trial the samples of the Guinea and Guatemala Grasses could hardly be said to have proved satisfactory, and, in these cases, their calculated values, as providing a maintenance rations were not confirmed. This is in agreement with the writer's feelings on the subject of those particular samples. The Guinea Grass, as mentioned, though stated to be little older than two months was becoming hard while the Guatemala Grass, four months old, was distinctly past its ideal stage for feeding.

Despite being in flower, the Para Grass, it is felt, rather substantiated its reputation for nutritive value while lastly the Sweet Potato Vines, as expected, proved to be of superior feeding value to the other fodders examined, thus confirming the value claimed for them, as a feed.

The most serious criticism which must be made for all fodders is with regard to dry matter content. In this respect, all rations eaten were unsatisfactory the dry matter supply, in nearly every case, being far below the standard requirements, rations in some cases being as much as five to ten pounds short. While serious in a maintenance ration, it must also be obvious that, under such circumstances, it might be difficult, even with the addition of concentrates, for an adequate amount of dry matter to be supplied.

The importance of an adequate supply of bulk in the rations of cattle cannot be too heavily stressed, if maximum digestibility is to be obtained. Unless a sufficiency is supplied digestibility will be impaired and the animal may experience discomfort. In addition this lack of dry matter, as in the present experiment, cannot be remedied by further consumption since the

animal

animal has already probably consumed its maximum of green roughage.

This low dry matter content is also a serious criticism to be levelled at the maintenance rations recommended by Maule (1930) of the fodders he examined for cattle.

In the present experiment a considerable portion of each animal's ration was water and it was noted that very little extra water was drunk, in addition. The consistency of the faeces was not markedly affected in the case of the four grasses, remaining just solid throughout. During Trials, however, the faeces of the animals, eating Sweet Potato Vines, changed considerably, becoming darker and considerably looser, though the animals showed no signs of scouring. In addition to low dry matter content, the relatively high protein content of the ration may have been partly responsible for this. With regard to the feeding of Sweet Potato Vines, it might therefore be considered advisable, to allow wilting to take place before feeding, thereby causing loss of some of the excess moisture. In this state, it is claimed by some that there is no loss in nutritive value, though the animals did not take quite so readily to it, when fed like this during the preliminary period of trial. This course naturally cannot be advised where grasses are fed.

Amounts of urine, excreted daily, did not in any case remain constant but on the whole excretions seemed often to be made with fairly regular fluctuations - a large quantity one day, followed by a smaller quantity the next. As might be expected, however, it can be seen, if the figures are compared, that higher moisture content in the fodders was accomplished by greater amounts of urine excreted.

In the light of the above, the effect of the rations fed being perhaps not as marked, as their calculated values might indicate, might partly be attributed to their low Dry Matter contents. Alternatively, the success of some is surprising, on consideration of this aspect and, as a result, the accuracy of the standard requirements for dry matter used, might be questioned.

The

The criticism which has been made of Guinea Grass, as being a relatively dry fodder, in the light of the above, might be claimed as an attribute.

(B) COMPARISON OF THE DIGESTIBILITY OF THE FODDERS EXAMINED.

The following table shows the average digestion coefficients obtained for the following nutrients, in each of the fodders examined.

TABLE 37.

	Dry Matter	Crude Protein	Pure Protein	Crude Fibre	Ether Extract	Silica-Free Ash	Nitrogen-Free Extract
1.Bamboo	52.5	49.6	47.5	61.0	80.8	55.1	51.5
2.Para	56.5	67.0	62.1	55.7	67.9	76.2	58.2
3.Guinea	47.9	65.3	37.9	54.7	60.3	-	48.5
4.Guatemala	59.1	62.7	52.9	64.1	63.4	21.1	58.4
5.S.P.Vines	56.1	65.1	59.3	36.1	75.0	-	72.3

From this it would appear that digestibility of nutrients was considerably higher throughout in the Para Grass, Guatemala Grass and Sweet Potato Vines than in the Bamboo Grass and Guinea Grass. On consideration of the varying stages of growth and condition, in which the fodders were cut, however, the above table does not, it is felt, afford a fair basis for comparison. From this table, however, several points are noticeably outstanding. In the first place the great variation in the extent to which some of the same nutrients were digested, in different fodders examined, must be evident. In the second place the generally low digestion coefficients of Guinea Grass, except for Crude Protein must be noted, this being rather in agreement with what might be imagined from the condition of the grass. On the other hand, considering

its

its age, the relatively high digestibility of the Guatemala Grass must be commended though this was probably enhanced by removal of dead material, as explained.

The Para Grass, as can be seen was, on the whole, the most highly digestible though only slightly more than the Sweet Potato Vines. The very low digestibility of Crude Fibre, in that fodder, is noteworthy, this being off-set by a higher digestibility of nitrogen-free extract.

There was, as can be seen from the tables of results, sometimes considerable variation between the digestion coefficients of the four animals, for any particular nutrient, this not being evident from the above table. There seemed however to be no connection between these variations, the extent of the digestibility of any particular nutrient in any fodder, by any one animal, not remaining proportionally constant in relation to that by the other animals, in the other fodders.

In general the digestion coefficients of the Sussex were slightly lower throughout the experiment. In no case, however, it is felt, could it be really said that the Indian animals i.e. Zebu and Sahiwal showed any higher digestive capacity, particularly in the case of Crude Fibre.

The digestion coefficients for the various nutrients compare very favourably with those obtained by Maule (1930), using cross-bred cows, for Uba Cane, Cane-tops and Elephant Grass also thos obtained by Hobbs (1931) for Savannah Grass, with six Zebu oxen. In this last case, the digestion coefficients were not outstanding for crude fibre though no inference can be drawn from this evidence alone.

Maule (1930) also found variations between individual animals in his three trials and pointed out that this tended to show, either that individuality has a greater influence on the digestibility of food stuffs than is attributed to it by Armsby or Kellner, or, that the variation observed may be connected with the theory that native or Indian animals are more economical in digestion.

The

The writer finds himself in agreement with the first of these statements. As regards the second, the implication is uncertain. If economy in digestion implies less requirements for maintenance, the writer feels this is dependent upon the previous plane of nutrition. The writer's contentions in this respect have already been stated. The pure Taurus animal is obviously at a disadvantage in this respect, to the pure Indicus, when imported into Trinidad but among local Zebus and cross-bred animals it is uncertain to what extent this economy is inherited or how long it can be maintained, under different conditions and upon another plane of nutrition. Consequently, with no particular data available, it is difficult to predict to what extent maintenance requirements for Trinidad animals differ from those recommended by English feeding standards.

Neither Maule's nor the present results, however, give any definite indication that higher digestive capacity is retained with Zebu blood, when animals are bred and acclimatised locally.

(C) COMPARISON OF THE APETITES OF THE EXPERIMENTAL ANIMALS AND OF THE PALATABILITY OF THE FODDERS EXAMINED.

As previously stated, the experimental animals were allowed to eat as much as they desired. The following table shows the average daily amounts of the fodders consumed during the experimental periods.

TABLE 38.

	Bamboo	Para	Guinea	Guatemala	S.P.Vines
1.Zebu	67	72	64	69	65
2.Sahiwal	55	59	58	60	57
3.Holstein	65	79	82	79	67
4.Sussex	55	74	69	73	58

The small variation in the average daily amounts consumed by the Sahiwal and the two Zebu animals (A used in Trials 1 and 2 and B in Trials 3, 4 and 5) is noteworthy. The palatability of the samples, except in the case of the Sweet Potato Vines, is in general, indicated by the relative amounts consumed though not in every case.

Of the grasses the Para Grass was undoubtedly the most palatable and the Bamboo Grass quite definitely the least relished by the animals. The relatively large amounts of Guatemala Grass eaten, considering its age and condition, is surprising. The writer has no hesitation in saying, however, that of the samples examined, the Sweet Potato Vines were the most acceptable of all the fodders examined, to the animals.

That the palatability is also rather indicated by the rapidity with which the animals take to the fodder is shown by the following table of the average daily amounts of the fodders consumed during the preliminary periods.

TABLE 39.

	Bamboo	Para	Guinea	Guatemala	S.P.Vines
1.Zebu	59	66	50	67	58
2.Sahiwal	45	52	49	56	57
3.Holstein	53	69	61	79	65
4.Sussex	46	56	60	71	59

From this it can be seen that except by the Zebu, there was little variation in the daily amounts consumed, during the whole trial of Sweet Potato Vines, though as mentioned, the sample fed during the preliminary period was older and harder than that

fed

fed during the experimental period. The smaller amounts of Bamboo Grass consumed, during the preliminary period, point to its relative unpalatability and the animals distaste for it at first. The above was also the case for the poor sample of Guinea Grass examined. The above figures further emphasised the palatability of the Guatemala Grass but the relatively lower figures in the case of the Para Grass are due it is felt to rather poorer quality material being fed during the preliminary period.

CONCLUSION AND RECOMMENDATIONS.

At the outset, the writer feels that he may be severely criticised for devoting too little attention to the results obtained from this experiment and too much to other aspects of the general problem. That this course has however been taken was partly due to the following reason. Owing to the time taken in conducting these trials and carrying out chemical analyses, no results could be obtained before early April. In addition, previous to that date, little time was available to the writer for a consideration of anything but the undertaking in hand. As a result, if this thesis was to be presented before the end of the session certain omissions would have to be made. The writer's reasons for choosing to foreshorten his discussion of results it is hoped will become clear from what follows.

In the earlier part of this thesis attention has been drwan, as closely as time and space would permit to some of the many limitations to such experimental work as this, some of which must be apparent from a consideration of the whole experiment. Unless these limitations are fully realised, the actual value of any results obtained cannot be truly estimated and if such results are merely stated without reserve they may be quite misleading if used in the computation of rations. Therefore it was felt to be essential to make clear these limitations before trying to draw any inference from results actually obtained.

"To initiate an experiment or series of experiments to determined the digestibility and nutritive value of some of the fodders commonly fed to cattle in Trinidad", Maule (1930) states, "is desirable in order to determine the amount of a fodder that should be fed to dairy cattle, to supply maintenance requirements, as given by Wood or Morrison for cattle in Europe and America, and hence calculate, using these figures for concentrated foods, and figures calculated from the results of this experiment for local fodders, rations for dairy cattle and draught oxen in Trinidad".

While

While this was probably unavoidable due to lack of any better values, the writer feels that the above resolve was anything but desirable. Nevertheless Maule follows up his work by calculating various rations in the above manner and estimating nutritive values per acre of the fodders examined. In such a wide application of results, to both dairy and working stock, from a single investigation, it is felt, may lie a distinct danger. Even had time permitted, the writer would have had distinct hesitation in following a similar course.

Apart from the fact that there is no proof that feeding standards in America or England are applicable in Trinidad it has also been pointed out how different nutritive values, obtained in those two countries, may be when similar feeds are utilised here. Even assuming any concentrate used was identical, there is no proof that the roughage necessarily utilised in the determination of the concentrate's nutritive value in either England or America even approximated to those, likely to be used in any ration with it in Trinidad. In no particular phase may the error be large but from what has been pointed out with regard to the associative effects of feeds when combined in rations, to say nothing of the error which may occur in the calculation of nutritive values from tables of digestible nutrients, it is felt, that the possible margin for error is considerable.

Maule (1930) also pointed out the desirability of comparing the digestibility or even chemical composition of the fodders in different stages of growth, in order to determine the most nutritious stage for cutting and feeding to cattle. Since that time there have been considerable advances in the knowledge of the chemical composition alone, of the main fodder crops. As has been pointed out, however, chemical composition alone is no sure indication of nutritive value. As regards digestibility determinations, no further work has been done except by Hobbs (1931) for Savannah Grass, till the present investigation. In this case however the fodders ~~examined~~ were examined in such varying stages of growth and

and condition that it is felt that the values, obtained for them do not provide a sound basis for comparison, without further confirmation.

These conclusions would so far, it is regretted, seem to be destructive rather than constructive. However if this work is to be continued it is hoped that the following recommendations, arising as a result of the present work, may be of value.

1. That the digestibility of the main fodder crops be compared not only at different stages of growth but at different seasons of the year. If this is to be done, it is felt that the crops should be grown for this purpose, under an approved system of management in order that they may be examined as desired. ✓
2. That as a result of the above when there is a sound basis for comparison, the most desirable fodders be included in rations with local feeding stuffs, to test how far these may meet requirements. If thought to be satisfactory these rations can then be tested out in practice to determine whether they serve the purpose for which they are intended. ✓
3. That in order that this may be done successfully, the nitrogen balances of animals under trial be determined and their protein economy be studied, since protein is the limiting factor in Trinidad rations. In this respect the following it is felt deserves mention. Watson (1940) has recently drawn attention to the work done in Germany on the possibility of saving protein, in the rations of ruminants, by feeding simple nitrogen compounds such as urea, glycol (amino acetic acid) and ammonium acetate. While as he states, "upon the whole it seems unlikely that these substances serve as actual sources of protein, it does seem, however, that they prevent the breakdown of true protein in the rumen - the bacteria living upon the simple nitrogen compounds in preference to the food protein . At any rate, in most trials, a protein-deficient ration, reinforced with urea, &c., has given definitely better results than the deficient ration itself,

and

almost as good results as a full-protein diet". In addition work by Hart (1939) and associates points to the conclusion that not only can non-protein nitrogen be utilised by ruminants but that it is most efficiently utilised when soluble sugar is given simultaneously.

Therefore, in view of the plentiful supply of molasses, it is felt, that if supplies of non-protein nitrogen could be obtained easily and cheaply and, after experiment, it was found possible to incorporate them with other feeds in rations, much of the difficulty with protein supply might be overcome.

4. That the animals utilised should be as nearly uniform in every way possible and if dairy cows are to be used, the writer's remarks in Part II. Section B be regarded.
5. That if such work is to be done, provision should be made for a more complete chemical analysis and attention paid to the mineral aspects of the problem.

Finally it might seem that the recommendations outlined cover rather an extensive field. However neither the importance nor the necessity for such work needs stressing but if it is to be of real value some definite systematic programme of research should, it is felt, be established.

Trinidad is comparatively well off for both fodders and concentrated feeds and while it is not in any way implied that the rationing of cattle is unsound, it is felt that there is distinct room for improvement, if the best use is to be made of local feeding stuffs.

That the work outlined by the previous recommendations would be very expensive cannot be doubted. However, if by it a more exact knowledge of the nutritive values of the fodders alone and when combined in rations is obtained the initial expense would be well repaid. Not only by the above work would it be possible for the most economical rations to be determined but also the full extent to which local feeds could supply requirements could be ascertained. The application of uncertain feeding standards and nutritive values in the computation of rations is uneconomical.

With

With the determination of the value of certain basic rations composed of available feeding stuffs and balanced for particular purposes, the above, it is felt, could largely be avoided.

SUMMARY.

1. The digestibility of the following five fodders in varying stages of growth and condition was determined, when fed to cattle.

   1. Bamboo Grass - *Paspalum fasciculatum*.
   2. Para Grass - *Brachiaria mutica, (Stapf)*.
   3. Guinea Grass - *Panicum maximum*.
   4. Guatemala Grass - *Tripsacum laxum*.
   5. Sweet Potato Vines - *Ipomea batatas*.

2. The nutritive values of the above fodders were calculated by methods outlined and are thus expressed, in lb. of Dry Matter, Starch Equivalent, Protein Equivalent and digestible Crude Protein, per 100 lb. of the fresh material, as follows:-

	D.M.	S.E.	P.E.	Digestible Crude Protein.
1.Bamboo Grass	20.80	9.47	0.61	0.65
2.Para Grass	19.90	9.18	1.12	1.26
3.Guinea Grass	21.45	8.69	0.90	1.39
4.Guatemala Grass	18.95	10.22	0.80	1.10
5.Sweet Potato Vines	21.90	12.08	1.55	1.88

3. The results were not altogether satisfactory in that the effect of the rations fed, particularly in the case of the Guinea and Guatemala Grasses, was not as marked as the calculated nutritive values might indicate. This may have been, to some extent, due to the Dry Matter content of the fodders examined which, in every case, was decidedly too low.

4. The results indicate (a) that the Bamboo Grass ration did not supply a sufficient quantity of protein for the maintenance requirements of cattle, (b) the high nutritive quality of Para

Grass

Grass, (c) that the Sweet Potato Vines were undoubtedly the most satisfactory fodder examined, in respect of both palatability and nutritive value.

5. The varying stages of growth and condition in which the fodders were examined precludes a true comparison of their nutritive values and, with no confirmatory evidence available, no application of the values obtained to rations in Trinidad, has been made.

6. The methods of experimentation and calculation of results have been described. The effect of the limitations to these methods, on the values obtained has been outlined and recommendations have been made for future reference.

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SOME ANALYSES (DRY MATTER BASIS) OF THE MAIN TRINIDAD FODDER CROPS, INCLUDING NUTRITIVE VALUES WHERE DETERMINED.

FODDER CROP.		Date of Analysis	Reference	Yield per acre (tons)		Dry Matter %	Crude Protein %	Pure Protein %	Crude Fibre %	Carbo-hydrate %	Total Ash %	Silica-Free Ash %	Age when cut (weeks)	Rainfall during growth period (inches)	S.E. (% of green material) lb.	P.E. (% of green material) lb.	Digest: Crude Protein (% of green mat:) lb.	N.R.	REMARKS.
1. BAMBOO GRASS		Nov.1940	Present analysis	6.00	G	20.80	6.25	5.69	34.55	47.90	11.30	5.20	10	14.0	9.47	0.61	0.65	1:15	Yield estimated.
2. PARA GRASS	(a)	Jan.1927	Kincaid (1927)	7.58	C	24.68	9.25	-	30.70	51.55	8.50	-	13	14.0	-	-	-	-	Rainfall above average during dry season 1926-7.
	(b)	Feb. "		7.56	C	25.69	8.38	- -	25.82	51.05	14.78	-	7	9.0	-	-	-	-	" " " " " " "
	(c)	May. "		7.70	C	28.34	7.56	-	31.91	52.67	7.86	-	10	15.0	-	-	-	-	" " " " " " " Patterson(1
	(d)	May.1937	Patterson (1938)	5.00	C	32.11	5.36	-	33.17	52.42	9.03	-	8	3.5	-	-	-	-	Fig.quoted are means of high & low cuts.This applies to all anal.with Refere
	(e)	Aug. "		11.00	C	21.17	6.24	-	34.63	47.23	11.88	-	8	10.0	-	-	-	-	Wet season 1937 abnormal - low rainfall and humidity with high temperature.
	(f)	Dec.1940	Present analysis	-	G	19.90	9.63	7.93	34.06	43.95	11.36	6.36	8	6.5	9.18	1.12	1.26	1:7	Impossible to give yield figure. In flower.
	(g)					24.6	7.80?	7.22	31.7	56.5?	10.9								
3. GUINEA GRASS	(a)	Dec.1926	Kincaid (1927)	5.28	C	19.50	9.56	-	29.74	47.23	12.47	-	11	11.5	-	-	-	-	Rainfall above average during dry season 1926-7.
	(b)	Feb.1927		5.84	C	23.75	12.63	-	32.74	41.66	12.97	-	7	11.5	-	-	-	-	" " " " " " "
	(c)	Apr. "		7.77	C	25.27	5.13	-	35.88	47.14	11.85	-	11	14.5	-	-	-	-	" " " " " " "
	(d)	Jan.1940	Present analysis	-	G	21.45	9.69	5.19	34.74	42.46	13.11	3.66	9	9.0	8.69	0.90	1.39	1:6	Impossible to give yield figure. In flower.
4. GUATEMALA GRASS	(a)	Dec.1926	Kincaid (1927)	6.09	C	14.83	11.37	-	28.25	50.00	10.38	-	12	11.5	-	-	-	-	Rainfall above average during dry season 1926-7.
	(b)	Feb.1927		8.17	C	17.16	9.81	-	32.01	49.59	11.59	-	9	12.0	-	-	-	-	" " " " " " "
	(c)	Apr. "		8.53	C	15.10	7.88	-	33.77	45.85	12.50	-	9	14.0	-	-	-	-	" " " " " " "
	(d)	May.1937	Patterson (1938)	5.50	C	26.68	6.78	-	33.27	50.91	9.03	-	8	3.5	-	-	-	-	See remarks for analyses of Para Grass - Patterson (1938) above.
	(e)	Aug. "		12.00	C	17.65	6.69	-	35.19	44.60	13.50	-	8	10.0	-	-	-	-	" " " " " " " " " "
	(f)	Jan.1940	Present analysis	8.00	C	18.95	8.00	-	39.50	45.19	7.31	2.57	16	17.5	10.22	0.80	1.10	1:9	"
5. ELEPHANT GRASS	(a)	Dec.1926	Kincaid (1927)	8.55	C	17.35	10.77	-	29.74	48.77	10.72	-	12	11.5	-	-	-	-	Rainfall above average during dry season 1926-7.
	(b)	Feb.1927		11.41	C	15.85	15.77	-	30.17	40.32	12.74	-	7	11.5	-	-	-	-	" " " " " " "
	(c)	Apr. "		13.23	C	18.73	6.81	-	34.53	49.97	8.69	-	11	14.5	-	-	-	-	" " " " " " "
	(d)	May.1930	Maule (1930)	10.00	G	16.68	7.60	-	29.50	47.00	14.30	-	9	-	8.64	-	0.8	1:10	No data available for rainfall." " "
	(e)	May.1937	Patterson (1938)	9.00	C	19.75	6.80	-	34.03	46.78	12.37	-	8	3.5	-	-	-	-	See remarks for analyses of Para Grass - Patterson (1938) above.
	(f)	Aug. "		19.00	C	13.65	6.82	5.94	33.16	42.78	17.22	-	8	10.0	-	-	-	-	" " " " " " " " " "
6. UBA CANE	(a)	Feb.1927	Kincaid (1927)	9.18	C	19.59	9.13	-	31.11	52.42	7.34	-	20	23.5	-	-	-	-	Stated to be poor sample. Annual rainfall 1927 above average.
	(b)	May. "		6.13	C	15.92	9.25	-	33.71	50.56	6.48	-	10	15.0	-	-	-	-	
	(c)	Feb.1930	Maule (1930	30.00	G	32.40	9.04	-	30.52	53.68	4.30	-	-	-	18.5	-	1.6	1:11	No data available for rainfall.
7. CANE TOPS		Mar.1930	Maule (1930)	-	G	27.60	5.00	-	34.00	55.00	6.00	-	-	-	13.6	-	0.6	1:25	Variety BH 10/12. No data available of age when cut,rainfall or yield.
8. SAVANNAH GRASS		Feb.1931	Hobbs (1931)	-	C	39.07	9.00	-	26.61	55.70	8.33	-	-	-	26.21	-	1.77	1:14	No data available of age when cut,how obtained, rainfall or yield.
9. SWEET POTATO VINES		Feb.1940	Present analysis	8.00	G	21.90	12.63	9.81	27.82	48.70	10.85	3.20	16	14.0	12.08	1.55	1.83	1:6	

N.B. Yields estimated; or calculated from plot harvests and quoted in tons fresh material per cut analysed.

G = Grown on Government Stock Farm, St. Joseph.

C = Grown on I.C.T.A. Farm.