# DIGESTIBLE NUTRIENT CONTENT OF SOME HAWAIIAN FEEDS AND FORAGES

By

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# CONTENTS

# INTRODUCTION

The livestock industry in Hawaii is particularly fortunate in that green forage is available throughout the year. Most of the beef cattle ranches extend from sea level up into the mountains and cover a wide climatic range. Thus the ranchers have available in the several vegetation zones (*26*)[1] "summer" and "winter" grazing areas. At the higher elevations forage species common to the temperate regions are found in abundance; for such species the nutritive values reported by Morrison (*24*) are believed to be applicable. However, at low altitudes in warmer climatic phases, are found many tropical or subtropical forage plants on which few or no data are available as to nutritive and productive values.

Determination of the productive values of feeds is an extensive study in itself, and the University of Hawaii Agricultural Experiment Station has already reported on the use of many Hawaiian forages in meat and milk production (*10, 11, 12*). The fundamental factor in productivity of a feed is its total-digestible-nutrient content, which in turn is dependent on composition and on the digestibility of the various elements provided by the feed.

Knowledge of the nutrient content, as determined by digestibility studies, enables the feeder to balance intelligently the rations of all classes of stock. The rancher or dairyman who is improving his pasture areas or planting forages for green feed wants to know what species will produce the most nutrients on an acre—or in other words, the most meat or milk per acre.

The purpose of the work reported here has been to determine the composition and coefficients of digestibility of certain feeding stuffs which are commonly used in Hawaii but on which such data are meager or not available. Although the materials studied were selected because of their economic importance to the livestock industry of the Territory, many of the forages are common in other tropical and subtropical areas.

During, or following the completion of, these investigations, workers in other tropical areas (*2, 3, 4, 8, 9*) have reported studies of the digestibility of tropical forages. The results obtained by these workers, combined with the data to be presented in this bulletin, should provide valuable information concerning the nutritive values of these various forages and should have widespread application. In cases where there has been duplication in the study of particular species, the reliability of the combined data is enhanced.

[1] Reference is made by number (italic) to Literature Cited, page 21.

The studies at the University of Hawaii Agricultural Experiment Station were begun as a regular project in 1936 with funds allotted from the sugar processing tax (Hawaii Tax Fund No. 8 under the Agricultural Adjustment Act).

## EXPERIMENTAL METHODS

The method of experimentation followed in these digestibility trials with steers was in accordance with the general principles laid down by Forbes and Grindley (*7*). Proximate analyses of feeds and excreta were made according to the methods described by the Association of Official Agricultural Chemists (*1*).

The steers were fed in a specially constructed barn containing eight stalls, each 3 feet 4 inches wide with a maximum length of 5 feet 8 inches. The animals stood on a raised, movable, slatted wooden platform through which the urine could easily pass and drain to a common gutter for disposal.

The feeding mangers were movable and could be adjusted to the length of the individual steers. They were lined with sheet metal and had steel stanchions to hold the animals in the stalls. A drop door was attached to the front of each stall to retain the feed, and during the time the animals were eating, a small flap was also dropped down at the rear of the manger to prevent any forage from being pushed out under the front feet of the animals. Figure 1 shows a view of the stall. The manger itself is shown in Figure 2.

In the early trials eight grade Holstein steers were used. These had been obtained from an Oahu ranch and were free from liver fluke and tuberculosis. Later four of these steers were sold because they would not consume feed in sufficient quantities and frequently went off feed as the digestion trial lengthened. Four Herefords obtained from a Maui ranch and four of the original Holsteins were used throughout all but one of the subsequent trials. In evaluating strip cane, four Holstein steers raised on the University Farm were used.

The ranch steers were not accustomed to handling, and after the collection period started they could not be properly exercised. To alleviate this disadvantage as much as possible, the animals were thoroughly groomed each day with curry comb and brush.

In most of the trials the steers were fed twice daily at 12-hour intervals; however, in special cases it was deemed advisable to offer the feed in three portions. The animals were offered water before feeding; if they refused it, water was again offered when the feeding period ended. Salt, in measured quantities, was offered at regular intervals. The steers were weighed at the beginning and end of each collection period.

Careful observation had shown that even the most palatable feedstuffs, if fed continuously to the limit of appetite, were refused to some extent in the collection periods. In order to minimize weighbacks, the animals were fed somewhat less (usually around 5 pounds) than maximum consumption. Once this intake had been established, no changes were made throughout that entire

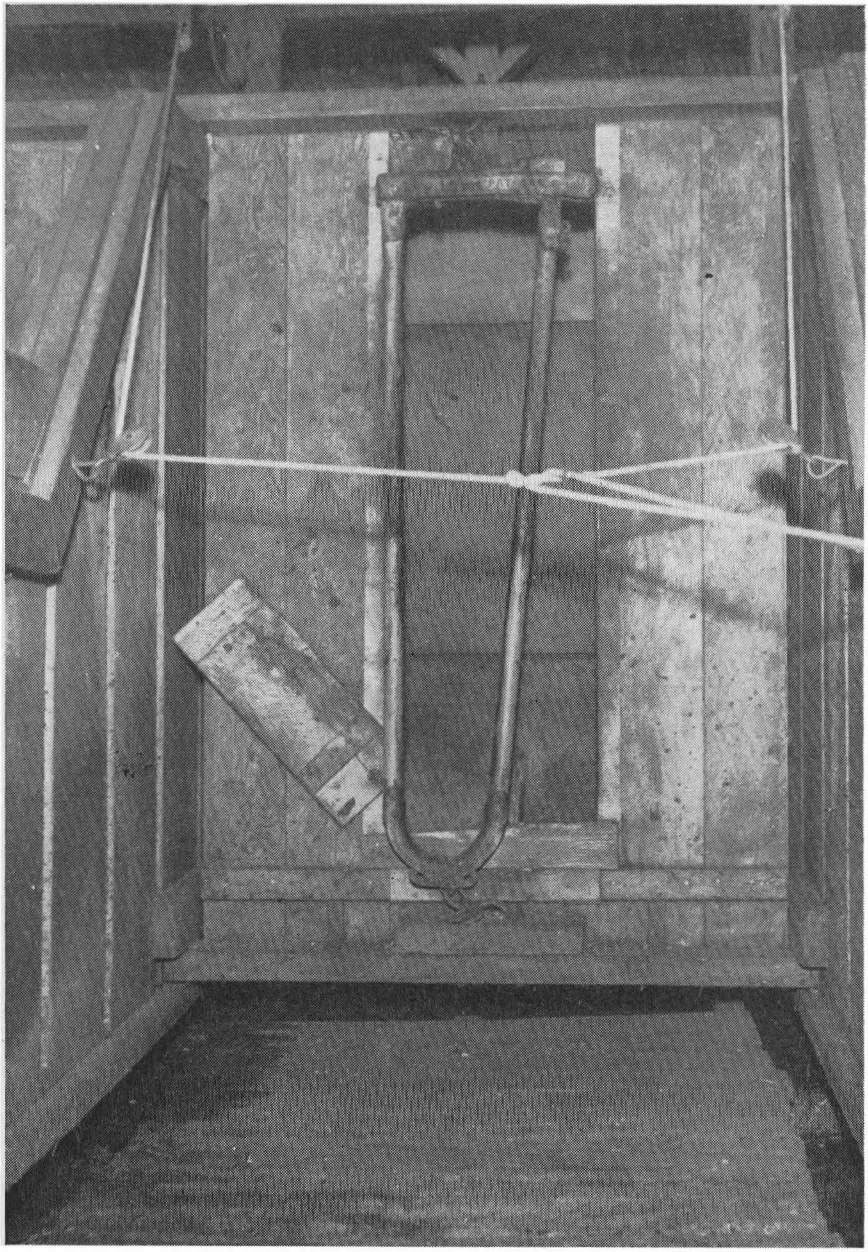

Figure 1.—View of front end of digestion stall.

trial. For each feed studied, the first collection period was always preceded by a constant-intake preliminary period of from 5 to 10 days. When feed adjustments were necessary because of nature of the ration or other causes, a new trial, with its corresponding preliminary and collection periods, was set up.

The original plan for all these trials proposed a continuous 20-day collection period divided into two equal sub-periods. However, because the quantity of a feed was frequently so limited, it was necessary to conclude the trial after the first 10 days of collection, and in one instance at the end of 5 days.

Forages were cut fresh daily and usually were run through an ensilage cutter in accordance with the common local practice for feeding soiling crops.

Throughout all preliminary and collection periods, a 1-kilo sample of the fresh green feed taken at each feeding was immediately dried in a Freas oven. After grinding in a Wiley mill, a composite sample for each period was obtained for analysis. Concentrates were similarly handled, except that where necessary 5 cc. of formalin were added to the sample as a preservative. Edible feed refusals were found in only a few trials and in these cases the dried orts for each steer over one period were combined for a single analysis.

Each animal was equipped with a harness arrangement to prevent loss of feces and thus one man was enabled to attend to all animals.[2] The fecal material for each steer was collected and placed in a tightly covered metal can con-

[2] Acknowledgment is made of the advice of Dr. E. B. Forbes in perfecting this fecal collection harness.

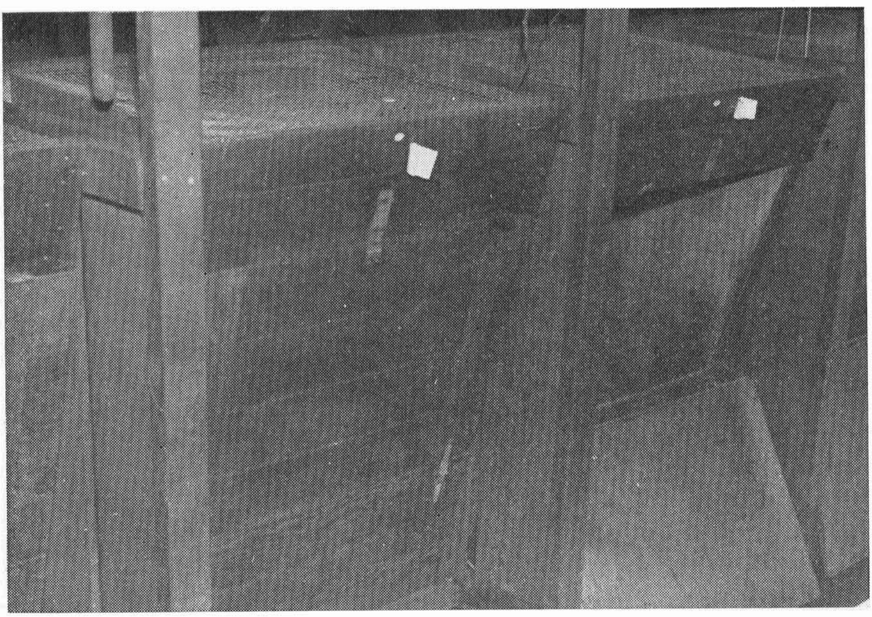

Figure 2.—Front view of manger showing door arrangement and screen above to prevent feed from being thrown out.

taining 25 cc. of formalin. The excreta from each steer were weighed at the end of each 24-hour period, carefully mixed, and a 5-percent aliquot taken. The aliquot was preserved with 2 cc. of formalin and held at 35° F. At the end of each collection period, the daily aliquots from each steer were thoroughly mixed and 2-quart samples of the composite obtained. One of these was taken at once to the chemical laboratory, the other constituted a reserve in case of accident.

Nitrogen determinations were run on the fresh material as received in the laboratory and also on the dried material, but in calculating digestibility, the protein ($N \times 6.25$) in the moist sample was used except in a very few instances where discrepancies seemed clearly evident. At first nitrogen and moisture were determined daily on the fresh material. However, as data were accumulated, it was found that no significant changes occurred in comparison to the analysis of the identical fresh sample held for 10 days or more. Because of this, all the data reported in this bulletin are on the latter basis. These results for fecal nitrogen are in line with those reported by Mead and Guilbert (*22*) at the California station.

In this work, no attempt has been made to differentiate between nutritive values of forages grown under varied climatic conditions or agricultural areas. All the roughages, except products of the sugarcane plant, were grown at the University Farm or cut from wild stands in the University neighborhood (elevation, about 100 feet; mean annual precipitation 34.6 inches ranging from a mean monthly low of 1.66 inches in July to a mean high of 4.90 in December).

No attempt was made to compare the palatabilities of the different feeds. As only one forage was offered in each test, no choice was permitted the animals. For information on palatability, the reader is referred to the work of Lyman and Ripperton (*19, 20*).

## FORAGES AND FEEDS STUDIED

The materials studied in the digestibility trials may be divided into the following three general groups: (1) carbonaceous forages, (2) leguminous forages, and (3) concentrates.

### CARBONACEOUS FORAGES

The carbonaceous forages include Napier grass (*Pennisetum purpureum*), Rhodes grass (*Chloris gayana*), panicum or Para grass (*Panicum pupurascens*), honohono (*Commelina diffusa*), Guinea grass (*Panicum maximum*), molasses grass (*Melinis minutiflora*), and the tops, strip cane, and sifted bagasse from the sugarcane plant (*Saccharum officinarum*). The growth habits of the grasses included in this study have been described by Whitney *et al.*, (*29*) and the age or stage of maturity at the time of the digestion trials are indicated in table 1, so no other discussion seems necessary for this class of roughages, unless it be for those obtained from the sugarcane plant.

*Sugarcane tops.*—These tops were from cane of the variety P.O.J. 2878 to which nitrogen had been applied at the rate of 219 pounds per acre during the growing period. At the time it was obtained from Waimanalo Plantation, the cane was approximately 12 months of age and the last fertilization of the field was 8 months before the cutting date. Though this variety is said by plantation men to be the poorest of all canes for feeding, the steers consumed it with relish.

*Strip cane.*—This material is a byproduct of the harvesting of sugarcane by the "grab" or other system. The stalks, with leaves still attached, are brought to the mill. The leaves and leaf sheaths "stripped" from the stalks by a series of rapidly revolving rollers are commonly known as "strip cane." This includes, in addition to the green cane tops and leaf sheaths, any dry cane trash that may not have been destroyed in burning of the fields previous to harvesting. The green cane tops may be partially dried, depending on the interval between burning the field and bringing the cane to the mill. Strip cane may include large quantities of earth if the harvesting is done during rainy weather and if washing facilities are inadequate. Because of this, digestive disorders may occur,[3] so for feeding purposes, every effort should be made to obtain a clean product.

Especially clean strip cane obtained from the Waialua Agricultural Company was used in determining these digestion coefficients. Compared to the same product of other mills the material used in this trial was relatively dry.

*Bagasse.*—Bagasse is the sifted, dried sugarcane refuse remaining after the juice has been expressed from the cane stalks. An endeavor was made to feed this material alone, but the bagasse (even when moistened with water or with molasses) was so unpalatable that one steer refused to eat and weighbacks from the others were large. However, the steers consumed most of the ration during a 10-day collection trial when a certain small quantity of fresh, green alfalfa and water sufficient to moisten the whole was mixed with the bagasse. The feed refusals were properly accounted for in the calculations. Thus, these results, obtained by difference and based on a concurrent trial on the alfalfa, are presented. Insofar as an associative effect of these two feeds might have existed, and also because the ration was at a sub-maintenance level, the results obtained may be only approximate. Actually, the amount of alfalfa on the dry matter basis was so small (3 percent) that any associative effect due to its presence could not be great. In Hawaii, bagasse is never fed alone but is always mixed with molasses and protein supplement. Therefore, it seems best to present our results as obtained in spite of any possible divergence originating through the method of offering the bagasse.

Bagasse may be considered a rather low grade roughage of value chiefly for the maintenance of work stock and ruminants and which can be used as a "filler" or where a cheap source of energy is needed. For productive purposes such as work, milk, or meat, it must be adequately supplemented with protein

[3] Unpublished data in files of the Animal Husbandry Department, University of Hawaii Agricultural Experiment Station.

and further sources of energy or total nutrients and made palatable with molasses.

That it can be used in practice is indicated by the fact that Naquin (*25*) has reported the feeding of a ration of bagasse and molasses, two parts each, with one part soybean-oil meal, to 20 working mules at the rate of 3 pounds per 100 pounds liveweight of the animal. During a 140-day period, the net gain in weight of the 20 mules was 660 pounds and only 3 of the animals lost weight. Lamb (*17, 18*) has reported favorably on the work output and growth curves of rabbits fed as much as 55 percent cane bagasse, which is a much higher percentage than is usually fed plantation animals. In these rabbit rations, some green cane tops were fed to maintain normal health.

## LEGUMINOUS FORAGES

The leguminous forages include Desmanthus (*Desmanthus virgatus*), koa haole (*Leucaena glauca*), pigeonpea (*Cajanus cajan*), and alfalfa (*Medicago sativa*).

Throughout the world successful animal husbandry is best built on a foundation of legumes. Yet paradoxically, the tropics, natural habitat of such plants, seem to have as one of their major problems the shortage of protein-rich forages. Harrison (*9*) has stated that a satisfactory leguminous fodder for the wet tropics has yet to be found. Hawaii, therefore, is fortunate in having a variety of such plants at most elevations under various climatic conditions and which grow with but little effort on the part of the rancher. At the higher elevations the common pasture legumes of temperate climates are abundant, while in the more tropical areas are found legumes not familiar to stockmen of the strictly temperate zones. In the wet zones, Kaimi Spanish clover (*Desmodium canum*) offers great promise (*13, 14*). Other economically important species of this genus have been found in both the dry and wet tropics.

Chief among the tropical legumes of value to Hawaii's stockmen situated in the areas of somewhat less rainfall, are koa haole (*Leucaena glauca*), *Desmanthus virgatus,* and the pigeonpea (*Cajanus cajan*). These plants are all shrublike with somewhat woody stems, particularly as the plant becomes old. These roughages have an extremely important place in the rations of livestock in Hawaii where the ordinary protein supplements are not readily available or are quite costly. The nutritive value of each of these has been reported from this station (*10, 11, 12, 15, 16, 28*) and the growth habits and culture of these and other legumes are discussed by Hosaka and Ripperton (*14*).

## CONCENTRATE FEEDS

Only three concentrate feeds have been studied in the course of these investigations. They are dried pineapple bran or pulp (without added molasses), algaroba meal (from the bean pod of the tree *Prosopis chilensis,* also known as the kiawe tree), and local flame-dried tuna-fish meal.

TABLE 1. Composition and digestibility

| FEEDING STUFF | TOTAL DRY MATTER | DIGESTIBLE PROTEIN | TOTAL DIGESTIBLE NUTRIENTS | NUTRITIVE RATIO | NUMBER OF ANALYSES |
|---|---|---|---|---|---|
| | *Percent* | *Percent* | *Percent* | | |
| *Green Roughages* (Grasses, etc.) | | | | | |
| Guinea grass (mature) | 26.2 | 0.5 | 10.0 | 19.0 | 1 |
| Honohono | 12.1 | 0.8 | 7.7 | 8.2 | 2 |
| Molasses grass (old) | 44.8 | 0.6 | 26.4 | 43.0 | 2 |
| Napier grass (young) | 23.8 | 0.6 | 12.2 | 19.3 | 1 |
| Napier grass (old) | 35.6 | 1.0 | 23.8 | 22.8 | 1 |
| Panicum grass (mature) | 25.0 | 1.2 | 14.4 | 10.9 | 2 |
| Rhodes grass (mature) | 28.8 | 1.3 | 16.6 | 11.3 | 1 |
| Rhodes grass (dead ripe seed) | 39.7 | 1.3 | 21.7 | 16.0 | 1 |
| Sugarcane tops (ripe cane) | 22.7 | 0.7 | 12.1 | 16.3 | 2 |
| *Green Legume Roughages* | | | | | |
| Alfalfa (half bloom) | 19.9 | 3.0 | 11.8 | 2.9 | 1 |
| *Desmanthus virgatus* | | | | | |
| Cultivated | 44.2 | 3.1 | 23.5 | 6.5 | 2 |
| Wild | 38.3 | 1.9 | 18.8 | 8.7 | 1 |
| *Leucaena glauca* | 30.5 | 5.5 | 18.4 | 2.4 | 2 |
| Pigeonpeas | | | | | |
| Old | 49.7 | 6.5 | 33.5 | 4.1 | 1 |
| Recent planting | 48.2 | 4.6 | 25.7 | 4.5 | 1 |
| *Dry or Semi-Dry Roughages* | | | | | |
| Alfalfa hay | 88.2 | 9.4 | 52.0 | 4.5 | 1 |
| | 88.2 | 9.9 | 48.5 | 3.9 | .... |
| "Strip cane" | 48.0 | ...... | 24.2 | ...... | 1 |
| Sugarcane bagasse | 90.3 | ...... | 41.0 | ...... | 1 |
| *Concentrates* | | | | | |
| Kiawe bean meal | 89.2 | 4.0 | 44.5 | 10.1 | 2 |
| | ...... | 3.7 | 36.0 | 8.7 | .... |
| Pineapple bran (non-molassized) | 85.3 | 1.0 | 60.1 | 59.0 | 1 |
| | 85.3 | 0.6 | 63.4 | 105.0 | .... |
| Tuna fish meal | 90.1 | 42.5 | 59.3 | 0.4 | 2 |

Previous to these trials the flame-dried fish product was sold to plantations as a nitrogenous fertilizer. After its value as a livestock food was pointed out, it has been used almost exclusively for livestock feeding. While the output of the cannery has never been entirely adequate to supply these needs, it has formed a valuable local source of a rather high quality protein and has compared favorably with imported tankage in swine feeding trials.[4] Its use for this purpose has saved money for stockmen and has also increased the income of the cannery.

In the trial reported in this paper, the ration was composed of fish meal, cane molasses, and panicum grass. The purpose of the molasses was to make the fish meal palatable because the steers would not eat it without this addition. The digestibility of the meal itself was then determined by difference, assuming valid our previous digestion coefficients for the panicum grass as estab-

[4] Unpublished data.

of feeds studied in Hawaii.

| AVERAGE TOTAL COMPOSITION | | | | | NUMBER OF TRIALS | DIGESTION COEFFICIENTS | | | |
|---|---|---|---|---|---|---|---|---|---|
| Protein | Fat | Fiber | N-free extract | Mineral matter | | Protein | Fat | Fiber | N-free extract |
| *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | | *Percent* | *Percent* | *Percent* | *Percent* |
| 1.5 | 0.4 | 8.8 | 11.9 | 3.6 | 8 | 34 | 6 | 41 | 49 |
| 1.3 | 0.3 | 3.3 | 5.6 | 1.7 | 4 | 65 | 53 | 64 | 79 |
| 1.6 | 0.9 | 19.0 | 20.1 | 3.1 | 8 | 36 | 51 | 66 | 61 |
| 1.2 | 0.5 | 9.4 | 9.6 | 3.1 | 8 | 46 | 54 | 64 | 53 |
| 1.6 | 0.6 | 14.4 | 14.1 | 4.9 | 8 | 60 | 74 | 79 | 74 |
| 2.0 | 0.5 | 8.5 | 10.8 | 3.2 | 16 | 60 | 51 | 67 | 64 |
| 2.3 | 0.6 | 10.7 | 11.4 | 3.8 | 8 | 58 | 42 | 73 | 60 |
| 2.4 | 1.0 | 14.9 | 17.7 | 3.6 | 4 | 56 | 58 | 67 | 58 |
| 1.4 | 0.5 | 8.5 | 10.5 | 1.9 | 16 | 54 | 53 | 60 | 54 |
| 4.1 | 0.8 | 5.4 | 7.8 | 1.8 | 3 | 74 | 36 | 46 | 73 |
| 5.2 | 0.9 | 19.6 | 15.9 | 2.5 | 8 | 60 | 56 | 42 | 69 |
| 4.4 | 0.9 | 15.1 | 15.7 | 2.2 | 4 | 44 | 47 | 44 | 59 |
| 7.4 | 0.9 | 7.3 | 12.2 | 2.8 | 16 | 74 | 33 | 36 | 79 |
| 9.4 | 2.6 | 14.7 | 20.1 | 2.8 | 7 | 69 | 69 | 50 | 78 |
| 7.6 | 2.2 | 15.7 | 18.0 | 4.7 | 2 | 61 | 47 | 32 | 76 |
| 13.4 | 1.9 | 33.9 | 31.3 | 7.7 | Ind. 2 | 70 | 15 | 51 | 79 |
| ...... | ...... | ...... | ...... | ...... | Dir. 2 | 74 | 32 | 47 | 68 |
| 1.3 | 0.5 | 20.3 | 23.6 | 2.3 | 4 | neg. | 32 | 51 | 57 |
| 1.7 | 0.9 | 40.6 | 39.9 | 7.2 | 5 | neg. | 54 | 58 | 41 |
| 8.5 | 1.4 | 20.7 | 51.7 | 7.0 | Dir. 4 | 47 | 69 | 8 | 71 |
| ...... | ...... | ...... | ...... | ...... | Ind. 6 | 44 | 48 | 1 | 59 |
| 4.0 | 1.9 | 19.4 | 57.2 | 2.8 | Dir. 2 | 26 | 69 | 71 | 74 |
| ...... | ...... | ...... | ...... | ...... | Ind. 2 | 15 | 53 | 79 | 79 |
| 58.2 | 7.9 | 0.7 | 3.4 | 19.9 | Ind. 8 | 73 | 94 | neg. | neg. |

lished by the same steers. The fact is appreciated that feeding molasses as well as the associative effects of feeds and a probably super-maintenance protein intake might have affected the digestibility of the protein (*6, 23, 24, 27, 30*). The results obtained in our work are moreover in line with figures reported by Morrison (*24*) for a similar product.

*Pineapple bran.*—Pineapple "bran," as it is locally called, is a dried pineapple pulp residue byproduct of canneries. It consists of the core, trimmings, and outer skin of pineapple fruits. This material is a major constituent of dairy rations in Hawaii and its use as a hog feed is increasing. A silage made from the undried pulp has been found to give excellent results in commercial fattening of beef cattle on the island of Maui. The digestibility of some of this material to which cane molasses was added in the drying process, has already been determined by Mead and Guilbert (*22*). In our work we were interested in testing the product without added molasses, as manufactured on

Maui and Oahu, and in comparing results with those obtained by the above workers.

In our experiment, the ration of the California workers was used with two steers, two others being fed pineapple bran alone, and a third pair, alfalfa hay alone. The alfalfa hay was a type commonly imported into the Territory and was probably produced and baled in California. It was slightly green and fairly leafy. On the whole, our results with pineapple bran in this test are comparable with those obtained by Mead and Guilbert on a similar product that contained added molasses.

On the basis of the digestible nutrients provided, the results with pineapple bran with no added molasses most closely approximate the values of Mead and Guilbert when the coefficients indirectly determined are used. The protein values are similar on the basis of the direct determination. The direct values are probably more reliable (*23*) except that this product is never fed alone in rations in Hawaii.

*Kiln-dried kiawe (algaroba, mesquite) bean meal.*—This product was obtained from the Ranch Department of the Hawaiian Sugar and Commercial Company of Maui. The ripe pods of the *Prosopis chilensis* tree fall to the ground, are collected, and are flame dried in a specially constructed kiln. The pods are quite hard when they come from the drier and so seem to be protected from the weevil that ordinarily attacks the sun-dried beans in storage. For feeding, they are passed through a hammer mill which produces a meal somewhat comparable to coarse corn meal. The seeds are released from the pods by this treatment and so are more readily available to non-ruminants. This is not always true of the sun-dried, unground beans as many of the seeds in their enclosures have been observed to pass undigested through the digestive tract of pigs and horses and even of cattle.

In this investigation, the bean meal was first fed to the animals along with Rhodes grass. Thus the values for the coefficients were determined indirectly by difference. As some of the values so calculated seemed rather low, four of the animals were fed kiawe meal alone in a later trial.

The values obtained directly are somewhat higher than the ones obtained indirectly and yet, except for the nitrogen-free extract, are not widely divergent. As the indirect values were calculated by assuming the previously determined digestion coefficients for the Rhodes grass to be unaffected, they are correct to the extent that this association of feeds did not affect the digestibility of either. All these values are much below those reported by Catlin (*5*) on an air-dry similar bean, *Prosopis velutina,* found in the southwestern United States. Since our values are in fair agreement by both methods, they are believed correct for the product on which they were determined. It might be that the artificial drying adversely affected the digestibility, and thus the desirability of determining the digestion coefficients on the sun-dried beans is suggested.

Except for livestock grazing where pasturage is not available, kiawe beans are not usually fed alone. The fact that such low values for the crude fiber were obtained in these trials may possibly be associated with the nature of the protective covering of each seed in the bean pod. Since the component "crude fiber" was not broken down into its constituent parts, the chemical data do not show the proportions of lignins, etc., that might influence the digestibility of this nutrient. It has been observed in practice that with whole beans these

TABLE 2. CaO and $P_2O_5$ in certain feeds.

| FEEDSTUFF | MOISTURE | AIR DRY BASIS | | NUMBER OF ANALYSES |
|---|---|---|---|---|
| | | CaO | $P_2O_5$ | |
| | *Percent* | *Percent* | *Percent* | |
| Pineapple bran | 15.20 | 0.30 | 0.19 | 2 |
| Tuna fish meal | 12.15 | 6.55 | 6.91 | 2 |
| Honohono | 11.93 | 1.33 | 0.90 | 2 |
| *Desmanthus virgatus* | 10.74 | 1.20 | 0.45 | 1 |
| Pigeonpea tops | 11.05 | 1.28 | 0.53 | 1 |
| Alfalfa hay (mainland) | 12.46 | 1.57 | 0.50 | 1 |
| Guinea grass | 11.33 | 0.73 | 0.34 | 2 |

coverings quite often come through undigested. In fact, this has led to the tree becoming widely disseminated throughout the Territory.

The apparent digestibilities determined in all these studies are summarized in table 1, which lists the average composition, digestible nutrients, and average digestion coefficients as found for the various feedstuffs. Notation is also made of the approximate age and culture of the forages studied.

Table 2 presents the calcium and the phosphorus found in some of the feeds under investigation. With the exception of beach areas which may contain old coral underlays, Hawaii's volcanic soils are low in lime. Phosphoric acid, though comparatively abundant, evidences considerable variation in the soils throughout the Territory. The low values for the feeds reported in this table point to the need for adding calcium and phosphorus supplements to rations consisting largely of locally produced feeds.

## DIGESTIBILITY OF COMPLETE RATIONS

The digestible nutrients for single feeding stuffs as reported in this bulletin may not necessarily apply when the ration of an animal is composed of several different feeds. This is true because of the many elements involved when adequate rations are fed. The plane of nutrition, the degree to which there is an associative digestibility of the feeds in the ration, and other factors may influence the digestibility of the nutrients in the ration as a whole.

It was possible on a few occasions during the course of these studies to determine the digestibilities of such complete rations fed to dairy cows for productive purposes. These data, discussed in the following paragraphs, are the result of digestibility trials run concurrently with experiments testing the value of the respective rations for milk production. Whenever such trials were conducted, the ration in question was fed to steers in the same proportion of concentrate to roughage as was established by the dairy cows, which consumed the roughage to the limit of appetite. The milk production value and the chemical composition of these rations are reported by Henke (*10*).

One of these tests compared the value of algaroba bean meal as the major constituent of the concentrate mixture as opposed to a mixture of which the major constituent was pineapple bran. Both were fed with Napier grass as the roughage.

The algaroba bean mixture was composed of 400 pounds algaroba bean meal, 300 pounds soybean oil meal, 200 pounds cane molasses, 100 pounds pineapple bran, 12 pounds salt, and 12 pounds bonemeal.

TABLE 3. The apparent digestion coefficients of complete rations.

| RATION AND STEER NUMBER | DRY MATTER | CRUDE PROTEIN | ETHER EXTRACT | CRUDE FIBER | NITROGEN-FREE EXTRACT | DIGESTIBILITY OF TOTAL NUTRIENT INTAKE |
|---|---|---|---|---|---|---|
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Napier and pineapple bran mixture | | | | | | |
| 1 | 69 | 70 | 69 | 59 | 75 | |
| 2 | 67 | 69 | 66 | 57 | 74 | |
| 3 | 71 | 74 | 71 | 62 | 77 | |
| 4 | 76 | 76 | 76 | 68 | 81 | |
| *Averages* | *71* | *72* | *70* | *61* | *77* | *72* |
| Napier and kiawe bean mixture | | | | | | |
| 5 | 68 | 73 | 72 | 54 | 74 | |
| 6 | 68 | 77 | 75 | 51 | 75 | |
| 7 | 68 | 76 | 78 | 54 | 75 | |
| 8 | 65 | 73 | 75 | 49 | 71 | |
| *Averages* | *67* | *75* | *75* | *52* | *74* | *69* |
| Sudan grass and concentrate mixture | | | | | | |
| 1 | 60 | 63 | 51 | 63 | 67 | |
| 2 | 61 | 65 | 55 | 63 | 69 | |
| *Averages* | *60* | *64* | *53* | *63* | *68* | *65* |
| Panicum grass and concentrate mixture | | | | | | |
| 7 | 60 | 66 | 37 | 58 | 64 | |
| 8 | 61 | 67 | 45 | 54 | 68 | |
| *Averages* | *60* | *66* | *41* | *56* | *66* | *62* |
| Strip cane ration | | | | | | |
| 13 | 66 | 57 | 55 | 42 | 77 | |
| 16 | 66 | 58 | 56 | 42 | 77 | |
| *Averages* | *66* | *57* | *55* | *42* | *77* | *65* |
| Napier ration | | | | | | |
| 14 | 63 | 62 | 56 | 48 | 74 | |
| 15 | 62 | 60 | 54 | 38 | 78 | |
| *Averages* | *62* | *61* | *55* | *43* | *76* | *65* |

The pineapple bran mixture contained 500 pounds pineapple bran, 400 pounds soybean oil meal, 200 pounds cane molasses, 13 pounds salt, and 13 pounds bonemeal.

Each ration was fed to four steers during a 10-day collection period. Table 3 lists the digestion coefficients as obtained. The most striking difference in this trial was in the digestion of the crude fiber, which seemed to be materially depressed in the kiawe bean ration. This result tends to corroborate the quite low values observed for the fiber in the digestion trial with kiawe beans as the sole feed, and may be an explanation for the lower milk production obtained in the feeding trials.

Another trial with dairy cows tested the value for milk production of panicum grass and Sudan grass when fed in combination with the same concentrate mixture. This mixture was composed of soybean oil meal, 19.9 percent; wheat bran, 47.8 percent; rolled barley, 29.9 percent; salt, 1.2 percent; and steamed bonemeal, 1.2 percent.

Table 3 also presents the results obtained in a digestibility trial with two steers on each of these rations during a 10-day collection trial. In this trial the most noticeable differences occurred in the ether extract and the fiber of the panicum grass ration, both of which were depressed as compared with the values given by the steers fed the Sudan grass. These differences, by lowering the total digestible nutrient intake, may account for the lower production value when a ration containing panicum grass was fed to the milking cows (*11*).

In a 20-day digestion trial carried on concurrently with the strip cane digestion trial and with a dairy feeding trial, comparison was made of the digestibility of the ration built around strip cane with that built around Napier grass. The concentrate mixture was composed of 25 pounds cane molasses, 38 pounds pineapple bran, 10 pounds coconut oil meal, 25 pounds soybean oil meal, 1 pound Hawaiian salt, and 1 pound steamed bonemeal.

It was found that 57 percent and 61 percent of the protein were digested in the respective rations and that each ration had 65 percent total nutrient digested (by calculation), as shown in table 3.

Results presented in this table strongly suggest that in spite of the non-utilization of the protein in strip cane when fed alone, in combination with the other feeds in the ration, as here fed, the nitrogenous material, and also the total nutrient, of the complete ration is nearly as available for productive purposes as that from a Napier grass-concentrate ration. In this respect, the production trial and the digestion trial are in agreement (*11*).

Thus strip cane offers great possibilities as a forage. It is cheap and, because of its abundance at certain times, the opportunity of ensiling it is presented. When supplemented by the right kind of concentrates, strip cane of good quality is a satisfactory feed. It is, however, low in carotene (precursor of vitamin A). Our analyses show some of this material from the Honolulu Plantation Company to contain only 0.56 parts per million of carotene.[5] Thus

[5] Unpublished data. Analysis made by Dr. L. E. Harris while at this Station.

the occasional feeding of some fresh green material to insure against a vitamin A deficiency is advisable where the ration is largely dependent upon strip cane.

## CALCULATED AND OBSERVED DIGESTIBILITY

With establishment of the actual digestibility of each of these complete rations, the necessary tools were available for comparing the theoretical with the observed digestibilities. In table 4, only the protein and the total nutrients are considered.

Each nutrient of each feed in the ration was multiplied by its appropriate digestion coefficient. For the roughages (except Sudan grass, in which case Morrison's (*24*) data were used), and for both pineapple bran and kiawe bean meal, the coefficients as established in this report were used. Whenever a concentrate mixture was fed, the digestibility of the protein and the total nutrients were computed as a weighted average through the use of the values given by Morrison and, as has been previously mentioned for the pineapple bran and the kiawe bean meal, the values as found herein. By this method the theoretical digestible intake of each nutrient was obtained. The sum of the four digested nutrients—protein, fat, fiber, and nitrogen-free extract—was then taken to represent the total nutrients that were digested from the ration as a whole.

TABLE 4. Relation between calculated and observed digestibilities of complete rations.

| EXPERIMENT | STEER | CRUDE PROTEIN | | | TOTAL NUTRIENTS | | |
|---|---|---|---|---|---|---|---|
| | | Calculated coefficients | Observed coefficients | Observed/calculated | Calculated coefficients | Observed coefficients | Observed/calculated |
| | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| *Strip cane vs. Napier* | | | | | | | |
| Strip cane ration | 13 | 58 | 58 | 100 | 70 | 66 | 94 |
| | 16 | 58 | 57 | 98 | 73 | 66 | 90 |
| Napier ration | 14 | 67 | 62 | 95 | 76 | 64 | 84 |
| | 15 | 67 | 60 | 89 | 76 | 66 | 87 |
| *Panicum vs. Sudan* | | | | | | | |
| Panicum ration | 7 | 81 | 66 | 81 | 62 | 62 | 100 |
| | 8 | 83 | 66 | 79 | 63 | 63 | 100 |
| Sudan ration | 1 | 73 | 63 | 86 | 66 | 65 | 98 |
| | 2 | 73 | 63 | 86 | 66 | 66 | 100 |
| *Pineapple bran vs. kiawe bean meal* | | | | | | | |
| Pineapple bran mix | 1 | 76 | 70 | 92 | 81 | 70 | 86 |
| | 2 | 76 | 69 | 90 | 81 | 69 | 85 |
| | 3 | 77 | 74 | 96 | 81 | 73 | 90 |
| | 4 | 77 | 76 | 98 | 81 | 77 | 95 |
| Kiawe bean mix | 5 | 63 | 73 | 116 | 78 | 69 | 88 |
| | 6 | 64 | 77 | 120 | 78 | 70 | 89 |
| | 7 | 59 | 76 | 129 | 78 | 70 | 89 |
| | 8 | 63 | 73 | 116 | 78 | 66 | 84 |

The necessary data on the gross intakes of each nutrient were already available in establishing the digestion coefficients of the rations.

In table 4 the gross protein intake as obtained from the feed consumed and analyses thereof, was divided into the calculated theoretical digested protein in order to obtain a calculated coefficient of digestibility. The gross total nutrient intake was found by adding the gross intake of each of the four nutrients involved. Similarly, by dividing this into the theoretical total digestible nutrient intake, a figure for the calculated coefficient of digestibility of all the nutrients in the ration was obtained. These data are also shown in table 4.

With somewhat different rations in each case, variations in the observed values as found with each steer might be expected. Actually these figures are rather close and thus strengthen the belief that any difference is due to the productive value of the ration and not to individual response. The digestibility of the protein (observed as percentage of calculated) seemed to be definitely depressed in two cases: (1) the panicum grass ration and (2) the Sudan grass ration. Digestibility was slightly depressed with the pineapple bran mix and the Napier grass ration. A marked elevation appears with the kiawe bean mix while the relationship in the strip cane ration is undisturbed. These differences are believed to be attributable to the fact that more of the total protein of the rations was furnished by the concentrate mixtures in the instances where there was little or no depression of protein digestion. The differences are thus in line with the findings of Maynard, Miller, and Krauss (*21*).

These findings are also a partial answer to the differences in the productive value of the respective rations (*11*) and tend to confirm the accuracy of the digestion trial with single ingredients. Thus in the comparative dairy feeding trials, strip cane and Napier grass were about equal when fed to lactating cows, so that data from the feeding trial supplemented by those from the digestion trial strongly point toward the greater availability of the total protein intake in rations including strip cane.

The Sudan grass ration was definitely superior to the panicum grass ration in all milk production trials. A possible reason may be the greater protein availability in the Sudan grass ration since the total nutrients as shown in table 4 were equally available.

On the other hand, the kiawe bean ration, which based on the protein should have been more productive, in two trials actually resulted in less milk. This would seem to indicate that the calculated values for protein as shown in table 4 are too low, thus resulting in the higher relationship as shown when the observed and the calculated values are compared. The digestibility of the kiawe bean meal as previously determined was a large factor in calculating the digestible protein of the concentrate mixture. These data from the trial with a complete ration would indicate that more of the protein of kiawe bean meal was actually available than found in the trial on the single feeding stuff. On the other hand, both rations seemed equally low in the total nutrient available.

# CONCLUSIONS AND SUMMARY

Stockmen in Hawaii have available for productive purposes many kinds of forages. This bulletin has established the nutrient value of the chief ones, particularly those more tropical in habitat. These include "honohono"; the following grasses: Guinea, molasses, Napier, panicum, Rhodes, and sugarcane (cane tops, strip cane, and cane bagasse); and the legumes: alfalfa, *Desmanthus virgatus,* koa haole, and pigeonpea.

The studies show that protein supplements must be fed with all the grasses in order to obtain rations that are properly balanced. In addition, three most widely distributed legumes (koa haole, *Desmanthus virgatus,* and pigeonpeas) have been found equal or superior in nutrient value to fresh green alfalfa, the roughage by which all legumes are usually measured.

It remains for the agronomist to perfect methods of culturing and harvesting these legume crops to secure maximum yields. When these points have been worked out, Hawaii will have available a valuable source of high quality protein that can be fed to all classes of livestock, particularly those raised under intensive conditions. The greater use of these local legumes, either in their natural state or as a specially dried meal, must be encouraged. Stockmen who are now feeding expensive imported protein supplements such as soybean oil meal, should be able to reduce the cost of production materially if greater dependence is placed on locally produced legumes.

On the basis of the work reported herein a calculation has been made of the amount of freshly cut leguminous material needed to replace 1 pound of 43 percent soybean oil meal. It would require 7 pounds of koa haole tops, 7 pounds of pigeonpea tops, or 12 pounds of *Desmanthus virgatus.*

For a more detailed report on the productive value of most of the forages, the reader is referred to University of Hawaii Experiment Station Bulletins 92 and 95 (*10, 11*).

Through the results obtained by these studies, the nutrient content of a local tuna fish meal previously used as fertilizer has been established and the product made available to hog producers in Hawaii as a valuable source of animal protein. This has resulted in increased income to the cannery and at the same time has reduced feed costs to hog feeders. Unpublished data from this Station have shown that the local fish meal is as satisfactory a protein supplement in hog feeding as is the imported meal.

Kiawe, or algaroba, meal has been investigated and the results show that it can partially replace expensive imported barley in the rations of Hawaii's livestock. By a proper combination of other locally available feeds with kiawe bean meal, barley can, in principle, be entirely replaced. However, the cost of picking the beans and preparing the meal is an extremely important item not considered in this bulletin.

The nutrient content of pineapple bran with no added molasses has been found similar to that already established by other workers for pineapple bran with added molasses. This feed is already so widely used in the Territory that no discussion of its food value is necessary.

Data are also presented on the digestibility of the nutrients of three complete rations as used in dairy cattle feeding trials. These figures indicate a depression of the digestibility of the protein when more of this nutrient came from the roughage, and furnish evidence as to why the rations compared differed in production value.

## LITERATURE CITED

(1) Association of Official Agricultural Chemists.
1935. OFFICIAL AND TENTATIVE METHODS OF ANALYSIS. Ed. 4, 710 pp., illus. Washington, D. C.

(2) Axtmayer, J. H., Asenjo, C. F., Jr., and Cook, D. H.
1938. THE NUTRITIVE VALUES OF SOME FORAGE CROPS OF PUERTO RICO. I. GRASSES. Puerto Rico Univ. Jour. Agr. 22: 95–121.

(3) ———, Rivera Hernandez, G., and Cook, D. H.
1938. THE NUTRITIVE VALUES OF SOME FORAGE CROPS OF PUERTO RICO. II. LEGUMES, GRASSES AND A MIXTURE. Puerto Rico Univ. Jour. Agr. 22: 455–481.

(4) ———, Rivera Hernandez G., and Cook, D. H.
1940. THE NUTRITIVE VALUES OF SOME FORAGE CROPS OF PUERTO RICO. III. GRASSES, LEGUMES AND MIXTURES. Puerto Rico Univ. Jour. Agr. 24: 3–31.

(5) Catlin, C. N.
1925. COMPOSITION OF ARIZONA FORAGES, WITH COMPARATIVE DATA. Ariz. Agr. Expt. Sta. Bul. 113, 19 pp.

(6) Forbes, E. B., Bratzler, J. W., Black, A., and Braman, W. W.
1937. THE DIGESTIBILITY OF RATIONS BY CATTLE AND SHEEP. Pa. Agr. Expt. Sta. Bul. 339, 30 pp., illus.

(7) ——— and Grindley, H. S.
1923. ON THE FORMULATION OF METHODS OF EXPERIMENTATION IN ANIMAL PRODUCTION. Natl. Res. Council Bul. 6, part 2, No. 33, 54 pp., Washington, D. C.

(8) French, H. H.
1941. THE NUTRITIVE VALUES OF SOME TANGANYIKA GRASSES. Empire Jour. Expt. Agr. 9: 23–28.

(9) Harrison, E.
1942. DIGESTIBILITY TRIALS ON GREEN FODDERS. Trop. Agr. [Trinidad] 19: 147–150.

(10) Henke, L. A.
1942. ROUGHAGES FOR DAIRY CATTLE IN HAWAII. Hawaii Agr. Expt. Sta. Bul. 92, 29 pp., illus.

(11) ———
1945. PROTEIN SOURCES AND SUPPLEMENTS FOR DAIRY COWS IN HAWAII. Hawaii Agr. Expt. Sta. Bul. 95, 21 pp., illus.

(12) ———, Work, S. H., and Burt, A. W.
1940. BEEF CATTLE FEEDING TRIALS IN HAWAII. Hawaii Agr. Expt. Sta. Bul. 85, 37 pp., illus.

(13) Hosaka, E. Y.
1945. KAIMI SPANISH CLOVER FOR HUMID LOWLAND PASTURES IN HAWAII. Hawaii Agr. Expt. Sta. Circ. 22, 8 pp., illus.

(14) ——— and RIPPERTON, J. C.
1944. LEGUMES OF THE HAWAIIAN RANGES. Hawaii Agr. Expt. Sta. Bul. 93, 80 pp., illus.

(15) KRAUSS, F. G.
1921. THE PIGEON PEA (CAJANUS INDICUS). ITS CULTURE AND UTILIZATION IN HAWAII. Hawaii Agr. Expt. Sta. Bul. 46, 23 pp., illus.

(16) ———
1932. THE PIGEON PEA (CAJANUS INDICUS). ITS IMPROVEMENT, CULTURE AND UTILIZATION IN HAWAII. Hawaii Agr. Expt. Sta. Bul. 64, 46 pp., illus.

(17) LAMB, A. R.
1938. UTILIZATION OF MOLASSES. III. FEEDING TRIALS ON LABORATORY ANIMALS TO DETERMINE THE VALUE OF BAGASSE, MOLASSES, AND KIAWE BEAN MEAL. Hawaii. Planters' Rec. 42: 89–96.

(18) ——— and WORK, S. H.
1939. THE UTILIZATION OF CANE BY-PRODUCTS IN LIVESTOCK FEEDING ON THE PLANTATION. Rpt. Hawaii. Sugar Technologists 2nd Annual Meeting, 11–19.

(19) LYMAN, R. A., and RIPPERTON, J. C.
1938. PALATABILITY TRIALS. Hawaii Agr. Expt. Sta. Rpt. (1937–1938): 62.

(20) ——— and RIPPERTON, J. C.
1939. COMPARATIVE PALATABILITY OF FORAGES. Hawaii Agr. Expt. Sta. Rpt. (1938–1939): 19.

(21) MAYNARD, L. A., MILLER, R. C., and KRAUSS, W. E.
1928. STUDIES OF PROTEIN METABOLISM, MINERAL METABOLISM, AND DIGESTIBILITY, WITH CLOVER AND TIMOTHY RATIONS. N. Y. (Cornell) Agr. Expt. Sta. Mem. 113, 33 pp.

(22) MEAD, S. W., and GUILBERT, H. R.
1927. THE DIGESTIBILITY OF CERTAIN FRUIT BY-PRODUCTS AS DETERMINED FOR RUMINANTS. PART II. DRIED PINEAPPLE PULP, DRIED LEMON PULP, AND DRIED OLIVE PULP. Calif. Agr. Expt. Sta. Bul. 439, 11 pp.

(23) MITCHELL, H. H.
1942. THE EVALUATION OF FEEDS ON THE BASIS OF DIGESTIBLE AND METABOLIZABLE NUTRIENTS. Jour. Anim. Sci. 1: 159–173.

(24) MORRISON, F. B.
1936. FEEDS AND FEEDING. Ed. 20, 1050 pp., illus. Ithaca, N. Y.

(25) NAQUIN, W. P.
1929. CANE PULP AS A CARBONACEOUS FEED FOR ANIMALS. Hawaii. Planters' Rec. 33: 407–409.

(26) RIPPERTON, J. C., and HOSAKA, E. Y.
1942. VEGETATION ZONES OF HAWAII. Hawaii Agr. Expt. Sta. Bul. 89, 62 pp., illus.

(27) SNELL, M. G.
1935. BLACKSTRAP MOLASSES AND CORN-SOYBEAN SILAGE FOR FATTENING STEERS. La. Agr. Expt. Sta. Bul. 266, 22 pp.

(28) TAKAHASHI, M., RIPPERTON, J. C., and SHIGEURA, G.
1942. LEGUMES. Hawaii Agr. Expt. Sta. Rpt. (1940–1942): 75–77.

(29) WHITNEY, L. D., HOSAKA, E. Y., and RIPPERTON, J. C.
1939. GRASSES OF THE HAWAIIAN RANGES. Hawaii Agr. Expt. Sta. Bul. 82, 148 pp., illus.

(30) WILLIAMS, P. S.
1925. THE EFFECT OF CANE MOLASSES ON THE DIGESTIBILITY OF A COMPLETE RATION FED TO DAIRY COWS. Jour. Dairy Sci. 8: 94–104.

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