MILK PRODUCTION IN NEW GUINEA.

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Introduction.

There are no cattle indigenous to the Territory of New Guinea, but during the past forty or fifty years, particularly during the German occupation, cattle were introduced into many parts of the country. A search through old German records (Statistics, German New Guinea, 1916) has revealed that mostly cattle of the Jersey and Guernsey breeds were imported, and the colour and conformation of many of the existing cattle give definite support to this statement. Much care was taken over the importation of these cattle, and the Germans had a government station at Kieta (*Bulletin Imperial Institute*, 1915) for the breeding and distribution of superior types. These cattle have interbred and increased in numbers,[(a)] so that to-day large mixed herds are to be found on plantations in practically all coastal districts of the Territory. They are never housed and, except in occasional cases where the cattle have access to cover crop, their feed consists only of natural pasture. Nevertheless, they are in fair condition and remarkably free from disease.

The individual milk yield of these cows seldom averages much more than one quart a day at any stage of their lactation period, so that they are not worth milking, except in cases where planters milk three or four to supply their own household requirements. The mean yield per cow of fifteen herds on different plantations was only 1.1 quarts per day, which is even lower than the yield from the poor, inefficiently producing, native cows of Ceylon and South India (Bruce, 1922; Crawford, 1938, and Bunting and Marsh, 1934).

Less than four years ago, a small herd of pure-bred Friesian cattle was imported from Australia for the purpose of supplying fresh milk to Rabaul. This is the only herd, producing milk on a commercial basis, in the coastal districts of the Territory. The average daily milk yield of this herd throughout the year is about half a gallon per cow, although, in May, 1940, 28 cows thoroughly milked were only giving 12 gallons per day, but at that time several of the cows had their calves running with them during the day, so that the actual yield was slightly higher than this amount. The standard daily yield for a Friesian cow in a temperate climate is 3.2 gallons (Bulletin 52, Ministry for Agriculture and Fisheries, 1937), and the original cows in this herd were giving from three to four gallons a day before their importation.

Because of these low yields, dairy farming in New Guinea is a most unattractive proposition, and although there are many centres in which sufficient people live to support one or even more dairies, there are only three dairies selling milk in the whole of the Territory. One is situated near Rabaul, and two in the high inland mining town of Wau, where climatic conditions are more conducive to dairying, being quite different from those in the coastal districts of the Territory.

(*a*) In 1909, there were less than 1,000 cattle in New Guinea (Amtsblatt f. Neu-Guinea vom 15. Sept. 1909) and to-day about 21,000 have been accounted for (Report on Administration of Territory of New Guinea, 1938-39) and there are many more. The increase has been mostly a natural one.

The object of this investigation was to show that these low milk yields are largely the result of inadequate feeding, and to indicate how the yield could be improved.

Climatology.

To understand fully the circumstances surrounding this investigation, it is necessary to know something of the climatic conditions of the coastal districts of New Guinea, where practically all cattle are located.

The Mandated Territory of New Guinea is situated 141° to 156° east longitude, and approximately 0° to 8° south of the equator, and, except for the high inland areas of the Mainland, its climate is typically tropical in the narrowest sense of the word. On the smaller islands and along the coastal belts of the Mainland, New Britain, New Ireland and Bougainville Island, where most agriculture is practised, the climate is hot and humid. There are no distinct seasons, although more rain falls when the north-west monsoons prevail, from December to April, than during the remainder of the year. The average rainfall varies from 100 to 300 inches per annum. The mean temperature is approximately 82° F. at all periods of the year. The greatest difference between the highest and lowest barometer readings during the year seldom exceeds 10 millibars. From observations taken over a period of years at five main coastal weather stations, the average relative humidity was found to be 81 per cent. at 9 a.m., 75 per cent. at 3 p.m., and 88 per cent. at 9 p.m. The average soil temperatures, taken at a depth of 9 inches in the Botanic Gardens in Rabaul, were 84° F. at 9 a.m. and 85° F. at 3 p.m., and these readings seldom varied by more than about 4° F.

It is thus seen that the climate of the coastal districts is entirely lacking in the seasonal variations found in more temperate zones.

Composition and Properties of Milk.

Table I. gives the composition of 70 mixed milk samples from the pure-bred Friesian herd to which reference has already been made, and 42 from other mixed herds in the Territory.

TABLE I.—AVERAGE COMPOSITION OF NEW GUINEA MILK.

Herd.	Total Solids.	Fat.	Solids-not-fat.	Specific Gravity.
	Per cent.	Per cent.	Per cent.	
Friesian	13.13	4.82	8.31	1.0298
Mixed	13.56	6.28	7.27	1.0290

Methods of Analysis.—Specific gravity was determined with a Westphal balance and corrected for temperature using the author's equation (Hutchinson, 1940). Fat was estimated by Richmond's (1930, *a*) modification of the Roese Gottlieb method, total solids by the evaporation of 10 c.c. of milk and solids-not-fat by difference. Normally, if the fat content and specific gravity were known, the total solids and hence solids-not-fat could be calculated from Richmond's formula (1930, *b*), but it has not yet been shown that Richmond's formula holds equally well under tropical and temperate conditions; in fact, there is evidence to the contrary. Calculating total solids by Richmond's formula for milk from the Friesian and mixed herds, we have 6.18 and 7.94 per cent. respectively. These figures are much lower than those found by direct estimation.

Discussion of Results.—Comparing the figures given in Table I. with those given by Morrison (1938, *a*), Richmond (1930, *c*) and Davies (1939, *a*), it will be seen that the solids-not-fat content and the specific gravity of the New Guinea milk is low, while the fat content tends to be high. A high fat content is to be expected, for it will be shown later that the pastures in the coastal districts of New Guinea are rich in carbohydrates, and it has been proved (Mackintosh, 1938, *a*) that the fat of milk is largely formed from the carbohydrates supplied in the feed. Furthermore, many of the mixed herds contain Jersey and Guernsey blood, and these breeds of cattle are noted for giving milk of high fat content.

The low specific gravities are accounted for as follows: The melting point of butter fat is about 86° F., so that it is liquid when drawn from the cow and, under the atmospheric conditions prevailing in New Guinea, solidification takes place so slowly that it remains in the liquid state during the day it is drawn, generally solidifying in the evening. It has been shown (Richmond, 1930, *d*) that the specific gravity of butter fat in the liquid state is lower than when in the solid state; so that the specific gravity of milk, in which the butter fat is in the liquid state, will be lower than when the butter fat solidifies. The low solids-not-fat content of the milk would also lower the specific gravity slightly.

The low solids-not-fat content appears to be general for milk produced in the tropics. Wright (1916-22) has recorded normal values a little over 8 per cent. for the solids-not-fat content of milk produced near Suva, whilst Southall (cited by Blackie and Flemons, 1939) made a series of determinations on milk from local suppliers in Fiji, and his figures indicate a wide variation in solids-not-fat tending to an average of 8.3 per cent. Further work in Fiji, by Blackie and Flemons (1939), shows the mean solids-not-fat content of mixed milks collected over a period of one year to be 8.33 per cent. French and Raymond (1936) have indicated a similar state of affairs in Tanganyika, stating that over 25 per cent. of the grade cows regularly give milk which contains less than the arbitrary legal limit of 8.5 per cent. solids-not-fat. In Mauritius (Annual Report, Department of Agriculture, 1938), the mean solids-not-fat content of a large number of mixed milk samples collected at different periods of the year was 8.4 per cent. In the Philippines (*Handbook of Philippine Agriculture*, 1939, *a*), where a number of milk samples from cows of different breeds have been analysed, similar results were also obtained. The mean of four analyses of milk from Holstein cows gave a protein plus lactose content of 7.42 per cent., and 37 samples from half Nellore-half Holstein cows gave 7.52 per cent.

Low Solids-not-fat—Probable Causes.—This lowering of the solids-not-fat may be due to several causes. It may be a natural adjustment brought about by the physiological necessity of secreting a liquid lower in calorific value to suit the naturally smaller needs of a suckling in a warm climate or it may be due to disease or faulty nutrition. The first cause seems unlikely as the fat content tends to be high, although there is the possibility that this high fat content may be due to other causes of difficult physiological control, for the fat content of milk is more readily changed than the solids-not-fat. If the second cause is responsible, it could almost certainly be detected by analysis, for the solids-not-fat are usually altered in composition by digestive ailments and by disease (Bergema, 1919).

The results of the analyses of the solids-not-fat fractions of 25 milk samples are given in Table II. Protein was estimated by the method outlined by Davies

(1939, *b*); lactose by the Fehling's Solution method outlined by Richmond (1930, *e*) and chlorine by Massot and Lestra's (1936) third method.

Reference will be made later to the mixed herds from which samples 11 to 25 were collected, for it was on these herds that determinations of weight were made and it was the pastures upon which they were feeding which were analysed.

These figures are not abnormal, although the lactose content is perhaps low and the chloride content a little high. Davies (1939, *c*) gives the normal lactose content of milk as 4.8 per cent. He also gives the normal chloride content of morning milk as ranging from 81 to 90 mgms. per 100 ml. (Davies, 1938), and, for samples from Friesian herds known to be giving milk low in solids-not-fat, the

TABLE II.—COMPOSITION OF THE SOLIDS-NOT-FAT FRACTION OF NEW GUINEA MILK.

No.	Herd.	Protein.	Lactose.	Ash.	Chloride.	
		Per cent.	Per cent.	Per cent.	Per cent. Cl.	Per cent. NaCl.
1	Friesian ..	3.06	4.42	.67	.136	.224
2	,, ..	2.97	4.29	.68	.146	.241
3	,, ..	3.15	4.55	.70	.127	.209
4	,, ..	3.16	4.62	.71	.121	.199
5	,, ..	3.06	4.40	.68	.123	.203
6	,, ..	3.07	4.45	.69	.140	.231
7	,, ..	3.16	4.67	.70	.118	.194
8	,, ..	3.24	4.68	.72	.117	.193
9	,, ..	3.17	4.59	.71	.124	.204
10	,, ..	3.12	4.51	.69	.130	.214
Mean	.. ..	3.12	..	..	..	..
11	Mixed ..	2.39	3.46	.56	.198	.327
12	,, ..	2.86	4.13	.64	.158	.261
13	,, ..	3.11	4.49	.69	.131	.216
14	,, ..	3.21	4.64	.71	.121	.200
15	,, ..	2.08	2.96	.46	.244	.402
16	,, ..	2.94	4.24	.65	.151	.249
17	,, ..	2.80	4.04	.62	.164	.270
18	,, ..	3.12	4.50	.69	.131	.216
19	,, ..	2.80	4.25	.68	.149	.246
20	,, ..	3.21	4.40	.69	.138	.228
21	,, ..	2.19	3.17	.50	.201	.331
22	,, ..	2.62	3.80	.58	.183	.302
23	,, ..	2.72	4.00	.59	.164	.270
24	,, ..	2.93	4.04	.67	.164	.270
25	,, ..	3.12	4.56	.70	.133	.219
Mean	.. ..	2.81	..	..	..	..

mode of the frequency distribution was 110 to 120 mgms. per 100 ml. A low lactose content accompanied by a high chloride and ash content is generally considered as indicative of disease or of digestive ailments. Mathieu and Ferré (1914) have found that the lactose (grams per litre) plus the lactose equivalent of the chlorides as NaCl (NaCl $\times$ 11.9) in grams per litre does not fall below 70 in a normal milk. They have termed this figure the "*constant moléculaire simplifiée*", (c.m.s.). Koestler (1922) has suggested that the value 100 $\times$ per cent. Cl. $\div$ per cent. lactose ("Koestler number") is of value in diagnosing milk from cows with diseased udders or otherwise giving abnormal milk. The value for normal milk is usually less than 2 and milk samples giving values above 3 may be regarded as abnormal, the latter value applying to milk containing .14 per cent. Cl and over. Computing the c.m.s. and Koestler number for the milk samples analysed, the results given in Table III. were obtained.

TABLE III.—C.M.S. AND KOESTLER NUMBER FOR NEW GUINEA MILK.

Friesian.			Mixed.		
No.	c.m.s.	Koestler No.	No.	c.m.s.	Koestler No.
1	70.9	3.1	11	73.5	5.72
2	71.6	3.4	12	72.4	3.82
3	70.4	2.8	13	70.6	2.92
4	69.9	2.6	14	70.2	2.61
5	68.2	2.8	15	77.4	8.24
6	72.0	3.1	16	72.0	3.56
7	69.8	2.5	17	72.5	4.06
8	69.8	2.5	18	70.7	2.91
9	70.2	2.7	19	71.8	3.51
10	70.6	2.9	20	71.1	3.13
			21	71.1	6.34
Mean	70.3	2.8	22	73.9	4.82
			23	72.1	4.10
			24	72.5	4.54
			25	71.7	2.92

Neither the c.m.s.'s nor the Koestler numbers for milk samples from the Friesian herd suggest that these cows were suffering from disease or digestive ailments, particularly as the ash content is low. The c.m.s.'s and Koestler numbers for samples 1, 2 and 6 are slightly above 3 and 70 respectively, but not appreciably high.

The milk samples from the mixed herds gave widely differing c.m.s.'s and Koestler numbers, the majority being abnormally high. The wide difference to be found in these figures is due no doubt to the fact that the samples were not from the bulked milk of herds of normal size, but generally from only three or four cows, so that individual variations might not have been completely eliminated. The reason for most of the figures being high is accounted for by the fact that the chloride content of the samples was correspondingly high. Davies (1932) has made detailed analyses of milk samples from healthy cows which were giving milk low in solids-not-fat and he found that the constituent mostly responsible for the deficiency was lactose and that invariably samples low in solids-not-fat and thus lactose are high in chlorides due to the fact that the maintenance of the osmotic pressure of the milk is affected by the substitution of ionized chlorides for lactose. Thus it is normal for these samples, low in solids-not-fat, and hence lactose, and high in chlorides to have high c.m.s.'s and Koestler numbers. This and the fact that the ash contents are low give no indication that these milk samples were from diseased cows or from cows suffering from digestive ailments.

The third possible cause will now be considered. In an excellent paper, "The Effect of Type of Feed on the Solids-not-fat Content of Milk", Roux, Murray and Schutte (1935) fed one group of six cows a heavy concentrate ration, a second group a heavy dry ration and a third group a heavy succulent ration.

The heavy concentrate ration maintained a higher level of production, a normal trend of solids-not-fat and a slow increase in percentage of butter fat with advance in lactation. The other rations appeared to have a depressing effect on the percentage of solids-not-fat and milk production dropped more rapidly and the percentage of butter fat increased to a greater extent than occurred in the heavy concentrate group.

During a period of three years, Cranfield (1927) studied variations in the solids-not-fat content of a herd of Shorthorn cows which frequently gave milk low in solids-not-fat. Feeding was found to be one factor which influenced the solids-not-fat content of the milk.

As a result of four years' investigation with a herd of cows, it has been shown (Trambics, 1938) that the percentage of solids-not-fat drops in summer months, the drop being more marked the severer the summer. It is considered that this drop is partly the result of a change in the sugar and protein content of the feed.

The results of these investigations indicate that poor feeding could be at least partly responsible for lowering the solids-not-fat content of milk. It will be shown presently, that the feed upon which New Guinea cows are feeding is often very low in nutritive value and it seems highly probable that these low figures for solids-not-fat are partly or wholly the result of faulty nutrition. In fact, it is probably for this reason that low solids-not-fat are more common in the tropics than in temperate climates, for in temperate climates pastures are, in general, more nutritive (see Table V.) and the practice of feeding concentrates is more common.

Factors Effecting Milk Yields.

Miscellaneous Factors.—The amount of milk a cow produces is effected much more readily and to a greater degree than its composition.. There are several factors which might be contributing towards low milk yields in New Guinea but, as will be shown presently, there is one factor which appears to greatly outweigh all others. It must be understood, however, that with the exception of the recently introduced Friesian herd, the cows are producing approximately as much milk as their dams which is probably their inherited capacity. After the introduction of the first cattle, each succeeding generation has probably produced a little less milk than the previous one, until a state of equilibrium has been reached in relation to their environment. Therefore, the low milk yields are the result of factors which have been operative over a number of cow-generations.

New Guinea cows are only milked once a day, in the early morning. An attempt was made to increase the production of the Friesian herd by milking twice daily, but the dairyman considered that the slight increase in yield was not sufficient to justify the extra labour involved.

The cattle are generally milked by natives, for most New Guinea cattle, with the exception of the Friesian herd, are too timid and frightened to be even approached by a white man. There is a possibility that the natives may not strip the cows as thoroughly as desirable, although the milk is generally high in fat and most fat is contained in the strippings (Van Slyke, 1908 and Eckles (—)).

The only complaint from which any of the cattle appear to be suffering is tick infestation, although they appear to be immune to tick fever. But ticks in New Guinea cattle are not common, although, unfortunately, they are spreading, and of the sixteen herds under observation during this investigation only one was found to be infected with them. Hence, although it is known that ticks do lower milk yields (Maynard, 1931), they are not responsible for low yields in the present instance.

For a cow in good health, the maximum yield is usually reached at 7 to 9 years of age but there is usually no marked decline in yield until she is about 12 years of age (Morrison, 1938, *b*). None of the cows under observation during investigation was more than 6 or 7 years of age.

If the weather is too hot for the comfort of the cows, it may cause a slight but decided reduction in yield, together with an increase in the fat content and other changes in the composition of the milk. Experiments have shown that such an effect is produced when cows are kept in an atmospheric temperature above 85° F. for more than 48 hours (Regan *et al.*, 1934). High humidities may also cause a drop in yield, high producing cows being more effected than low producers (Bender, 1928). The temperature in New Guinea frequently reaches 85° F. but remains there only for a relatively short time and, as the cows are all low producers, neither temperature nor humidity should effect milk yields to more than a small extent.

Cows imported into a tropical country are more susceptible to heat than those born there. In the case of exotic breeds, it has been shown (Bonsma *et al.*, 1940) that as soon as the atmospheric temperature rises above 80° F., it is accompanied by a rise in the body temperature and a considerable increase in the respiration count. The respiratory centre loses its normal function of controlling the rhymthmical movement of respiration, the breathing consequently becoming rapid, irregular and shallow. Such factors would almost certainly have a disturbing influence on the delicate mechanism of milk production, in the imported Friesian cows.

Dietary Factors.—During a preliminary investigation into the low milk yield of New Guinea cows, the herd of Friesian cattle was fed concentrates imported from Australia in addition to being grazed all day. The concentrate was mixed with chaffed elephant grass (*Pennisetum purpureum*) and the amount fed depended approximately upon the individual response of each animal. It was found that during a very short time, the milk yield could be increased more than 30 per cent. This suggested that the cause of the low milk yield was partly dietary. Consequently, it was decided to investigate the diet of these cows and this led to a determination being made of the nutritive value of the more common grasses and fodder crops found in the coastal districts of New Guinea.

Nutritive Value of Fodder Crops.—It is well known that different grasses and legumes vary widely in nutritive value. Even plants of the same species may vary considerably in composition depending upon their habitat and stage of maturity. For instance, immature grass is relatively high in protein and low in crude fibre. As the grass matures, the percentage of protein decreases and that of crude fibre increases. Hence, a pasture that grows considerably faster than it can be consumed, will soon have a stand of mature grass, high in fibre but low in nutritive value. In recent years, the work of Woodman and associates at Cambridge has emphasized the value of immature grass for feeding purposes and milk production.

In New Guinea, particularly on plantations along the coastal belts, there are extensive areas of green, succulent and apparently nutritious pastures. Because of the climatic conditions, there is no period of maximum growth, but plants are growing rapidly all through the year and consequently these pastures consist of a high proportion of mature grass. Cattle do not graze these pastures indiscriminately but generally seek the younger grass, of which there is only a very limited amount. This necessitates their covering extensive areas each day.

On plantations the grass is cut periodically, but it commences growing immediately and within a very short time reaches maturity again. If there are cattle on the plantation, it is probable that they will not have availed themselves of the opportunity of grazing on the freshly cut areas, for most tropical cattle are of a very nervous and timid disposition and generally migrate to those parts of the plantation where there is least activity and excitement. It would be too expensive to enclose the cattle within fenced areas, for timber is frequently scarce and the areas would have to be large and the fences substantial.

Samples of the more common grasses and sedges of which New Guinea pastures are composed have been collected and analysed. These samples were divided into mature and immature samples. By mature grass is meant grass at or past the flowering stage and by immature grass is meant young grass which is sufficiently high to be easily grazed, but which shows no sign of flowering. Each sample analysed was taken from a number of pooled samples collected from one locality, although, in some cases, it was not possible to collect corresponding mature and immature samples from the same locality.

Sixteen samples of mixed pastures were also collected and analysed, but, as has already been pointed out, whenever possible, cattle eat only the immature grass. They also show preference for certain grasses. For instance, they will never eat Kunai (*Imperata arundinacea*), no matter how young and succulent it may be, if there are other grasses available. Thurston grass (*Paspalum conjugatum*), is perhaps the most common pasture grass in the Territory and on some plantations it is the only grass. Couch grass (*Cynodon dactylon*) is relished by cattle and is plentiful around Rabaul, although comparatively rare in other parts of the Territory. Because of these facts, samples of the more nutritious and succulent portions of these sixteen pastures were also collected and analysed for moisture, crude protein and digestible crude protein. These unavoidably contained some mature grass but they were very similar to those eaten by the cow. They were not cut, but plucked by hand in order to simulate a cow's method of grazing.

All estimations were made in duplicate on the fresh samples, 5 grams being taken for each determination. Crude protein, which was estimated in preference to true protein for reasons to be given later, is nitrogen $\times$ 6.25. Crude fibre was estimated by the method given in Allen's *Commercial Organic Analysis* (1937). The ether-soluble extract was determined in a Soxhlet extractor, moisture in a hot air oven at 105° C. and sugar and starch (or nitrogen-free extract), were computed by difference. The results of these analyses are presented in Tables IV. and VI.

TABLE IV.—COMPOSITION OF NEW GUINEA PASTURES, GRASSES AND SEDGES.

Common Name.	Scientific Name.	Water.	Crude Fibre.	Sugar and Starch.	Crude Protein.	Eth. Sol. Extract.	Ash.	Nature of Specimen.	No. of Analyses.
		%	%	%	%	%	%		
Kunai ..	*Imperata arundinacea* ..	61	14.8	19.7	1.3	0.4	2.8	Immature ..	3
		48	18.4	29.0	0.8	0.3	3.5	Mature	3
Thurston ..	*Paspalum conjugatum* ..	82	4.9	7.0	3.2	0.7	2.2	Immature ..	3
		74	7.4	14.4	1.5	0.4	2.3	Mature	3
Nut ..	*Cyperus rotundus* ..	78	6.5	10.5	2.4	0.2	2.4	Immature ..	3
		67	10.4	17.9	1.9	0.2	2.6	Mature	3
Love or Seedy	*Chrysopogon aciculatus* ..	69	9.0	15.2	3.4	0.4	3.0	Immature ..	3
		61	13.3	20.7	1.8	0.2	3.0	Mature	3
Couch ..	*Cynodon dactylon* ..	66	10.2	16.7	3.5	0.5	3.1	Immature ..	2
		57	12.5	23.7	3.0	0.3	3.5	Mature	2
Elephant ..	*Pennisetum purpureum* ..	89	4.6	2.9	1.2	0.5	1.8	1 ft. high.. ..	1
		86	7.0	4.2	0.7	0.5	1.6	4 ft. high.. ..	1
		62	13.2	21.8	0.5	0.3	2.2	16 ft. high (mature)	1
Karapai ..	*Pennisetum macrostachyum*	81	7.2	6.8	2.3	0.4	2.3	Immature ..	3
		75	12.6	8.4	1.2	0.3	2.5	Mature	3
Pasture ..	.. .. ..	70	10.3	15.4	1.4	0.4	2.5	Mixed	16
		(As percentage of dry matter)							
		..	34.3	51.3	4.7	1.3	8.3	Mixed	16

In order to compare the results given in these tables with figures for pastures growing in temperate climates, Table V. has been compiled. This table gives the chemical composition of a number of mixed pastures used for the grazing of dairy cattle in some of the more prominent milk-producing countries.

Comparing the figures in Tables IV. and VI. with those in Table V., it is seen that the protein content of New Guinea pastures, when the whole pasture is sampled, is appallingly low. When mostly the younger portions of the pastures are sampled the protein content is nearly double and, considering New Guinea pastures are unimproved natural pastures, for the most part growing on loose, easily leached soil, it is considered that these results would probably be in good agreement with results obtained for pastures growing under similar conditions in temperate climates. The ash and ether-soluble extract are also low; there is no appreciable difference in the starch and sugar content and the fibre content is, in general, higher. These differences are largely accounted for by the fact that the samples contained a high proportion of mature grass.

Pasture Digestibility.—A chemical analysis is not in itself sufficient for the determination of the nutritive value of a feed. The proportion of the feed which is digestible is also required to be known.

When the digestibility of a feed is determined biologically it is generally assumed that the whole of the dung consists of undigested food. This is incorrect, for faeces always contain metabolic waste products. Attempts have been made to

TABLE V.—COMPOSITION OF PASTURES IN TEMPERATE CLIMATES.

Country.	Season.	Water.	Crude Protein.	Crude Fibre.	Sugar and Starch.	Ash.	Ether Extract.	No. of Estimations.	Reference.
		%	%	%	%	%	%		
(Results expressed as percentage of green matter.)									
Australia ..	Summer	..	9.87	..	..	..	..	19	Hutchinson (1939, a)
South Africa ..	Summer	..	7.0–9.0	..	..	..	..	..	du Toit *et al.* (1940)
South Africa ..	Winter	..	3.3–4.0	..	..	..	..	..	du Toit *et al.* (1940)
America ..	..	74.2	4.7	5.3	12.0	3.2	0.7	86	Newlander *et al.* (1933)
America ..	..	71.3	5.7	6.4	12.8	2.7	1.1	262	Morrison (1938, *c*)
America ..	..	69.8	4.7	6.5	14.5	3.7	0.8	40	Morrison (1938, *c*)
South America	..	75.6	3.7	6.5	10.8	2.6	0.8	179	Morrison (1938, *c*)
(Results expressed as percentage of dry matter.)									
South Australia	..	..	8.0	29.6	51.4	9.5	1.6	...	Davies *et al.* (1934)
England ..	Spring	..	11.3	24.0	53.6	8.3	2.8	35	Moon (1939)
England ..	Winter	..	13.4	28.3	49.6	6.0	2.7	14	Thomas and Boyns (1936)
Canada ..	..	5.3	14.7	24.3	..	..	..	..	Crampton (1934)
America ..	..	..	17.5	23.4	46.5	8.3	4.9	..	Woodward (—)

determine the amount of metabolic residue in the faeces by feeding a nitrogen deficient ration. Kellner (1880), working with herbivora, suggested a value of .4 gram of nitrogen per 100 grams of organic matter digested. Pfeiffer (1883-87) carried out a number of experiments with pigs and the figures he obtained agreed with Kellner's value for herbivora. However, it has since been shown (Ashton, 1936; Morgen *et al.*, 1914, and Mitchell and Hamilton, 1929) that a definite figure cannot be accepted for the metabolic nitrogen of all rations for the figure varies with different feeds fed in different ways, nevertheless Pfeiffer (*loc. cit.*) concluded from his experiments that the nitrogenous products of metabolism must be taken into account in determining the protein digestibility in animal experiments.

Efforts to determine the digestibility of a food *in vitro* have been successful in the case of protein. This has been effected by artificial digestion in acid gastric juice and has served to determine the total protein which is digestible. Such determinations, however, tend to measure the true digestibility in the digestive tract rather than the effective digestibility as measured by animals.

Pfeiffer (*loc. cit.*) carried out experiments to determine the crude protein digestibility of certain feeding stuffs (1) with animals, (2) by artificial digestion and (3) with the value obtained in the animal experiment corrected for the nitrogen-containing metabolic residues. There was excellent agreement between the values obtained in the artificial digestion and the values obtained in the animal trials when corrected for the metabolic residue in the faeces. More recently (Watson and Horton, 1936), a ration of artificially dried grass was fed at the plane of nutrition to six sheep. The digestibility coefficients obtained by the different methods were:—

Animal experiments uncorrected for metabolic residues ..	63.30
Animal experiments corrected for metabolic residues ..	76.24
Artificial digestion	76.95

This also shows excellent agreement between figures obtained by the last two methods.

The main objection to the artificial methods is that the digestibility of certain protein constituents encased in very tough or fibrous cells is included in the determination, whereas, in actual practice, this protein may pass through the animal undigested.

In New Guinea there are two animals available for digestibility trials, the cow and the goat, but climatic conditions, insect pests, and the temperament of the New Guinea cows and goats do not permit digestibility trials being carried out satisfactorily and with the necessary accuracy. Hence, in the present instance, it was considered that more reliable results could be obtained by an *in vitro* method rather than a biological method carried out under such unfavorable conditions. The method chosen was that recently employed by Schwarze (1937) in determining the amount of digestible protein in lucerne plants and various seeds. The digestion was carried out with pepsin-hydrochloric acid and pancreatin-soda mixtures.

Figures giving the amount of digestible crude protein in the more nutritious portions of the sixteen previously mentioned pastures are included in Table VI. The average amount of digestible crude protein in the first fifteen samples was 1.65 per cent. and for the sixteenth sample, which was collected from the pasture upon which the Friesian herd was grazing, 1.66 per cent.

It is interesting to compare the average figure for digestible crude protein given in Table VI. with figures for pastures in more temperate climates. For this purpose Table VII. has been compiled. It must be remembered, however, that, although the results were obtained from the most nutritious portions of the pastures, they were natural, unimproved pastures containing no introduced grasses or legumes of high nutritive value, whereas the English and American figures were probably for improved pastures.

TABLE VI.—PARTIAL ANALYSES OF THE MORE NUTRITIOUS PORTIONS OF NEW GUINEA PASTURES.

No.	Moisture.	Crude Protein.	Digestible Crude Protein.	
	Per cent.	Per cent.	Per cent. Fresh wt.	Per cent. Dry wt.
1	79	3.1	2.33	..
2	75	2.5	2.03	..
3	69	2.0	1.46	..
4	72	1.8	1.31	..
5	74	2.1	1.55	..
6	76	3.5	2.70	..
7	68	1.9	1.31	..
8	71	2.9	2.03	..
9	67.	1.4	0.91	..
10	74	2.1	1.49	..
11	78	2.2	1.56	..
12	69	2.0	1.44	..
13	66	1.7	1.19	..
14	72	2.2	1.58	..
15	78	2.4	1.90	..
Mean	73	2.3	1.65	6.1
16	76	2.6	1.66	6.9
Mean of all results ..	73	2.3	1.65	6.1

From these results it is seen that the digestible crude protein content of New Guinea pastures is low, although approximately the same as for the best Queensland pastures. However, if the results for Queensland and New Guinea pastures were exactly comparable, it is probable that the New Guinea figure would be lower. By comparing values for the best pasture in each country, it is interesting to note that the digestible crude protein content appears to increase as the climate becomes more temperate. The reason for this may be that pasture improvement is practically unknown in tropical countries and is not as common in sub-tropical as in temperate climates.

TABLE VII.—DIGESTIBLE CRUDE PROTEIN CONTENT OF PASTURES.

Country.	Climate.	Digestible Crude Protein.	Remarks.	Reference.
		Per cent.		
New Guinea	Tropical ..	1.65	Young	This investigation
Queensland	Sub-tropical ...	1.6	Best	Brünnich (1926)
United States of America (southern)	Sub-trop.-temp.	2.6	Fertile	Morrison (1938, *d*)
United States of America..	Temperate ..	3.3	Poor to fair ..	Morrison (1938, *d*)
United States of America	Temperate ..	4.4	Fertile	Morrison (1938, *d*)
England	Temp.–cold ..	2.2*	Extensively grazed	Mackintosh (1938, *b*)
England	Temp.–cold ..	4.4*	Closely grazed ..	Mackintosh (1938, *b*)

* Calculated.

Weight of Cows.—Suitable scales for weighing the cattle were not available so that their weights had to be determined indirectly.

Kendrick and Parker (1936) have compiled a table for estimating the live weights of dairy cattle from heart-girth measurements based on a study of 1,721 actual weights and heart-girth measurements of Holstein and Jersey cattle. A similar table has also been compiled by Ragsdale and Brody (1935) in which the estimated live weights for a given heart-girth are somewhat lower than those given by Kendrick and Parker (*loc. cit.*). Other methods of live-weight estimation have been suggested in the *Queensland Agricultural Journal* (1910), by Singh (1933), and by Dmitrochenko (1926).

Morrison (1938, *e*), in his standard work *Feeds and Feeding,* recommends the method of Kendrick and Parker (*loc. cit.*) for estimating live weight of dairy cattle and this method undoubtedly has advantages over the other methods. The live weights of sixteen groups of New Guinea cows from whom milk was obtained are given in Table VIII. In general, each group of cattle measured was typical of the whole herd.

New Guinea cows vary in size somewhat although, generally speaking, they are small, being about the size of a small Jersey cow. There are indications that the first importations were probably larger for, when the Friesian cows were imported from Australia almost four years ago, they were healthy and of normal size but the offspring of these cows have apparently ceased growing at less than 900 lb. live weight.

TABLE VIII.—LIVE WEIGHTS OF TYPICAL NEW GUINEA MILCH COWS.

No.	Mean Heart-girth Measurement.	Mean computed Live Weight.	Numer of Cattle. measured.
	inches.	lb.	
1	62	700	4
2	60	637	4
3	55	501	4
4	59	607	20
5	70	987	4
6	57	552	2
7	65	800	3
8	63	732	3
9	66	835	2
10	67	871	5
11	64	760	4
12	59	607	6
13	62	700	3
14	65	800	4
15	58	579	5
Mean	62	711	..
16	68	910	17

Pasture Consumption per Cow.—This may be determined by comparing the yield of clippings obtained from a grazed area immediately after the grazing trial with the clippings from a similar ungrazed check area, or, it may be determined by feeding a known weight of pasture to a cow in an enclosure, weighing the unconsumed portion at the expiration of a certain time and computing the feed consumed by difference. There are disadvantages to both methods. In the former, the assumption must be made that the grazed and check areas are identical and, unless an elaborate experiment is planned, this assumption may be far from the truth. While in the latter, a cow, which readily submits to stall feeding, would almost certainly consume more pasture if the pasture were already cut, than if the cow had to expend additional energy in grazing it. In this investigation, the latter method was chosen, for there was neither the necessary grass-cutting machine, nor experimental paddocks available with which to carry out estimations by the first method.

The feeding trials were conducted with the assistance of Brother Wochner at the Vunapope Catholic Mission at Kokopo where there is a herd of about nine hundred cattle, twenty of which are milked daily. These cows were quite typical of the majority of New Guinea cows and the daily milk yield averaged about 1 quart per cow. The cows were only milked once a day.

Before satisfactory results were obtained a considerable amount of preliminary experimentation was found necessary. After the first trial, it was found that even approximate values for the normal amount of pasture consumed during a given period could not be satisfactorily determined. Young pasture which had been obtained from areas in which the cows frequently grazed, was stall-fed to selected cows, but within a very short time after it had been plucked, and before it could be consumed by the cow, the pasture lost its freshness and became limp and dead in colour and the cows would not eat it.

It is a common habit in New Guinea to feed cows whilst milking them and it has been found that they relish fresh young bananas, in fact, the cows are loath to leave their stalls while any banana still remains in the feeding box. This allowed determinations to be made of an upper limit to the amount of feed, and hence dry matter, which cows will consume in 24 hours. By an upper limit is not necessarily meant the maximum amount of feed which the cows will consume in 24 hours but an amount which is in excess of that usually consumed by a cow on pasture during this period.

For the second preliminary experiment two cows each weighing about 700 lb. were chosen. In the early morning these cows were milked, and hand fed as usual and then instead of being turned out into the plantation to graze they were allowed to remain in their stalls for 24 hours, being fed from time to time throughout the day weighed quantities of fresh feed consisting of one part by weight of pasture and two parts by weight of freshly cut bananas. At dusk sufficient feed was fed to last until morning, and at the expiration of 24 hours the unconsumed feed was weighed. The cows had access to a common feeding box and were fed water *ad libitum*. The amount of feed consumed per cow was a little less than 50 lb.

During the trial, the stall fed cows had access to feed during the whole 24 hours and they appeared to take full advantage of it, whereas, if they had been turned out to graze, as usual, they would have been driven some distance before any feed was available and even then, considerable areas would have been covered during the course of the day in order to collect but small amounts of feed. In the heat of the day, the cows usually rest in the shade of any trees which might be nearby, thus losing more grazing time.

Having the above information upon which to work, a more accurate feeding test was then conducted. For this another two cows each weighing 710 lb. (heart-girth 62 inches) were chosen. They were stall fed as in the preliminary experiment with feed consisting of one part by weight of fresh young pasture and two parts by weight of bananas, the mixture having a moisture content of 79 per cent. The feed consumption is given in Table IX., the results being in good agreement with those previously obtained.

A similar experiment, in which chaffed young elephant grass (96 per cent.) and bran (4 per cent.) were fed instead of bananas and pasture, was later conducted with two Friesian cows weighing 910 lb. (heart-girth 68 inches) and the results are also given in Table IX. These cows would not eat the pasture-banana mixture.

TABLE IX.—DAILY FEED CONSUMPTION PER COW.

Experiment.	Fresh Feed consumed.	Moisture Content of Feed.	Dry Matter consumed.
	lb.	Per cent.	lb.
First (cows 710 lb.) ..	45	79	9.5
Second (cows 910 lb.) ..	124	89	13.6

In comparison with food consumption figures for dairy cows in temperate climates (Woodward, 1936) these figures are very low. This is probably due to the scarcity of palatable and nutritious feed, although, it is not to be expected that these animals would be large eaters, for they would then be too susceptible to overheating in a country where atmospheric temperatures are so high.

Digestible Crude Protein Consumption.—From the results of the preceding section and those given in Table VI we have—

lb.

Amount of dry matter consumed per day by a cow weighing 710 lb. < 9.5

∴ Amount of digestible crude protein consumed daily .. $< \frac{6.1 \times 9.5}{100}$

$< .58$

Amount of dry matter consumed per day by a Friesian cow weighing 910 lb... .. .. < 13.6

∴ Amount of digestible crude protein consumed daily .. .. $< \frac{6.9 \times 13.6}{100}$

$< .94$

Protein Requirements.—Protein requirements for dairy cows have not been determined for cows living under tropical conditions. In the tropics, there is less loss of body-heat due to radiation and conduction than in a colder climate. Hence, slightly smaller amounts of digestible nutrients, particularly fat and carbohydrate, may be required, but it is doubtful whether, in the case of protein, the difference would be sufficiently large to be of practical significance.

In addition to the true proteins, other nitrogenous compounds of a less complex character also occur in feeds in relatively small quantities. These are generally grouped with true protein under the term crude protein.

Some investigators have expressed their results in terms of digestible crude protein, some as digestible true protein and, in 1924, a Departmental Committee of the Ministry of Agriculture and Fisheries in England advocated expressing protein requirements in terms of "protein equivalent", which is the percentage digestible true protein plus one half the difference between the percentage of digestible crude and digestible pure protein.[a]

The lack of justification for stating protein requirements in terms of digestible true protein is emphasized by Forbes (1924), who states that, "The true protein of a feed does not contain all its amino acid fraction, while the crude protein contains all—and much else—some of related character—and some not related. All things considered, the writer favours the continuance of the crude protein standard in the literature of animal production." Morrison (*loc. cit.*) in his standard work, *Feeds and Feeding,* expresses results in terms of digestible crude protein in preference to digestible true protein, the reason for his choice being that "there may be as great a difference in nutritive value between two pure proteins, as there may be between a crude protein and the mixture of these simpler compounds occurring in common foods." McCandlish (1938, *a*), after discussing the best units in which to express protein requirements in feeding standards, sums up by saying, ". . . it appears probable that there is more justification for a feeding standard being based on digestible crude protein rather than on true protein."

The non-protein nitrogenous compounds may be divided into two portions, one consisting of amino acids and their derivations, and the other of simpler nitrogenous compounds. There is no doubt that the amino acids and their derivations contribute towards the protein value of the feed, and it has been pointed out by Mitchell and Hamilton (1929) that the simpler nitrogenous compounds, though probably of no use to carnivorous or omnivorous animals, may perhaps be of some value to ruminants, and their possible value to ruminants is set forth in a paper by McCandlish (1938, *b.*).

In view of these facts, it is concluded that there is more justification for protein requirements being expressed in terms of digestible crude protein than digestible true protein, and because of the small differences to be generally found between digestible crude and digestible true protein and the consideration given above, there appears to be little justification for the term "protein equivalent."

In Table X are given the more recent figures obtained by various investigators for the digestible crude protein maintenance requirements per 1000 lbs. live weight. Where results were expressed in terms of digestible true protein, the conversion was effected by use of the factor 1.2, and protein equivalent was converted by using the factor $\frac{12}{11}$.

(*a*) The relationship between digestible crude protein (C), digestible true or pure protein (T) and protein equivalent (E) may be obtained as follows:—

According to Armsby (1917) .. .. $5C = 6T$

$\therefore C = 1.2T$

And by definition .. .. $E = T + \frac{C-T}{2}$

$= \frac{11C}{12}$

TABLE X.—DIGESTIBLE PROTEIN REQUIREMENTS FOR MAINTENANCE.

Authority.	Date.	Protein Requirements.	Result in Terms of Digestible Crude Protein.
		lb.	lb.
Eckles	1913	.5 true	.6
Haecker	1914	.7 crude	.7
Armsby	1917	.5 true	.6
Hills *et al.*	1922	.6 crude	.6
Buschmann	1923	.45 true	.54
Hansson	1926	.5 true	.6
Möllgaard	1929	.45 true	.54
Morrison(*f*)	1938	.6 crude	.6
Forbes and Kriss ..	1931	.6 crude	.6
Mackintosh(*c*)	1938	.6 Prot. equiv.	.65

In Table X, the majority of figures indicate that for maintenance, a cow weighing 1,000 lb. requires approximately .6 lb. of digestible crude protein daily. During the latter stage of pregnancy, a cow would probably need considerably more than this amount, so that, when dealing with a mixed herd in which there are cows at all stages of pregnancy, slightly more digestible crude protein would be required.

In the tropics, it is possible that protein requirements may be slightly less, for reasons already indicated. On the other hand, there is the possibility that New Guinea cows, which are naturally inclined to be careless in their habits, may not utilize their feed as efficiently as cows in temperate climates, although there are no real grounds for such a supposition. Taking all these factors into account, it seems reasonable to conclude that for maintenance, milch cows in New Guinea require approximately .6 lb. of digestible crude protein per 1,000 lb. of live weight daily.

It has been found that maintenance requirements are more closely proportional to body surface than live weight. The reason for this is that the body loses most of its heat by radiation and conduction from the skin surface, and this loss is proportional to the area of that surface. Also, the weights of the most active tissues of the body, in animals of different sizes, is more closely proportional to the surface of their bodies than to their live weights. Taking these factors into consideration, it has been deduced that if .6 lb. of digestible crude protein per 1000 lb. live weight is required daily, then cows weighing 910 and 710 lb. would require approximately .55 and .45 lb. respectively (Morrison, 1938, *g*).

During recent years, much experimental work has been carried out on the subject of protein requirements for production. Protein requirements for production are generally expressed as so many lbs. of digestible crude protein per 10 lb. of milk containing a certain fat content. No information is given as to the protein content of the milk, for, generally, the results are intended for incorporation in feeding standards where the quality of the milk is judged according to its fat content. The protein content of milk may vary from 3.05 to 3.85 per cent. (Davies, 1939, *d*), and although equations have been obtained connecting the fat and protein content of milk (Kahlenberg and Voris, 1931, and Ohio Station Bulletin 446, 1930), the results obtained are unsatisfactory. Hence, most experiments planned to determine protein requirements for production are of little value in determining the number of units of digestible crude protein required to produce one unit of milk protein.

Hills *et al.* (1922), conducting extensive investigations over a period of 13 years, found that cows produced satisfactorily on rations providing 1.26 to 1.46 times as much digestible crude protein as there was protein in milk. As the result of an extensive review of literature published by investigators working in American experiment stations, Morrison (1938, *h*) concluded that, in addition to maintenance needs, a cow required 1.25 times as much digestible crude protein as there is protein in the milk. This is confirmed by McCandlish in Scotland (1938, *c*).

Thus it seems fairly well established, that in addition to the protein allowance for maintenance, approximately 1.25 times as much digestible crude protein as there is protein in the milk is also required. Cows of high productive capacity need more than this amount, although it is claimed that when amounts greater than 1.60 times the amount of protein in the milk are fed, the production is not increased appreciably (Morrison, 1938, *i*).

In New Guinea, the possibility is that a larger and not a smaller amount of protein may be required for production, for as already mentioned, cows may not be able to utilize their feed as efficiently as they would under temperate conditions. Nevertheless, it seems reasonable to conclude that at least 1.25 times as much digestible crude protein as there is protein in the milk would be required for production purposes.

Protein available for Production.—If the amount of digestible crude protein required for maintenance is subtracted from the maximum amount of digestible crude protein which is likely to be consumed in a day, the resulting amount represents the maximum amount of digestible crude protein which is available for production thus,

For the mixed herds	.58 — .45 lb.
	= .13 lb.
For the Friesian herd	.94 — .55 lb.
	= .39 lb.

Now the average amount of protein in New Guinea milk, as given in Table II., is

For the mixed herds	2.81 per cent., or
	.281 lb. per 10 lb. of milk.
For the Friesian herd	3.12 per cent., or
	.312 lb. per 10 lb. of milk.

and the amounts of digestible crude protein required to produce 10 lb. of milk of the above protein content are

For the mixed herds .. .. .. $\frac{5 \times .281 \text{ lb.}}{4}$

= .351 lb.

For the Friesian herd .. .. .. $\frac{5 \times .312 \text{ lb.}}{4}$

= .390 lb.

so that, the maximum amount of milk which the protein intake of these cows permits them to secrete is

For the mixed herds .. .. .. $\frac{.13 \text{ lb.}}{.0351}$

$= \frac{.13}{.0351 \times 2.58}$ quarts.

$=$ 1.4 quarts.

For the Friesian herd .. .. .. $\frac{.39 \text{ lb.}}{.0390}$

$= \frac{.39}{.0390 \times 2.58}$ quarts.

$=$ 3.9 quarts.

and considering the assumptions made, these figures are in good agreement with actual fact. Actual production figures are lower than the above figures, which is to be expected, for the above figures are based on high consumption figures and on results for digestible crude protein which were determined on the most nutritious portions of the pastures which were not always available to the cows. Nevertheless, it indicates that cows in New Guinea are producing approximately as much milk as their protein, and hence, feed consumption, permits and, although there may be other factors influencing their yield, this dietary factor is paramount.

Improving Milk Production.

To improve milk production in New Guinea, it is necessary to improve the milk producing qualities of the cattle and to provide them with a good supply of a more nutritious feed.

Because of their low feed consumption, the cattle need a supply of feed even higher in nutritive value (particularly protein) than that usually fed in temperate climates. By keeping the cattle within fenced areas their grazing could be so regulated that the pastures never reached maturity. This would provide the cows with a slightly more nutritious feed but the initial expense and upkeep of wooden fences would prohibit their use on many plantations. The most satisfactory solution to the problem would be to improve the pastures by the introduction of plants of high nutritive value.

The improvement of the cattle can be brought about by the introduction of new blood or by selection, that is, by the castration of inferior males and the selection of only the best females for breeding purposes. However, it would be no use endeavouring to improve the cattle by either of these means until legumes or other plants of high nutritive value have been first established in the Territory.

Tropical Fodder Plants.

Much scientific investigation has centred around the problem of finding a suitable legume that will grow under tropical conditions. Legumes are more valuable than grasses for they are richer in protein and also carry the all-important nitrogen into the soil. Unfortunately, lucerne, subterranean clover and many other valuable legumes which grow in temperate climates cannot be grown successfully in the tropics but there is no reason to believe that there are not other plants of equal nutritive value indigenous to the tropics.

Both in the *Handbook of Philippine Agriculture* (1939, *b.*) and in the *Bulletin of the Imperial Institute* (1939), special reference has been made to *Centrosema pubescens* as a forage crop. The plant is claimed to be relished by cattle and to be high in protein. In tropical America, Hawaii, Mauritius, Madagascar and many other countries, *Leucaena glauca* has been used for many years as a fodder. It is excellent for cattle but has a depilatory effect on horses. Both these legumes have been growing in the Territory for a number of years, having been first introduced as a cover crop and shade respectively. *C. pubescens,* and to a less degree, *L. glauca,* give a slightly disagreeable odour to milk if the cows have been feeding on them up to the time of milking. This may be remedied by taking the cows off the feed for about four hours before being milked.

The *Bulletin of the Imperial Institute* (1927) also contained a brief note on the possibility of growing *Pueraria thunbergiana* as a fodder crop. This legume was introduced into New Guinea several years ago as a cover crop and is to be found growing on some plantations. Information on varieties and methods of cultivation is to be found in a paper by Calvino (1937).

Preliminary tests over the last three or four years at the Fitzroyvale Plant Introduction Station in Queensland have revealed the promising growth of the legume *Stylosanthes guyannensis*—vernacular name "Trifolio"—from Brazil. McTaggart (1937) has described its growth habit, palatability, soil and climatic requirements and strain selection. *Stylosanthes sundaica* [(a)] (Townsville lucerne), a small legume found in the neighbourhood of Townsville, in North Queensland, has also been receiving some attention of late as a tropical legume. Both these plants have been recently introduced into the Territory where they are doing very well. The former has a high proportion of stalk and few leaves.

Wester (1924) claims that *Vigna marina* (Silani), a perennial vine growing in the Philippines, is two and three times as nutritious as green lucerne and cowpeas respectively. This vine is of very common occurrence in the coastal districts of New Guinea, its local name being "Beach Bean".

Burkill (1935) states that in parts of Java where cattle breeding is important *Sesbania grandiflora* (Agati) is much planted. The cattle eat the leaves, which are said to increase the milk yield. A saponin is said to be present but it appears to be harmless. This plant has recently been introduced into New Guinea and is growing in the Botanic Gardens.

On several occasions, mention has been made in the *Queensland Agricultural Journal* of *Alysicarpus vaginalis* as a fodder plant. This plant is to be found growing in many parts of New Guinea where it grows to a height of about two feet.

Desmodium heterophyllum (Japanese clover) grows well in the British Solomon Islands where it is considered an excellent cattle feed. Recently, it was introduced into the Territory and it is growing profusely on a plantation near Kokopo and in the Botanic Gardens.

(a) In the *Queensland Agricultural Journal*, this plant is also referred to as *S. mucronata* and *S. procumbens.*

The leaves and stalks of Peanut (*Arachis hypogaea*), Kau Kau (*Ipomoea batatas*), Velvet Bean (*Mucuna deeringiana*), Mauritius Bean (*Mucuna aterrima*) and Cowpea (*Vigna sesquipedalis*) plants are other crops which have been suggested as good fodder crops and which are already growing in the Territory.

All these plants and, in addition, paw paw (*Carica papaya*), sweet cassava (*Manihot utilissima*) and banana (*Musa sp.*) leaves have been analysed and the results are given in Table XI. These results will now be discussed, paying particular attention to protein contents.

The analyses of the first seven plants in Table XI. show them to be good sources of protein. *Leucaena glauca* has the highest protein content but is only of value as a fodder when less than three months old, for after this, it becomes woody and ultimately grows into a tree from 20 to 30 feet high. It ratoons well, but, unless allowed to grow to maturity, does not reseed. It would be an excellent soiling crop, but could not be fed to cows within four hours of milking because of feed-taint. This is a distinct drawback.

Sesbania grandiflora resembles *Leucaena glauca* in many respects both having a pinnate leaf. Unless frequently cut it also grows into a tree about twenty feet in height. Both the young and the mature plants have comparatively few leaves and even in its young stages the plant is rather woody. The latter reason probably accounts for the fact that in Java, only the young leaves are fed to cattle. It would be a very laborious task picking sufficient leaves each day for a dairy herd. *Manihot utilissima, Alysicarpus vaginalis, Desmodium triflorum* and *Centrosema pubescens* each have approximately the same protein content. The sweet variety of *Manihot utilissima,* when very young, is promising as a fodder. It is relished by goats, although the author has no knowledge of its being fed to cattle. *A. vaginalis* and *D. triflorum* are to be found growing in many parts of the Territory but they are not eaten by either cattle or goats if there is more palatable feed available. This is probably due to their dry woody nature. *C. pubescens* is grown on many plantations as a cover crop and is relished by cattle. However, it could not form part of a mixed pasture for it is a very rampant grower and would very soon shade out grasses and other constituents of the pasture. Furthermore, it causes an obnoxious feed-taint if fed within four or five hours of milking. *Desmodium heterophyllum* comes next in protein content, and is promising as a pasture constituent in pastures growing only a few inches high, although it is not a very succulent feed. The *Stylosanthes spp.* and *Pueraria thunbergiana* are also good sources of protein although not outstanding.

These analyses give valuable information on the composition of a number of legumes and other plants which have been suggested or are being used for the feeding of cattle in tropical countries. Valuable as some of these plants are as sources of protein, they would be of little value in improving existing pastures for they would either shade out all existing grasses, need constant attention or have some other draw-back. The ideal legume would be one which has a high protein content, is succulent and palatable, grows to a height of about 2 feet (so that it will not be hidden or overgrown by tall grasses), ratoons well and reseeds itself. None of these plants possessed all or most of these qualities. Because of this, attention was next turned to certain indigenous legumes which had come under notice.

TABLE XI.—ANALYSES OF PROMISING FODDER PLANTS.

Common Name.	Scientific Name.	Water.	Crude Fibre.	Sugar and Starch.	Crude Protein.	Eth. Sol. Extract.	Ash.	Nature of Specimen.	No. of Analyses.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.		
..	*Leucaena glauca* ..	70	7.7	13.1	6.8	.5	1.9	Stalks and leaves ; immature plant	1
..	*Leucaena glauca* ..	64	10.6	17.7	4.5	.3	2.9	Leaves ; mature plant	1
Agata ..	*Sesbania grandiflora* ..	77	4.2	11.5	4.7	.7	2.9	Leaves ; mature plant	1
Cassava (sweet) ..	*Manihot utilissima* ..	77	8.3	7.4	4.5	.6	2.2	Leaves ; immature plant ..	1
..	*Alysicarpus vaginalis* ..	67	16.5	9.3	4.4	.3	2.5	Stalks and leaves ; plant flowering	1
Centrosema ..	*Centrosema pubescens* ..	79	8.0	6.2	4.4	.3	2.1	Stalks and leaves ; immature plant	1
Clover ..	*Desmodium triflorum* ..	71	8.9	13.4	4.4	.5	1.8	Stalks and leaves ; immature plant	1
Japanese clover ..	*Desmodium heterophyllum*	72	10.4	10.9	4.0	.5	2.2	Stalks and leaves ; immature plant	1
Townsville lucerne	*Stylosanthes sundaica* ..	81	6.7	6.7	3.3	.3	2.0	Leaves and stalks ; immature plant	1
Trifolio ..	*Stylosanthes guyannensis*	74	7.3	13.0	3.2	.2	2.3	Stalks and leaves ; immature plant	1
Trifolio ..	*Stylosanthes guyannensis*	74	7.3	13.0	3.2	.2	2.3	Stalks and leaves ; immature plant	1
..	*Pueraria thunbergiana* ..	83	6.8	4.8	3.1	.3	2.0	Stalks and leaves ; immature plant	1
Velvet bean ..	*Mucuna deeringiana* ..	82	5.5	7.0	2.9	.6	2.0	Stalks and leaves ; immature plant	1
Mauritius bean ..	*Mucana aterrima* ..	80	6.5	8.1	2.8	.5	2.1	Stalks and leaves ; immature plant	1
Beach bean ..	*Vigna marina*	89	2.2	4.6	2.5	.6	1.3	Leaves and stalks : immature plant	1
Banana ..	*Musa* sp.	82	7.1	5.8	2.4	.4	2.3	Leaves ; immature plant ..	2
Peanut ..	*Arachis hypogaea* ..	91	2.6	2.3	2.2	.8	1.1	Stalks and leaves ; immature plant	2
Peanut ..	*Arachis hypogaea* ..	88	4.7	3.5	1.8	.6	1.4	Stalks and leaves ; mature plant ..	2
Cowpea ..	*Vigna sesquipedalis* ..	79	6.7	9.1	2.0	.4	2.8	Leaves and stalks ; immature plant	1
Kau kau ..	*Ipomoea batatas* ..	85	3.8	6.4	1.8	.5	2.5	Stalks and leaves ; immature plant	2
Paw paw ..	*Carica papaya*	80	6.3	9.1	1.1	.5	3.0	Stalks and leaves ; mature plant ..	2

There were four legumes indigenous to the Territory which, from casual observation, appeared to possess many of the above-mentioned qualities. The results of their analyses are given in Table XII. The first plant will be described in detail later. *D. polycarpum* was found growing on the Mainland and, in appearance, it greatly resembles *D. tortuosum*. *I. endecaphylla* was a small creeping plant found on New Britain and New Ireland. There was some doubt as to whether this plant was truly indigenous. *G. tenuiflora* was discovered on the Mainland, and in appearance it greatly resembles a small *Centrosema pubescens*. Seeds of these four legumes were collected and grown in experimental plots in the Botanic Gardens.

TABLE XII.—COMPOSITIONS OF PROMISING FODDER PLANTS.

Scientific Name.	Water.	Crude Fibre.	Sugar and Starch.	Crude Protein.	Eth. Sol. Extract.	Ash.	Nature of Specimen.	No. of Analyses.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.		
Desmondium tortuosum	72	9.9	10.3	4.8	.7	2.3	Immature ..	7
	50	15.6	28.4	2.7	.5	2.8	Full maturity	6
Indigofera endecaphylla	74	7.8	11.1	4.3	.7	2.1	Immature ..	1
	69	12.9	11.4	4.0	.6	2.1	Mature ..	1
Galactia tenuiflora ..	78	9.8	5.1	4.3	.9	2.5	Immature ..	1
	72	11.0	9.3	3.7	.7	2.7	Mature ..	1
Desmodium polycarpum	79	9.1	5.0	4.0	.7	2.2	Immature ..	1
	74	12.8	7.0	3.2	.6	2.4	Mature ..	1

Desmodium tortuosum.*—Of the plants mentioned in Table XII. *D. tortuosum* has the highest protein content, and was found to be superior to the other plants in several respects.

This legume was first discovered growing on New Hanover, but it has since been found on New Ireland, New Britain, and the Duke of York Islands. It is known as "koako" by the natives of the Duke of York Islands, who claim that the plant has a medicinal value. It is relished at all stages of growth by both cattle and goats.

Normally, the plant grows to a height of about 2 ft. 6 in., although plants over 5 feet were noticed growing under the shade of an embankment. It appears to grow well on almost any type of soil, and photographs 1 and 2 show the mature plants, under similar climatic conditions, growing on a heavy clay soil and on a poor light volcanic soil, respectively. If anything, the clay soil seems to favour a lower and more dense growth. When cut, the plant ratoons well, and photographs 3 and 4 were taken of plants having ratooned for the first and second time respectively. In the Botanic Gardens, there are plants which have ratooned for the fifth time and are still as healthy as ever, although after the fourth ratoon the ratio of stalk to leaf began to increase and the plants did not grow to their former heights. Photographs 5 and 6 were taken two and eight weeks, respectively, after sowing the seed. The plant generally reaches maturity in less than two months and reseeds of its own accord.

* The plant was first named *D. stipulaceum*, by which name it has been referred to in certain departmental reports. Recently Mr. W. D. Francis, of the Botanic Museum and Herbarium in Brisbane, identified the plant definitely as *D. tortuosum*.

Five of the more important minor constituents of koako have been determined and the results are given in Table XIII.

TABLE XIII.—MINOR CONSTITUENTS OF KOAKO.

Constituent.	Immature Plant.	Mature Plant.
Calcium	.239 per cent.	.224 per cent.
Phosphorus	.124 per cent.	.084 per cent.
Iron	.0090 per cent.	.0082 per cent.
Carotene	180 mgms./kg.	210 mgs./kg.
Vitamin C	.33 per cent.	.24 per cent.

Calcium, phosphorus and iron were estimated by methods similar to those previously described for milk (Hutchinson, 1939, *b*). The carotene content of the plant was estimated by the method developed by Bolin and Khalapur (1938). The carotenoids of plants usually consist chiefly of β-carotene with small admixtures of α-carotene and cryptoxanthine (Fixsen and Roscoe, 1937-38, *a*, and Morton, 1940). Since .6 microgram of β-carotene has a vitamin A potency of approximately 1 international unit a rough conversion of carotene into international units of vitamin A could be made by multiplying the carotene content in micrograms by 1.6. Vitamin C was estimated in an acqueous extract by titration with 2 : 6 dichlorphenolindophenol after the removal of colouring and reducing substances with mercuric acetate and hydrogen sulphide.

It is interesting to compare the results obtained for immature koako with those obtained by different workers for young lucerne, the "king of all fodders".

TABLE XIV.—COMPOSITIONS OF KOAKO AND LUCERNE.

Constituent.	Koako.	Lucerne.	Reference.
Water	72 per cent.	82.4 per cent.	Fox and Wilson (—)
Crude protein	4.8 per cent.	6.2 per cent.	Fox and Wilson (—)
Digestible crude protein ..	3.8 per cent.	3.2–4.0 per cent.	Morrison (1938, *j*)
Ether Sol. Extract ..	.7 per cent.	.6 per cent.	Fox and Wilson (—)
Sugar and starch.. ..	10.7 per cent.	6.4 per cent.	Fox and Wilson (—)
Crude fibre	9.9 per cent.	2.4 per cent.	Fox and Wilson (—)
Ash	2.3 per cent.	2.2 per cent.	Fox and Wilson (—)
Calcium..	.239 per cent.	.385 per cent.	Fox and Wilson (—)
Phosphorus	.124 per cent.	.11 per cent.	Fox and Wilson (—)
Iron	.0090 per cent.	.0083 per cent.	Fox and Wilson (—)
Carotene..	180 mgs./kg.	90-400 mgms./kg.	Fixen and Rosecoe (1937–38, *b*)
Vitamin C	.33 per cent.	.07–.38 per cent.	Fixsen and Roscoe (1937–38, *b*)

Excluding crude fibre, koako contains a higher percentage of dry matter than lucerne, the excess being mostly composed of sugar and starch. The crude protein content of lucerne is higher than that of koako, but the results are not exactly comparable. Crude protein was estimated in the lucerne plant when 3–5 in. in height while the results for koako were obtained from a number of samples collected at all stages of growth up to the budding stage. From the results of Table XV., however, it is seen that the crude protein content of very young koako would be nearer 6 than 5 per cent. The ether soluble extract, the ash, phosphorus and iron contents are higher in koako than in lucerne, but calcium is considerably lower. The vitamin A and C content of koako compare very favorably with that of lucerne.

Before drawing final conclusions from this comparison, it should be remembered that the koako chosen for analysis was not any particular strain chosen for its high nutritive value, nor did it receive particular attention, such as the application of fertilizers, during its cultivation. If only the best strains of koako high in nutritive value were cultivated and the soil upon which they were growing was kept well watered and, if necessary, fertilized, koako might rank as high in nutritive value as lucerne.

Table XV. gives the crude protein content and the yield per acre of the plant at different stages of growth. Figures for yield were obtained from a small experimental plot consisting of three rows of koaka, 20 feet long and 2 feet apart, the density of planting working out at 300,000 plants per acre. The multiplication of corresponding pairs of figures gives the yield of crude protein at each stage of growth.

TABLE XV.—PROTEIN CONTENT AND YIELD PER ACRE OF KOAKO.

Stage of Growth.	Yield per acre.	Crude Protein.	Crude Protein Yield per acre.
	lb.	Per cent.	lb.
Quarter mature (6 inches) ..	1,320	4.96	65.47
Half mature (12 inches) ..	2,360	4.83	113.99
Three-quarters mature (18 inches)	3,150	4.48	141.12
Budding	3,660	3.45	126.27
Mature	3,510	2.48	87.05

If the yield of crude protein is plotted against stage of maturity, Figure 1 is obtained. From this figure, it is seen that the largest yield of crude protein for a given area is obtained by feeding the plant immediately before the budding stage. Of course, the younger the koako is grazed the higher is its nutritive value but it has less bulk in its younger stages and, in order to grow sufficient to feed a herd, it would be necessary to have extensive areas growing so that, after a certain area had been grazed, sufficient time would elapse for the plant to make fresh growth, before grazing it again. The yields per acre of first and second ratoons were found to be approximately 4,500 and 6,210 lb. respectively.

On a dry matter basis, the crude protein content of immature koako is approximately 17.1 per cent. and the digestible crude protein is 13.6 per cent., whilst the crude protein content of young New Guinea pasture is 8.5 per cent. and the digestible crude protein is 6.1 per cent. Consider a pasture consisting of 90 per cent. immature koako by weight and 10 per cent. young pasture. This pasture would have a digestible crude protein content of 12.85 per cent. on a dry matter basis. Young koako is relished by cattle and it is reasonable to assume that, if unrestricted, a New Guinea cow weighing 710 lb. would consume approximately 9.5 lb. dry weight daily and a Friesian cow weighing 910 lb., 13.6 lb. (from

Table IX.), so that the daily protein digestion of these cows would be 1.22 and 1.75 lb. respectively. Deducting protein requirements for maintenance and computing as before, it is seen that this amount of protein would be sufficient for the daily production of nine and twelve quarts of milk per cow for the mixed and Friesian herds, respectively. In the case of the mixed herds, the figure is

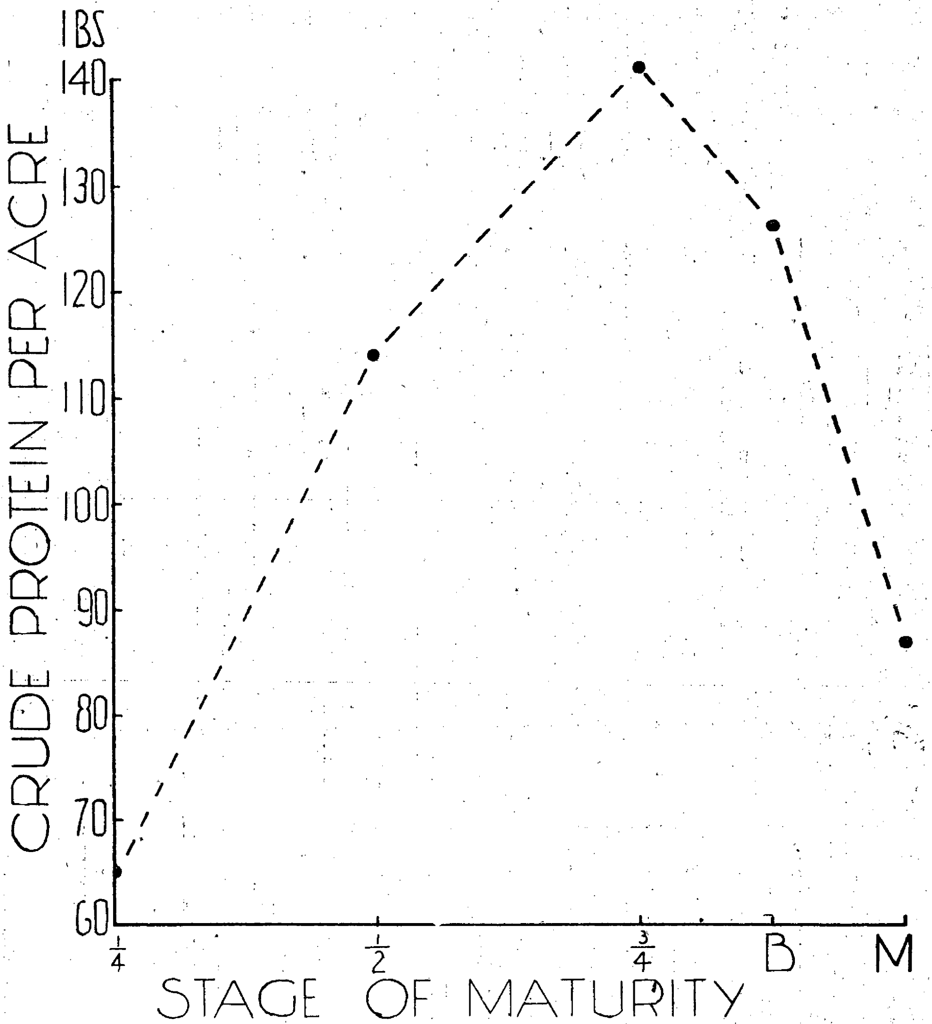

Figure 1.

over six times the yield computed previously and nine times the actual yield, and in the case of the Friesian herd, it is over three times the computed yield and six times the actual yield. These figures could be further increased by the addition of concentrates to the daily ration. Because of the numerous assumptions inherent in the above calculations, the results can only be considered as rough approximations.

It is not considered that koako is the ideal legume for New Guinea conditions, nor that it is superior to all other legumes growing in the Territory, but it possesses distinct advantages over the other legumes considered during this investigation. It is of easy cultivation, palatable, has a high protein content and would be a valuable asset to existing pastures.

As already emphasized, the milk yield of the common New Guinea cow cannot be improved by feeding alone. It is necessary that the herds should be improved by the introduction of new blood or by selection, but this improvement cannot be permanently achieved unless the cows are also given a more nutritious feed, which can be best supplied by feeding the cows on pasture containing a high proportion of a legume such as koako.

Summary.

A number of mixed milk samples collected from a Friesian and other mixed herds in the Territory of New Guinea have been analysed. The fat content was found to be high, while the solids-not-fat and specific gravities were low. The solids-not-fat portions of twenty-five milk samples were analysed and the Koestler number and "*constant moleculaire simplifiée*" computed. These results led to the conclusion that the cause of the low solids-not-fat was probably the result of inadequate feeding.

The milk yield of New Guinea cows is extremely low but it has been shown that it is as high as the protein consumption of the cows permits. To arrive at this conclusion, a number of pastures were analysed for digestible crude protein and the weight and daily feed consumption of a number of cows determined.

Numerous fodder crops have been analysed and the results discussed, paying particular attention to protein contents. *Desmodium tortuosum,* which is indigenous to the Territory, was shown to have great possibilities as a tropical fodder crop. Its composition is compared with that of lucerne.

Acknowledgments.

I wish to acknowledge with gratitude the assistance I have received from numerous planters in supplying me with milk and pasture samples—from Mr. Reed, of Reed's Rabaul Dairy, and Father Lyons, of the Vunapope Catholic Mission, for allowing me to carry out feeding experiments on their cattle; and to Mr. W. D. Francis, of the Botanic Museum and Herbarium in Brisbane, and Mr. R. E. P. Dwyer, of this Department, for identifying botanical specimens.

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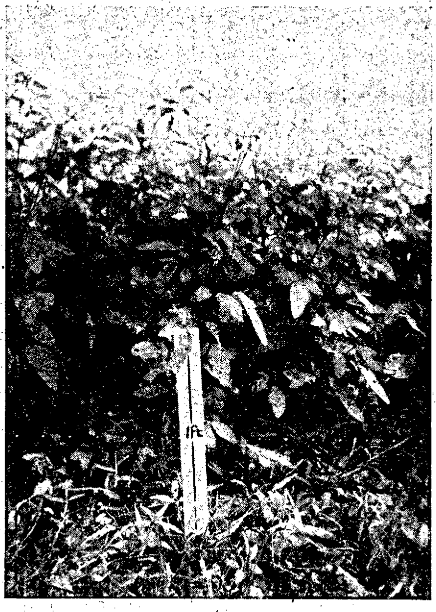

Figure 1.—*D. tortuosum* growing on heavy clay soil.

Figure 2.—*D. tortuosum* growing on light volcanic soil.

Figure 3.—*D. tortuosum*, first ratoon.

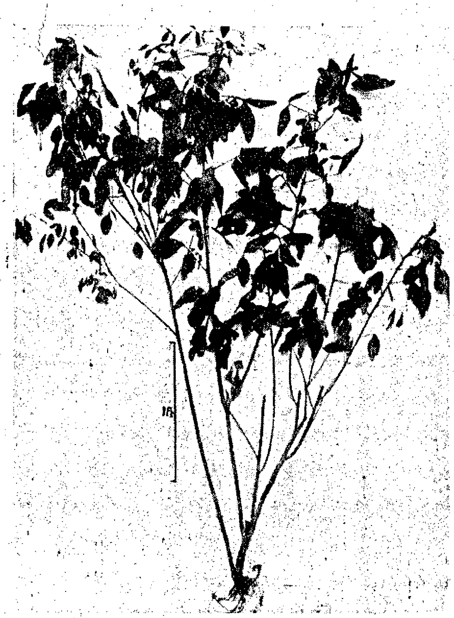

Figure 4.—*D. tortuosum*, second ratoon.

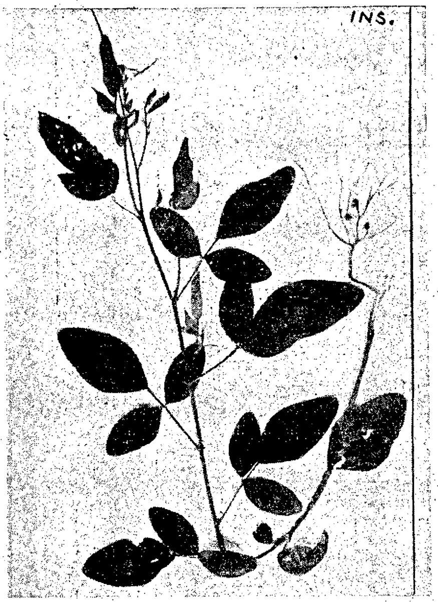

Figure5.—Mature *D. torfuosum*, eight weeks old.

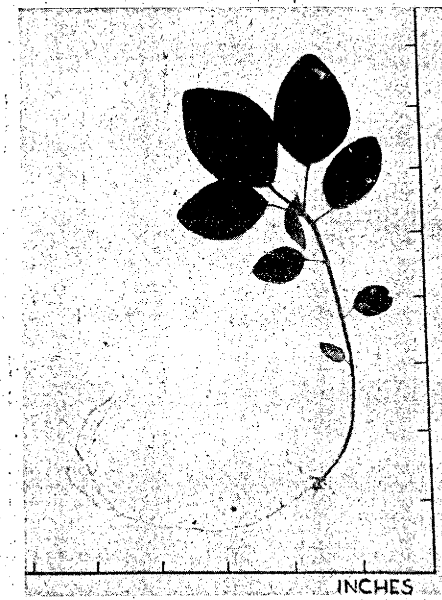

Figure 6.—Young *D. tortuosum*, two weeks old.

A herd of typical New Guinea cattle.

A pure-bred Friesian herd in New Guinea.

(Photographs by Chee Hoi Meen.)