The Influence of the Various Mineral Constituents on Animal Nutrition, and the Effects of Deficiencies and Evidence of such in Ceylon.

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CEYLON cattle and other live-stock are inferior in some respects to those of other countries. This inferiority has been attributed to a variety of causes—for instance, the hot climate, insufficiency of pasture, disease, and lack of skill on the part of the cattle-breeders. None of these causes offers an adequate explanation.

Hot climate cannot be held to be the cause in view of the fact that other countries with similar or even hotter climates can breed much superior cattle: Parts of India, Texas, the Argentine, and Australia, for example. Probably the hot climate has some detrimental effect on cattle imported from the Temperate Zone; but even for such cattle, in my limited experience, the climate of Colombo does not appear to have any very serious ill effects, granted that conditions of feeding and management be attended to.

The position as regards disease in Ceylon is much better than, for instance, in India or South Africa. Rinderpest is not enzootic as it is in India; Surra is not present to the same extent; Foot and Mouth disease and Piroplasmosis are no worse than in India; T.B. & C.A. and such diseases as East Coast Fever, and Nagana are unknown in Ceylon.

As regards our horses, they are remarkably free from disease with the exception of Osteoporosis; and this is an important exception in connection with the subject we are discussing. Such diseases as Glanders, Equino Piroplasmosis, African Horse Sickness, and Dourine are absent, while Surra is practically unknown.

It will, therefore, be seen that as far as disease is concerned, we are in a much better position than many other countries.

In parts of the Island, there are occasions when pasture is scarce, especially during dry weather. Ceylon does not, however, suffer from droughts, comparable with such as occur in Australia and Texas, where thousands of head of stock may

succumb in a severe drought. The wet zone practically never suffers from severe drought. The opening up of large areas under cultivated crops, such as tea and rubber, has undoubtedly lessened the area of jungle and waste land available for grazing in parts of the Island. At the same time, it must be pointed out that there is no evidence that the inferiority of Ceylon cattle dates from the opening up of such cultivated areas; nor are the cattle of the planting districts inferior to those of non-planting districts. Again, cattle kept on coconut estates in the Western Province, where pasture is generally available practically the whole year round, show the same inferiority. On our Farm at Ambepussa, where of recent years pasture has been ample all the year round, the cattle, although they appear full, do not develop as they should.

Lack of skill on the part of cattle-breeders does exist, but I am inclined to think that this is an effect rather than a cause. That the Ceylon cattle-breeder has not reached a higher standard in the art of cattle-breeding is more likely to be due to lack of response on the part of his raw material rather than to inherent incapability of mastering the subject. Included under this head, inbreeding is frequently advanced as a potent cause of the trouble, yet no convincing evidence that inbreeding is unduly rife is brought forward.

Until recent years, practically the sole means of transport in Ceylon was by cattle transport. The constant movement of carts from one part of the Island to the other must have resulted in the mixing of strains from different localities. Again, in the past, there has been a tendency to exaggerate the evils of inbreeding. Indiscriminate inbreeding may be harmful, but inbreeding with rigid elimination of weakly and unfit specimens is not. Witness the development of such breeds of cattle as the Shorthorn, Hereford, and Aberdeen Angus, and the Thoroughbred horse.

The vast majority of Ceylon village cattle are quite uncared for in any way, and under such conditions, weakly and unfit calves die at an early age, leaving only the stronger and fitter to carry on the race, and thus minimising the effects of inbreeding if such should occur.

As none of the above factors appears to offer an adequate explanation of the inferiority, I would suggest another possible factor, namely, deficiency of certain mineral elements in the soil and pasture. The mineral constituents of a food-stuff are those substances, which remain as a residue after combustion of a sample. In an analysis of a food-stuff, they are all grouped together under the heading " Ash." This heading includes such substances as Calcium, Phosphorus, Potassium, Sodium, Magnesium. Iron, Silicon and Iodine. They are not present in

the food-stuff, nor in the animal body in a pure state, but as salts of the various Acids, such as Calcium Carbonate, Iodine Chloride, Magnesium Sulphate, etc.

Each of these substances is present in varying amounts in the different grasses and fodders, and in varying amounts in samples of grasses of the same botanical species grown on different soils. It will be readily understood that as the plant derives these substances from the soil, the amounts in which they are present in the plant will vary with the nature of the soil.

Grouping them all together, Smith, in his Veterinary Physiology, summarises their functions as follows:—

" The salts of the body direct its metabolism: they are connected with assimilation, secretion, and excretion, and the building up of the skeleton. Moreover, they maintain the blood and lymph at neutrality; the saliva alkaline, the gastric juice acid, the intestinal fluid alkaline, and the urine alkaline or acid depending on the species of animal. They also regulate the water flow from blood to tissue and *vice versa*; they play an essential part in blood clotting, rhythmical contraction of the heart, irritability of muscle and nerve, milk curding, and growth."

It will be seen then that their functions are important and varied. A few of the more important of these substances merit a more detailed description: Calcium, for instance, forms a greater part of the animal body than any other of the mineral elements. It is present in all the tissues of the body, but in greatest amount in bone. It is an essential part of the structure of bones, teeth, tusks, and horns; and hence young, growing animals require larger amounts than adults. If adequate amounts are not available in the diet, neither bone, horn, nor tusks can reach their fullest developments.

Large amounts of Calcium are excreted daily in the milk of lactating animals, varying with the quantity of milk produced. A cow giving 12 bottles of milk per day will excrete in the milk alone about $1\frac{1}{2}$ oz. Calcium in addition to that excreted in the fæces and urine.

As well as being required for the development and replacement of wear and tear in bony structures, and for the production of milk, Calcium has another and very important function.

In the daily metabolism of the body, that is, the digestion of food, the breaking down, and building up of body tissues, and the production of energy, etc., injurious acids, such as Carbonic, Phosphoric, Sulphuric, and Hydrochloric, are produced. In order that these injurious acids may be rendered harmless, and removed from the body, they must combine with basic elements, such as Calcium, Potassium, Magnesium, and Sodium. An

animal, which is fed on a ration rich in acid elements, will, therefore, require large quantities of the basic elements including Calcium to effect their removal.

The diet of cattle containing, as it does, a large proportion of grass, is unlikely to contain an excess of acid elements, unless the grass is grown on sour, swampy, soil, when it may contain a high percentage of Oxalic Acid; but in the case of the ration, usually fed to horses in Ceylon, this factor is apparently of importance.

Horses in Ceylon are fed almost entirely on cereals, such as Oats, Bran, and Chaff; they get no hay, and comparatively little grass. Cereals, as a class, are poor in Calcium, but are rich in Phosphorus. Hence the horses are frequently receiving less than their minimum requirements of Calcium, and at the same time, a heavy excess of phosphorus, which, in its elimination, depletes the body of its basic elements including Calcium. This I consider to be undoubtedly the cause of the prevalence of Osteoporosis among horses in Ceylon.

Sufficient has been said to show that Calcium is a very essential element of the diet for growth, especially of the skeleton, milk production, and the maintenance of a proper balance between the acid and basic constituents of the body.

Phosphorus.—Like Calcium, Phosphorus is an essential part of the bony and connected structures, and when it is deficient in the diet, the best development of these structures cannot be obtained. It is also excreted in large amounts in the milk.

Sir Arnold Theiler's work in South Africa with cattle, bred from imported European stock and reared on veldt soils deficient in Phosphorus, has directed attention to the great importance of this element in the diet.

His work shows that in addition to being required for the actual building up of bone, and for the continued production of milk, it has a general stimulating effect on the whole system; for instance, young cattle, which had remained practically stationary in growth and weight for months on Phosphorus-deficient pasture, made remarkable increases in weight, following the addition of small quantities of Phosphorus in the form of Bone Meal to the diet.

One lot of cattle getting bone meal in addition to the grazing gained an average of 320 lb. per head in 10 months, while a corresponding lot in the same pasture, but not getting bone meal, gained only 70 lb. per head. On reversing the experiment, that is, transferring the bone meal from one lot to the other, the results were even more striking, for the lot, which in the previous 10 months had gained only 70 lb. per head, now gained 200 lb. per head in 4 months, while the others gained only 20 lb. per head.

These remarkable increases in weight were due to a certain extent to the formation of new bone, but also to the production of fat and muscle, thus showing that Phosphorus, in addition to being used as a building stone in the formation of bone, had acted as a general stimulant to all the vital processes of the body. An effect, which, as Theiler points out, is very similar to that produced by vitamines.

An excess of Phosphorus, especially if there be a deficiency of Calcium and other basic elements, may have injurious effects by causing a drain on the Calcium reserves of the body.

Potassium, Sodium, and Magnesium are present in all the tissues, and tissue fluids of the body, but in much smaller amounts than in the case of Calcium and Phosphorus. The risk of their being deficient in the diet is, therefore, less than in the case of Calcium and Phosphorus.

Their chief function is the maintenance of the proper balance between the acid and basic constituents of the body fluids. This is a most important function. The blood plasma, for instance, comes into contact, directly or indirectly, with all the cells of the body. These cells are very sensitive to, and adversely affected by, any increase in the acidity of the fluid. The ordinary activities of the body entail the combustion of Proteins, Fat, and Carbohydrates with the production of such injurious substances as Carbonic, Hippuric, Uric, Sulphuric, Hydrochloric, and Phosphoric Acids. These must all be neutralised and removed as they are produced. This neutralisation is effected by their combination with the bases, *e.g.*, Pot: Sod: and Mag: Calcium and N.H. 4 to form neutral salts. If any of these be deficient in the food, there is a call on the reserve stores in the bones and other body tissues. In addition, they are required to maintain the osmotic pressure of the cells and body fluids at the level necessary for the carrying on of their vital functions.

Considerable amounts of Potassium are excreted in the milk.

Iodine—Is required for the formation of the active principle of the thyroid gland, which has very important functions in the regulation of metabolism and growth.

Iron—Is an essential constituent of the Haemoglobin of the blood, and plays an important part in oxidation and catalysis of enzymes.

Silicon—Is present in minute quantities in bone, horn, and hair. It is an element not at all deficient in Ceylon pasture; in fact it is more likely to be present in excess. In combination with Calcium as Calcium Silicate it forms a very insoluble substance, so that Calcium, present in a pasture grass in the form of Calcium Silicate, is of no value to the animal body. For instance, rice bran, on chemical analysis, showed a high percentage of Calcium,

yet on feeding this to young cattle, the results were very disappointing. This was probably due to the fact that much of the Calcium was in the form of insoluble Calcium Silicate.

An adequate supply of these substances, then, is essential for the proper growth, and development of animals. The following ill-effects have been found to follow when the diet is deficient in one or more of the elements.

The young animals grow slowly, and take a long time to mature; they are stunted in size, and show very poor development of the bony skeleton, and its associated structures, such as tusks and horns. The death-rate especially among young stock is high; calves at birth are very small; the rate of sterility is high; " Pica " or depraved appetite is common, and the animals are seen to eat clay, sand, earth from ant-hills, lime-wash from walls and other kinds of rubbish. When Phosphorus is the element which is deficient, a particular form of depraved appetite in which cattle will readily eat bones, may be developed.

Diseases, such as osteoporosis and osteomalacia, are prevalent. If Iodine be deficient, goitre is common.

On certain pastures in New Zealand, which appeared luxuriant and abundant, but which were shown to be deficient in Iron and Phosphorus, it was found that cattle could not live for longer than 12 months, while sheep died within 3 months.

All these ill-effects will be shown in their most striking form, when cattle of improved, quickly-growing, and deep-milking breeds are introduced to an area, where mineral constituents are deficient.

The indigenous cattle of such areas, while they are small in size, and mature very slowly, are unlikely to show the more striking ill-effects, such as the development of osteomalacia.

The condition of affairs as found in Ceylon agrees very closely with the symptoms detailed above, which have been shown to be due to deficiency of mineral elements.

Our native cattle are of very small size, grow, and mature very slowly, their bones are very light, and poorly developed, the horns are small and stunted, and milk-producing powers are very poor. On the other hand, it must be pointed out that the muscular development of cart-bulls is good for the size of the animals. This applies, however, only to matured adult cattle over 6 years of age. The natural rate of increase is very low, the cattle population having remained practically stationary at 1,500,000 for the past 20 years, as far as statistics show.

The failure of the cattle population to increase is not due to deaths from contagious diseases, nor to slaughter of cattle for food purposes, and indicates a high rate of sterility and calf mortality.

As regards imported cattle of improved breeds, it is quite impossible to keep them entirely on grazing. They must be stall-fed, or they succumb.

Bone-eating is not very common, but is seen in parts of the Island.

Depraved appetite is very common, the usual substances eaten being gravel, earth from ant-hills, and lime-wash off walls.

Ceylon-bred horses, with the exception of a few bred on Delft, are almost invariably stunted, weedy specimens. They are cow hocked, droop rumped, and knock-kneed.

Osteoporosis is very common, especially among imported horses. This disease does not occur in the Jaffna Peninsula or on the islands off the north-west coast.

Ceylon-bred buffalos are smaller in size, and slower in rate of growth than Indian buffalos, and have not the same size and thickness of horn. Wild buffalos in the Game Sanctuary are larger than the domesticated stock.

Ceylon Goats are rather small, but are not so greatly inferior as the cattle, horses, and buffalos.

As regards wild animals, a striking feature is the inferiority in horn and tusk of Ceylon Herbivora, compared with similar species in India.

Sir Samuel Baker's remarks on this point in his book, *Eight Years in Ceylon*, are of interest. After stating that tusks in elephants in Ceylon are of the greatest variety, he says, "Nothing produces ivory or horn in fine specimens throughout Ceylon. Although some of the buffalos have tolerably fine heads, they will not bear a comparison with those of other countries. The horns of the native cattle are not above 4 inches in length. The elks' and the spotted deer's antlers are small, compared with deer of their size on the continent of India. In India, the bull elephants have tusks, and the cattle and buffalos have very large horns. My opinion is that there are elements wanting in the Ceylon pasturage (which is generally poor) for the formation of both horn and ivory."

These remarks by Sir Samuel Baker will be borne out by any sportsman familiar with Ceylon game.

The preference, which wild animals show for water from dirty, muddy pools even when clear, river water is available close at hand, is probably a form of pica.

Ceylon carnivora are not, to my knowledge, inferior to those of similar species in India.

To summarise—Ceylon herbivora are deficient in the following respects; Firstly in development of the bony skeleton and its associated structures, such as horn and tusk; secondly in rate of growth; thirdly, in milk-producing powers; fourthly

Osteoporosis occurs commonly in horses all over the Island with the exception of the Jaffna Peninsula and Delft Island; fifthly the rate of increase of the cattle population is almost nil; and sixthly, imported stock of larger and better breeds cannot live on Ceylon pasture without supplementary feeding.

These deficiencies are not shown to the same extent by goats, whose diet consist of shrubs and bushes rather than grass and are not shown at all by Ceylon carnivora.

It will be seen, therefore, that there is a close analogy between the state of affairs in Ceylon, and certain effects, which it has been proved, can be produced by deficiency of mineral elements. Judging from the evidence shown by the live-stock, the elements, which one would expect to find deficient, are Calcium and Phosphorus. Mr. Joachim's analyses of pastures show that these two elements are generally deficient save in the Hambantota and Jaffna districts.

It is of interest that grass from Jaffna and Hambantota districts did not show deficiency of Calcium or Phosphorus. In Jaffna, Osteoporosis does not occur, while the ability of the pasture of the Hambantota district to maintain live-stock has been well shown by the rate, at which game have increased in the Yala Game Sanctuary.

The following methods have been adopted in various parts of the world to supply deficient minerals:—

(1) Manuring the soil with Phosphatic manures and Calcium. This is obviously the most direct method of attack, but has the drawback of being expensive. It is more suited to mixed farming than to grazing.

(2) Supplementing the grazing by food-stuffs known to be rich in the deficient minerals. As regards Phosphorus, there are many food-stuffs, available in Ceylon, rich in this element. For example, the various poonacs and pollard.

Food-stuffs rich in Calcium are, however, scarce in Ceylon, and of the commonly-used food-stuffs, two only can be classified as satisfactory suppliers of Calcium, namely, Gingelly Poonac and Dhall. As a class, food-stuffs derived from the Leguminosae are rich in Calcium. The well-known value of Lucerne for cattle and horse feeding is probably connected with its high Calcium content. Efforts to acclimatise this plant in Ceylon are worthy of support.

(3) Addition of Bone Meal: This would appear to be the most practical method available. It has given very good results in South Africa, America, and England. By feeding bone meal, both Calcium and Phosphorus

are supplied in a form readily availed of by the animal body. Bone meal may be fed by mixing with the other food-stuffs, if such are being fed. For cattle on pasture, it can be mixed with a little salt, and given as a lick, or the cattle may be passed through a crush, and a known quantity administered to each one as it passes. Theiler's work has shown that spasmodic feeding of bone meal is worthless. To obtain results, it must be given daily.

The bone meal used must be guaranteed sterile, and fit for live-stock feeding. Ordinary bone manure should not be used on account of the risk of introducing disease.

Special brands of bone meal suitable for this purpose are now on the market, and can be obtained in Colombo.

Any of these three methods can be recommended to Ceylon cattle-breeders. It should be pointed out that the cost of the bone meal will be largely recovered in the enhanced value of the manure from the cattle.

Discussion.

MR. STURGESS remarked that all he had heard that day connected with diseases and deficiencies directed attention to the wonderful balance of nature.

The problems regarding mineral deficiencies in diet of animals had come into prominence during the last decade together with vitamines, deficiency diseases and the very powerful glandular extracts.

Up to 1914 the teaching was that animals obtained what they required from the food with the exception of common salt which all admitted to be beneficial.

Regarding nutrition attention was focussed on proteins, carbohydrates and fats and little attention paid to the "Ash" except to replace what was removed by plants from the soil He suggested that in future analyses should be complete and show the constituents of the ash, and it would be very useful if such analyses were recorded for each district and a map made showing the deficiencies or excesses for each district.

Nature has prescribed an optimum composition which cannot be improved upon but is easily upset.

The Law of the minimum (applied) want of a particular element may cause effects in one of two ways—either by its absence, or by the toxic effects of others in excess normally restrained by the absent element.

Mineral matters are mostly electrolytes and their action is synergic.

As well as a minimum requirement—the proper ratio of one to the other must be maintained.

Bases in excess were always required to neutralise acids formed in the metabolic processes of the living body—sourness in soil or nourishment was detrimental to plants and animals alike.

Milk contained the elements necessary in proper proportions and will maintain it powerfully. If bases are deficient the tissues withdraw it from the alkali reserves in the body and if persistent shortage goes on will abstract it from the last line of alkali reserve, viz., the bony skeleton. Calcium was probably the most important element of all. It has great effect on the permeability of the cell wall and acted as a restrainer of regulator.

It is specially required at three periods of life—

Growth—when the bulk is increasing

Pregnancy—when the mother must supply nutriment for the offspring

Lactation—when a large quantity is abstracted in the milk.

It was usually combined with phosphorus and a third substance was necessary for proper nutrition namely, Vitamin D. or the antirachitic vitamine.

Regarding ourselves most of us got along very well but there were many instances of weakly constitution—mostly due to accumulated errors mainly dietetic. Eventually the whole gamut of deficiency effects appeared —stunted growth, malnutrition—deficient lactation—neurasthenia and such diseases as urticaria and sprue. Most of these run parallel with the mineral contents of the blood and tissues—chiefly calcium.

Generalisation was not safe in prescribing supplementary mineral constituents and the decision as to their composition must always be based on an accurate analysis of the diet.

There were many instances of natural craving to be observed—possibly the local custom of taking lime (calcium) with "*betel*" was one.

Both animals and plants had a remarkable power of selection and storage. Tissues often show a composition widely different from the medium in which they exist—for example Nitella in Pond water, with reference to plants and the blood corpuscles in the plasma in which they flow with reference to animals.

Per million parts.

Nitella tissues and sap	*Pond water in which it grows*
Sodium 230	5
Potassium 2·120	trace.

Per thousand parts.

Blood cells	*Plasma in which they flow*
Sodium *trace*	4·358
Potassium 3·326	0·254

How all these changes came about was a puzzle yet to be solved.

His Excellency the Governor concluded the discussion by thanking Messrs. Joachim and Crawford for their interesting papers.