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Utilization of Cassava Meal (*Manihot Esculanta* Crantz) in Swine Feeding

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(*Paper accepted :* 14 *June* 1978)

Abstract : The two feeding trials conducted with growing and finishing swine on the use of cassava meal indicate that the HCN free cassava meal could be used successfully as a substitute for maize upto 40% of the ration. However, the unprocessed cassava meal depressed both growth rate and food efficiency. Also, the scouring of swine experienced with the feeding of unprocessed cassava meal could be prevented completely by detoxifying it. The cassava based diets reduced carcass recovery percentages slightly ; though statistically non-significant. The data here was not conclusive as only one animal was used per treatment for carcass analysis. However, the cassava meal did not alter backfat thickness in the HCN-free ration but the unprocessed meal caused an adverse effect on the backfat thickness, indicating that HCN interferes with energy utilization also.

1. Introduction

The necessity to spare cereal grains for human consumption has made it essential to evaluate other sources of energy supplements for animal feeding. Cassava (*Manihot esculanta* Crantz) is one such product that requires investigations.

Studies on Cassava as an energy supplement for swine have begun in the early part of this century. However, the results reported on the use of Cassava in swine rations were not consistent. Maner[11] reported that the maximum level of Cassava that could be utilized by swine was 40 per cent. Work reported from Nigeria[14] indicates that growing and finishing swine could effectively use 40 and 55 per cent Cassava respectively, when incorporated into their rations. Several other authors[4,7] have reported that Cassava could be successfully used upto 60 per cent in swine rations. Further, Aumaitre[2] has found Cassava to be a better source of energy supplement for wine, than maize, wheat, oats and barley.

However, other authors have reported that Cassava caused retardation of growth in swine, as its level was increased in rations.[3,10,18] It has been suggested that hydrocyanic acid (HCN) could be the cause of the growth inhibitory effect in Cassava.[9]

Hence, the studies reported here were undertaken in the Department of Animal Husbandry, University of Sri Lanka, Peradeniya Campus, to evaluate whether the growth inhibitory effects of Cassava was due to the presence of HCN. This was done by feeding Cassava meal with and without HCN to growing and finishing swine.

2. Experimental

Cassava meal was prepared from fresh Cassava tubers, chopped into slices of about quarter of an inch in thickness, by drying in a Unitherm Oven at 100°C for 8 hours and grinding the dried material. HCN was eliminated from dried Cassava chips by using the dry-soak-dry method suggested by Rajaguru.[16] Chemical composition of the Cassava meal used are reported in Table 1.

TABLE 1. Chemical Composition of Cassava Meal

Dry matter %	...	...	86.30
Crude Protein %	...	...	2.60
Crude Fibre %	...	...	1.75
Ether Extract %	...	...	0.04
Ash %	...	...	1.50
Nitrogen free Extract %	...	...	80.41

Two experiments using cross-bred swine were conducted utilizing the same facilities and experimental procedures. Animals of each treatment were housed in separate pens and water was supplied *ad libitum*. They were fed twice a day. Intake capacity of feed in each group was judged by the amount consumed within the first half an hour of feeding and based on this, feeding amounts were adjusted at weekly intervals. The rations were fed in a wet form.

Experiment 1.

18 cross-bred swine comprising 15 males and 3 females were randomly alloted to three treatments on the basis of sex and weight. They were around 60 days of age and had an average weight of 10.56 kg at the time of initial selection.

The first experimental ration contained 35% unprocessed Cassava meal. The second experimental ration contained 35% Cassava meal treated to fully eliminate HCN. These two rations were compared with a maize-based control ration. All three rations were balanced to carry nutrients recommended for growing swine by the National Research Council of U.S.A.[13] The composition of rations is shown in Table 2.

This experiment was conducted for five weeks and weekly weight gains and daily feed consumptions were recorded. Feed efficiency was calculated by using the following formula,

$$\text{Feed efficiency} = \frac{\text{Average feed Consumption}}{\text{Average Weight Gain}}$$

TABLE 2. Percentage composition of Rations for Growing Swine

	Maize	Cassava	Coconut poonac	Gingelly poonac	Rice Bran	Fish Meal	Bone Meal	Zoodry*
Control	35	—	30	5	20	8	2	0.25
35% HCN free Cassava Meal	—	35	35	5	14	10	1	0.25
35% Unprocessed† Cassava Meal	—	35	35	5	14	10	1	0.25

*Vitamin and Mineral supplement.

†Unprocessed Cassava Meal contained 100 PPM of HCN.

Experiment 2.

Fifteen crossbred castrated males averaging 23.55 kg were randomly assigned to five dietary treatments. A maize based ration, which was formulated to provide the nutrient requirement of finishing swine according to the N.R.C. standards,[13] served as the control. This ration was compared with experimental rations containing 20, 30 and 40 per cent HCN free Cassava meal. A fifth ration containing 40 per cent unprocessed Cassava meal, was included to study the effects of HCN on the performance of finishing swine. All five rations were balanced to be isocaloric and iso-nitrogenous. The composition of these rations is presented in Table 3.

TABLE 3. Percentage composition of Rations for Finishing swine.

	Maize	Cassava	Coconut poonac	Gingelly poonac	Rice Bran	Fish Meal	Bone Meal	Zoo-dry	Methi-onine.
Control	40	—	35	5	14	5	1	0.25	0.25
20% HCN free Cassava Meal	—	20	32	8	33	6	1	0.25	0.25
30% HCN free Cassava Meal	—	30	32	5	23	9	1	0.25	0.25
40% HCN free Cassava Meal	—	40	30	8	11	10	1	0.25	0.25
40% Unprocessed* Cassava Meal	—	40	30	8	11	10	1	0.25	0.25

*Unprocessed Cassava Meal contained 114 PPM HCN.

Weekly weight gains and daily feed consumptions were recorded throughout the experimental period, which lasted nine weeks. At the end of the experiment, one animal was randomly selected from each treatment and was slaughtered after recording the live weight. The dressing percentage was calculated by using dressed weight as a percentage of live weight. Backfat thickness was calculated by averaging the fat thicknesses at first rib, last rib and last lumbar positions. The technique described by Hew and Hutagalung[9] was used in determining carcass composition.

3. Results

Experiment 1.

The performance of growing swine fed Cassava meal rations is presented in Table 4.

TABLE 4. Effect of HCN free and unprocessed cassava meal on rate and efficiency of gain of growing pigs.

	Average initial weight kg	Average final weight kg	Average weight gain kg	Average feed consumption* kg	Average feed efficiency* kg
Control	10.53	17.52	6.99*a*	23.33	3.34
35% HCN Cassava meal	10.60	18.03	7.43*a*	23.33	3.14
35% Unprocessed Cassava meal	10.46	16.44	5.98*b*	22.73	3.79

Statistical significance at 5% level is denoted by different letters.
*Statistically not significant.

There were no significant differences (P 0.05) in average weight gain or feed conversion of animals fed maize based control ration and those fed on rations containing HCN free Cassava meal. Animals receiving the ration containing unprocessed Cassava meal gained more slowly (P 0.05) than those fed the other two rations.

The feed conversion efficiency of animals fed unprocessed Cassava meal was 13.4% and 20.6% lower than those fed on control and HCN free Cassava meal rations, respectively. However, the differences were not statistically significant.

Experiment 2.

The preference of finishing swine fed different levels of Cassava meal is presented in Table 5.

TABLE 5. Effect of HCN-free and unprocessed Cassava meal on rate and efficiency of gain of finishing swine.

	Average Initial Weight kg	Average Final Weight kg	Average Weight Gain kg	Average Feed Consumption. kg	Average Feed Efficiency* kg
Control	23.48	38.03	14.55*a*	57.27	3.94*a*
20% HCN-free Cassava Meal	23.79	36.66	12.88*a*	57.27	4.45*a*
30% HCN-free Cassava Meal	23.48	36.81	13.33*a*	57.27	4.30*a*
40% HCN-free Cassava Meal	23.33	37.12	13.79*a*	57.27	4.15*a*
40% Unprocessed Cassava Meal	23.64	33.03	9.39*b*	57.27	6.10*b*

*Statistical significance at 5% level is denoted by different letters.

There were no significant differences (P 0.05) between the performance of animals fed with maize based control ration and those fed with different levels of HCN-free Cassava meal. However, incorporating unprocessed Cassava meal containing HCN into the swine rations resulted in significantly lower (P 0.05) average weight gains and feed conversion efficiency.

Summary of the carcass characteristics of experimental animals is presented in Table 6.

TABLE 6. Effect of Cassava Meal on the Carcass Characteristics of swine.

	Live Weight (kg)	Carcass Weight (kg)	Dressing Percentage (%)	Average Backfat Thickness (mm)
Control	37.73	27.76	73.58	25.50
20% HCN-free Cassava Meal	35.45	24.69	69.65	21.83
30% HCN-free Cassava Meal	34.09	23.81	69.84	24.66
40% HCN-free Cassava Meal	38.18	27.02	70.77	26.33
40% Unprocessed Cassava Meal	30.91	20.74	69.14	17.50

The dressing yield ranged from 69.14 to 73.58 per cent, with animals on control and 40% unprocessed Cassava meal showing the highest and lowest carcass recovery, respectively. Carcass recovery of the animal fed on 40% HCN-free Cassava meal was 3.84% lower than that on the control ration.

Based on the averages of three measurements, animals on 40% HCN-free cassava meal showed backfat thickness comparable to that on the control ration. The lowest backfat thickness was observed with the animal fed on 40% unprocessed Cassava meal, which was 8.83 and 9.66 mm lower than those on 40% HCN-free Cassava meal and control rations respectively.

The results of the proximate analysis of carcasses are shown in Table 7.

TABLE 7. Effect of Cassava Meal on the Chemical Composition of Carcasses.

	Dry Matter %	Crude Protein %	Crude Fat %	Bone Ash %
Control	66.70	35.20	51.04	50.06
20% HCN-free Cassava Meal	60.42	39.10	47.98	49.99
30% HCN-free Cassava Meal	63.09	36.64	53.01	42.88
40% HCN-free Cassava Meal	65.56	35.80	52.61	47.92
40% Unprocessed Cassava Meal	63.56	34.70	48.97	48.76

The treatments appear to have no effect on the moisture, crude protein, crude fat or on the bone ash content of the carcasses. There seems to be an inconsistent individual variation with respect to some nutrients.

4. Discussion

The results of the two trials have shown clearly that Cassava meal, when processed to eliminate HCN, can be used as the main source of energy in both growing and finishing swine without depressing their performances. No depression in growth rate or efficiency of feed conversion was observed in animals fed HCN-free Cassava meal at levels as high as 40 per cent. (Tables 4 and 5). Similar observations have been recorded by many workers.[2,4,7,9,11]

On the other hand, feeding unprocessed Cassava meal caused a marked depression in weight gain and efficiency of feed conversion in both growing and finishing swine, confirming a number of earlier reports.[8,10,18] The results of this study suggest that the HCN present in the unprocessed Cassava meal may be the toxic factor responsible for depressing the performance of animals. This may be due to the interference of HCN with the utilization of vitamin B complex and protein,[17] thus resulting in depressed growth. Also it appears from these experiments that the swine were unable to utilize the energy in Cassava for growth due to the protein imbalance caused by HCN.

In Experiment 1, 50% of the growing swine fed with unprocessed Cassava meal containing 100 PPM HCN developed scour, while those on HCN-free Cassava meal did not show any signs of scouring. Many workers have observed incidence of scouring, when Cassava was fed.[1,10,12,14] None of these workers have used HCN-free Cassava meal in their experiments. The problem of scour caused by unprocessed Cassava meal could be overcome by processing Cassava meal according to the dry-soak-dry techniques described by Rajaguru.[16] HCN therefore, appears to be the contributing factor to scouring. The mechanism by which HCN causes scour in swine is obscure.

When finishing swine, were fed unprocessed Cassava meal containing 114 PPM HCN only mild cases of scouring were observed. It may be possible that finishing swine could tolerate a higher level of HCN than growing swine. However, no evidence of HCN toxicity was observed in both growing and finishing swine suggesting that the levels of HCN present in the unprocessed Cassava meals used in these two experiments could be tolerated by both growing and finishing swine. Coursey[6] reported that 50 to 100 PPM HCN Cassava was moderately poisonous to swine.

The above results suggest that HCN may be the contributing cause for digestive disturbances. The loss in weight gain, when unprocessed Cassava is fed at high levels to swine, may be partly due to low utilization of nutrients due to digestive disturbance. Hence it is essential that all HCN and related glucosides be removed from Cassava before using for swine feeding. HCN-free Cassava meal is well utilized by swine.

Replacing maize by Cassava in swine rations appears to somewhat reduce the dressing yield. The phenomenon is difficult to explain as the rations were iso-caloric and iso-nitrogenous. There were no appreciable differences in the backfat thickness between rations based on maize and processed Cassava. (Table 7). Chou *et al*[5] and Castillo *et al*,[3] also did not find any increase in backfat thickness due to the use of Cassava meal. This is to be expected since the energy content of maize and Cassava appear to be similar. Feeding unprocessed Cassava meal seems to reduce the backfat thickness suggesting that HCN present in the unprocessed Cassava meal may be interfering with the efficiency of energy utilization. However, the carcass data should not be considered conclusive, since only one animal was slaughtered per treatment.

It can be concluded that Cassava meal when well detoxified could be an ideal substitute for maize in swine rations. Also once detoxified it could be safely used upto 40% of the ration as an energy supplement. Since Cassava yields more energy per hectare than any other crop, its use as an energy supplement in swine rations would lower the cost of feed.

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Aromaticity of Some Polycyclic Hydrocarbons

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Abstract : Based on Perturbation Molecular Orbital (PMO) calculations of some even alternant hydrocarbons an 'aromatic index' is defined. This index could be used as a measure of the aromaticity of a particular position of the ring or of the ring itself. It is useful in comparing the aromaticity of these hydrocarbons and in understanding certain properties of these compounds. It was also observed that the K-region of the polycyclic hydrocarbons which were carcinogenic had an aromatic index less than 0.3. When calculating this index, another index 'Dewar number' which is a useful reactivity index too, can be calculated.

1. Introduction

The idea of aromaticity originally began in relation to the chemical behaviour of particular compounds such as benzene in a wide range of reactions and to some extent in connection with physical properties like diamagnetic susceptibility. That is, it was bound with distinct type of reactivity and not with properties of isolated molecules. The development of valence bond (VB) and molecular orbital (MO) theories permitted the calculation of thermochemical resonance energies, a quantity which could be measured. This is a property of the ground state of molecules with only a secondary influence on reactivity. There are many objections to using chemical reactivity as a criterion of aromaticity. There are many polycylic benzenoid compounds which are much less stable and much more reactive than benzene, but undergo addition reactions rather than substitution reactions. Thus the criteria of aromaticity shifted from a chemical to a physical point of view.

The possession of large resonance energy has generally been accepted as a diagnosis of the aromatic character of a compound. Dewar[2] has defined an aromatic compound as follows :— An aromatic compound is a cyclic compound with a large resonance energy where all the annular atoms take part in a single conjugated system. Hückel[6] using MO theory showed that a monocyclic coplanar system consisting of trigonally hybridized atoms which contain $(4n + 2)\ \pi$ electrons will have a closed shell configuration and therefore possesses electronic stability. The Hückel rule however is limited in applicability as it is concerned with monocyclic systems only. The Hückel rule depends on the existence of degenerate MOs, and therefore a molecule should have at least a threefold symmetry axis for the rule to be applicable. Further, the theoretical work of Longuet Higgins and Salem[8,9] have shown that as the ring becomes larger the $(4n + 2)$ rule does not apply since the ring system will consist of alternate single and double bonds.

Craig[1] has also proposed an empirical rule, which could be applied only to hydrocarbons in which at least two centres lie on a symmetry axis that converts one Kekulè structure to another. The structural formula is first labelled with equal numbers of spin symbols α and β, as far as possible alternately, different symbols being given to the ends of all the double bonds in the Kekulè type structure. The sum is then taken of the number (f) of symmetrically related π centres not on the symmetry axis and the number (g) of interconversions of α and β by rotation about the axis. If this sum, $f + g$, is even, the VB ground state is symmetric and the compound may be expected to be aromatic. If the sum is odd, it is expected to be non-aromatic.

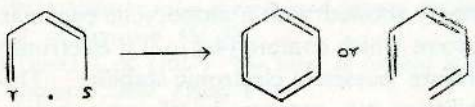
In this paper, the PMO[3] method is utilised and an index termed 'aromatic index' which is the difference in the energy between the compound and the corresponding polyene is defined. The calculations themselves are very simple for even alternant systems, without the necessity to solve secular equations as in the Hückel method.

2. PMO method

The first order change in π energy in the union of two odd alternant hydrocarbon (odd AH) radicals R and S to form RS where there is a non-bonding MO (NBMO) Φ_o of R and Ψ'_o of S which are degenerate is given by

$$\delta E = \Sigma\, 2\, a_{or}\, b_{os}\, \beta_{rs}$$

where a_{or} and b_{os} are coefficients in the NBMOs Φ_o and Ψ_r of R and S respectively, and where the sum is over all the pairs of atoms r in R and s in S through which R is linked to S in RS. β_{rs} is the resonance integral between atoms r and s. This simple result can be used in the calculation of resonance energies of even alternant hydrocarbon (even AH) systems. Let us illustrate this for an even AH system. This can be formed by the union of an odd AH and methyl where both the odd AH and methyl have NBMOs. The change in π energy is then given by $\delta E = 2\Sigma\, a_{or}\, \beta_{rs}$. Thus benzene and hexatriene can both be formed by the union of 2, 4 pentadienyl with methyl where the methyl is being represented here as a dot.



Assuming β_{rs} to be constant and equal to β,

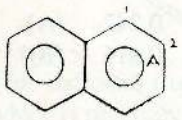
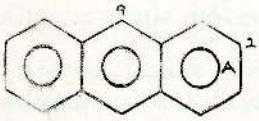
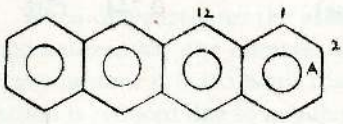
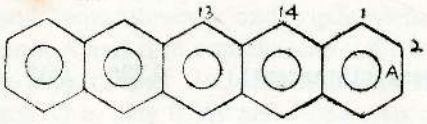
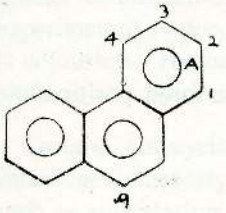
$$\Delta E \text{ (benzene)} = 2\beta\,(a_{or} + a_{os})$$

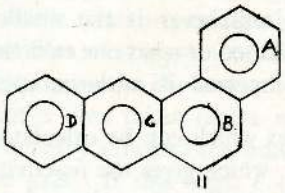
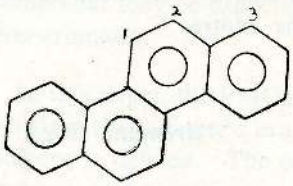
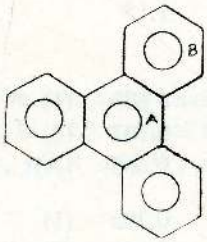
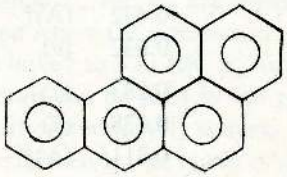
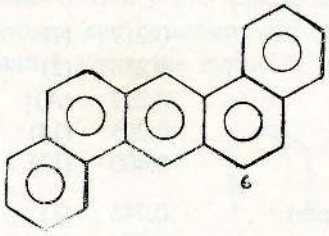
$$\Delta E \text{ (hexatriene)} = 2\beta a_{or} \text{ or } 2\beta a_{os}$$

depending whether the bond formed is with atom r or s. a_{or} and a_{os} are the coefficients of the non-bonding MO of 2—4 pentadienyl on atoms r and s respectively. The 'aromatic index' is then defined by $W = 2\,a_{or}$ or $2a_{os}$, whichever is the smaller value. The aromatic index is in effect the extra energy released or what one calls the resonance energy. If the aromatic index is <0, the compound is antiaromatic.[4]

The Dewar number $N = 2\,(a_{or} + a_{os})$ is another index which can be calculated simultaneously with the calculation of the aromatic index, which gives the reactivity of a particular centre to electrophillic substitution. The smaller the value of N, the easier would be the electrophillic substitution at the centre.

3. Results

Compound		*Aromatic Index*	
	(benzene)	1.15	
	(napthalene)	0.603	(1)
		0.707	(2)
		0.655	(A)†
	(anthracene)	0.392	(1)
		0.471	(2)
		0.432	(A)†
		0.632	(9)
	(naphthacene)	0.283	(1)
		0.338	(2)
		0.311	(A)†
		0.410	(12)
	(pentacene)	0.217	(1)
		0.256	(2)
		0.237	(A)†
		0.295	(14)
		0.400	(13)
	(phenanthrene)	0.743	(1)
		0.873	(2)
		0.816	(3)
		0.874	(4)
		0.824	(A)†
		0.359	(9)

Compound			Aromatic Index	
	(*)	(benzanthracene)	0.848	(A)†
			0.237	(B)†
			0.237	(11)‡
			0.598	(C)†
			0.514	(D)†
		(chrysene)	0.475	(1)
			0.417	(2)
			0.675	(3)
		(triphenylene)	0.242	(A)
			0.916	(B)†
	(*)	(benzpyrene)	0.244	(7)‡
	(*)	(dibenzanthrancene)	0.286	(6)‡

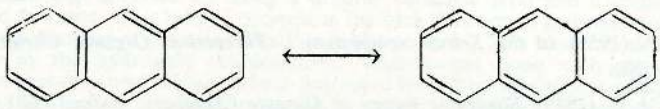
†A.I. of a ring is taken as the average of the A.I.'s of the non-fused position.

*These compound are carcinogenic.

‡K region position.

4. Discussion

When one observes the aromatic indices of benzene, napthalene, anthracene, naphthacene and pentacene, it is seen that its value decreases along the series. (The maximum values are 1.15, 0.707, 0.632, 0.410, 0.400). This is in accordance with the observed increase in unsaturation of these compounds, as one traverses along the series. The reactions of benzene are mainly electrophillic substitution while anthracene, naphthacene do take part in addition reactions. Another feature that emerges from these calculations is that as one goes towards the centre of the molecule, the aromatic index increases. This could be understood in terms of the usual resonance structures. Fries[5] formulated the rule that the most stable arrangement of a polynuclear compound is that which has the maximum number of rings in the benzenoid condition. For anthracene, therefore, the important resonance structures are as follows :—



This indicates that the middle ring has more benzenoid character than the end rings, which is precisely what the calculated aromatic index predicts. Likewise, the variation of the aromatic indices of the various rings could be explained.

Another feature which emerged from the calculations on linear polynuclear hydrocarbons is that cyclisations at the $2(\beta)$ position is preferred to the $1(\alpha)$ position.

When one compares the aromatic indices of the constituent rings in phenanthrene and anthracene, one observes that the difference in the indices of rings A and B in phenanthrene is 0.465 while that in anthracene is 0.200. This indicates that delocalisation is reduced due to angular fusion and is more localised in the outer rings. This is borne out again from the aromatic indices of the constituent rings in naphthacene and benzanthracene and triphenylene. The differences in the aromatic indices of rings A and B in naphthacene is 0.10 while that in benzanthracene is 0.611 and 0.674 in triphenylene. In benzanthracene, the differences in the indices between rings B, C and D is only 0.361 and 0.084 respectively, showing that in benzanthracene there is greater delocalisation amongst rings B, C and D and not among ring A. Further experimental evidence of this is that naphthacene is orange yellow while triphenylene is colourless. Hence, when angular fusion takes place one observes a hypsochromic shift.

Certain polycyclic aromatic hydrocarbons show carcinogenic activity. This carcinogenic activity was correlated with the reactivity towards addition reactions such as epoxidation. Pullman[10] showed that these reactions take place in regions

termed as K regions, where the bond order is exceptionally high. In our calculations the polycyclic hydrocarbons which are carcinogenic (these are labelled*) have at these K regions aromatic indices less than 0.3. Thus the K regions can also be characterised by low aromatic indices of values less than 0.3.

The calculations of the aromatic indices for these even alternant polycylic hydrocarbons are very simple and do not require more than pencil and paper. It must however be stressed that these aromatic indices cannot predict the position of attack of a electrophile, for which the Dewar number would be more useful. The Dewar number can be calculated simultaneously with that of the aromatic index so that there is no additional labour involved. For non-alternant hydrocarbons to calculate these indices, separate Hückel calculations must be done on the hydrocarbon and the corresponding non-cyclic hydrocarbon.

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Reduction in Chlorate Content in De-Nora Type Electrolytic Diaphragm Cells used for the Manufacture of Caustic Soda in Sri Lanka

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(*Paper accepted : 28 July* 1978)

Abstract The sodium hydroxide produced in the De-Nora diaphragm cells at the Paranthan Chemicals Corporation, Sri Lanka, has 1.30 to 1.50 g sodium chlorate per 100 g of sodium hydroxide. Pilot cells were constructed in the laboratory with a single carbon anode and a double steel cathode, in order to investigate the optimum conditions under which the electrolysis of brine would lead to the maximum production of sodium hydroxide with a minimum proportion of chlorate. Reduction of chlorate contaminant was achieved by using a lowered catholyte level and a consequential increased flow rate. This led to a decrease in the back diffusion of hydroxide ions and a consequent decrease of chlorate formation in the anolyte. This however, also led to a decrease in the hydroxide concentration. Experiments done with simultaneous replenishment of anolyte liquor and pre-heating of feed brine have shown a reduction in anolyte chlorate and consequent reduction in catholyte chlorate. Repetition of these experiments at Paranthan Chemicals Corporation, *in situ*, at current loads of 3000 A, showed an even more significant chlorate reduction when simultaneous replenishment of anolyte liquor and pre-heating of feed brine was carried out. Experiments were also carried out with increasing replenishing rates at a constant feed brine temperature of 55°C. Anolyte chlorate concentration was thereby reduced to 0.1 to 0.08 g per 100 g sodium hydroxide. It is shown that spent anolyte liquor could be re-circulated to the cells *via* the saturators, thus eliminating the wastage of brine.

1. Introduction

Caustic soda is produced in the De-Nora type diaphragm cells at the Paranthan Chemicals Corporation, Sri Lanka. The cells are narrow and high consisting of a single anode comprising of twenty-six bars, made out of graphite material and a perforated double steel cathode on either side of the anode. On the anode side of the cathode, the diaphragm is pasted (on the periphery) and stitched at intervals. The diaphragm material consists of asbestos paper and cloth. The cathode is submerged. The design includes an arrangement by which the height, and therefore the hydraulic pressure of the liquid in the anode and cathode compartments of the cell may be varied according to the permeability of the diaphragm, as it changes with age. The hydrostatic pressure in the anode and cathode chambers may differ by as much as twenty-five inches.

The effluent of the cell contains 1.30 g to 1.50 g of sodium chlorate per 100 g of sodium hydroxide and all the cells suffer from this defect. In the manufacture of soap (85% of Sri Lanka's caustic soda being used for this purpose), caustic soda is treated with coconut oil, the resultant by-product being glycerine. Glycerine is one of Sri Lanka's non-traditional export products. The chlorate that is present in the caustic soda contaminates the glycerine thereby reducing the export value of glycerine.

The primary reactions that take place in the chlora-alkali cell are :

at the cathode : $2H_2O + 2e \longrightarrow H_2 + 2OH^-$ (1)

at the anode : $2Cl^- \longrightarrow Cl_2 + 2e$ (2)

Due to the following secondary reaction,

$Cl_2 + H_2O \longrightarrow HOCl + Cl^- + H^+$ (3)

$HOCl \rightleftharpoons OCl^- + H^+$ (4)

$2\ HOCl + OCl^- \longrightarrow ClO_3^- + 2Cl^- + 2Cl^- + 2H^+$ (5)

$6\ OCl^- + 3H_2O \longrightarrow 2Cl_3^- + 4Cl^- + 6H^+ + 3/2\ O_2 + 6e$ (6)

There exists a chloride, chlorine, hypochlorite and chlorate system.

Most of the chlorine, bubbles out of the solution as chlorine gas but a certain amount dissolves in the anolyte liquor, this amount depending on the chloride ion concentration (Figure 1)[9] and temperature. Foerster and Mueller[2,3] formulated the path taken by the dissolved chlorine ultimately leading to the formation of chlorate. The dissolved chlorine undergoes hydrolysis according to Equation 3. Ibl[5] has shown that the above reaction is fast and takes place in the bulk solution as well as in the diffusion layer, close to the anode where chlorine is generated. Hypochlorous acid produced dissociates according to :

$$HOCl \longrightarrow ClO^- + H^+$$

The dissociation constant for this dissociation is :

$$4 \times 10^{-8}\ \text{mol.}\ l^{-1}\ \text{at}\ 25°C.$$

Chlorate may be formed in either of two ways :

1. Chemical formation as represented by the Equations 3, 4 and 5.
2. Electrochemical formation at the anode as represented by Equation 6, with simultaneous oxygen evolution.

In strongly alkaline media[6] the electrochemical oxidation can be represented as follows :

$5ClO^- + 8H_2O \longrightarrow 3ClO_3^- + Cl^- + 6H^+ + 2O_2 + 16e$ (7)

According to Ibl and Landolt[6] in alkali cells electrochemical chlorate is predominant.

The work reported here was directed towards finding optimum conditions under which the electrolysis of brine would lead to the production of sodium hydroxide with a minimum proportion of chlorate.

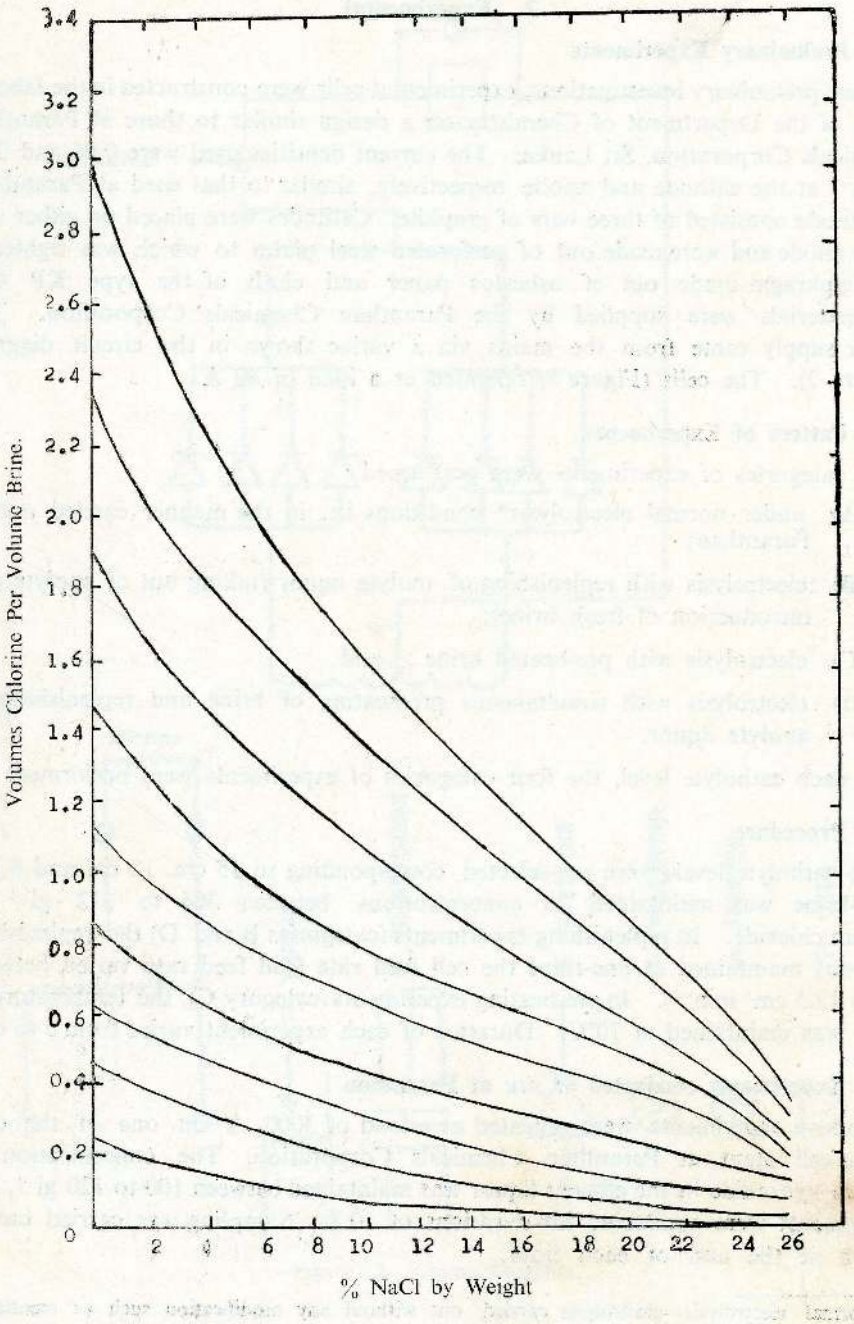


Figure 1. Solubility of Chlorine in Brine

2. Experimental

2.1. Preliminary Experiments

For our preliminary investigations, experimental cells were constructed in the laboratories of the Department of Chemistry on a design similar to those at Paranthan Chemicals Corporation, Sri Lanka. The current densities used were 0.06 and 0.07 A cm^{-2} at the cathode and anode respectively, similar to that used at Paranthan. The anode consisted of three bars of graphite. Cathodes were placed on either side of the anode and were made out of perforated steel plates to which was tightened the diaphragm made out of asbestos paper and cloth of the type KP 407. All materials were supplied by the Paranthan Chemicals Corporation. The power supply came from the mains via a variac shown in the circuit diagram (Figure 2). The cells (Figure 3) operated at a load of 40 A.

2.2. Pattern of Experiments.

Four categories of experiments were performed :

(A) under normal electrolysis* conditions i.e. in the manner carried out at Paranthan;

(B) electrolysis with replenishing of anolyte liquor (taking out of anolyte and introduction of fresh brine);

(C) electrolysis with pre-heated brine ; and

(D) electrolysis with simultaneous pre-heating of brine and replenishing of anolyte liquor.

At each catholyte level, the four categories of experiments were performed.

2.3. Procedure

Three catholyte levels were pre-selected corresponding to 15 cm, 12 cm and 8 cm. Feed-brine was maintained at concentrations between 304 to 312 gl^{-1} of sodium chloride. In replenishing experiments (categories B and D) the replenishing rate was maintained at one-third the cell feed rate (cell feed rate varied between 4.7 to 12.5 cm^3 min^{-1}). In pre-heating experiments (category C), the temperature of brine was maintained at 70°C. Duration of each experiment varied from 5 to 6 h.

2.4. Experiments conducted *in situ* at Paranthan

The above experiments were repeated at a load of 3000 A on one of the cells in the cell plant at Paranthan Chemicals Corporation. The concentration of sodium hydroxide in the effluent liquor was maintained between 100 to 120 gl^{-1}, and experiments were conducted for durations of 10 h. Sampling was carried out as before at the end of each hour.

*Normal electrolysis—electrolysis carried out without any modification such as mentioned under category B, C and D.

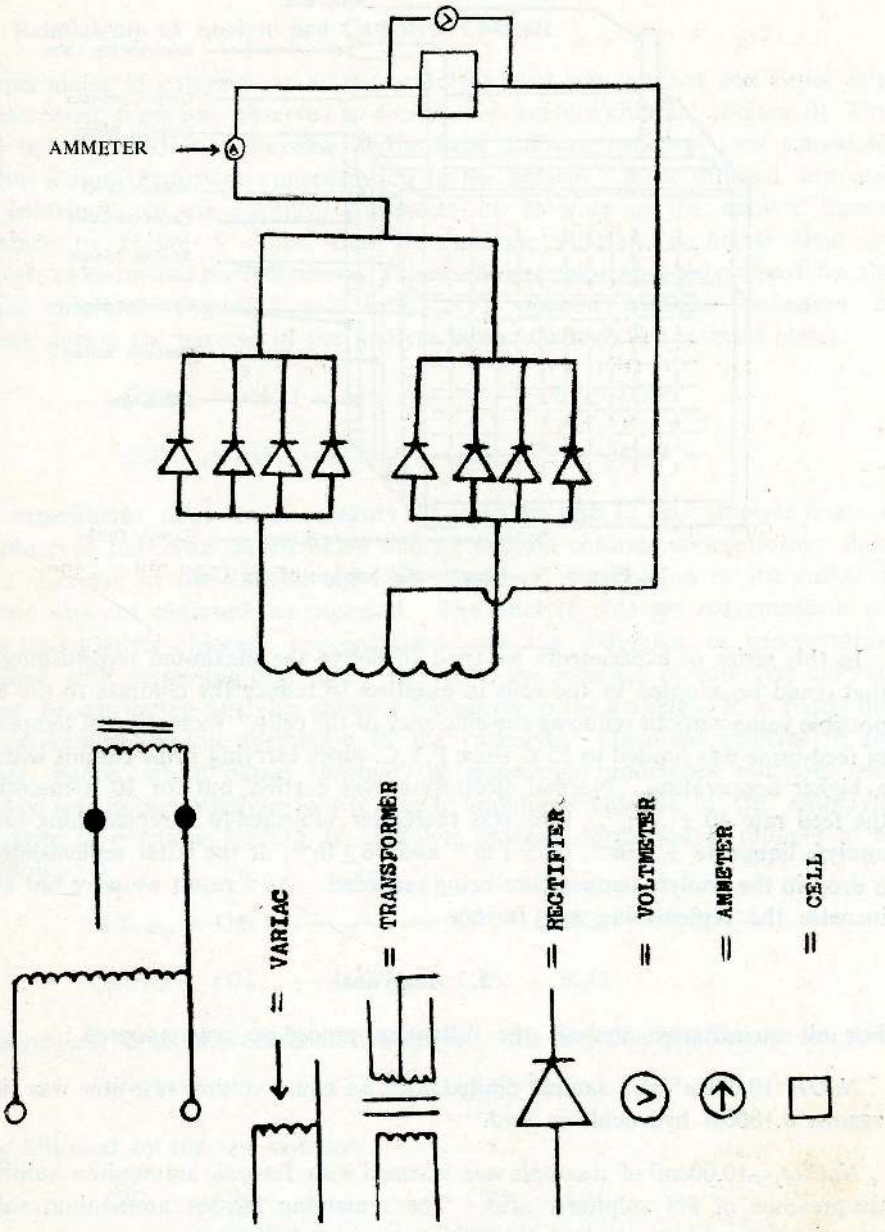


Figure 2. Circuit Diagram

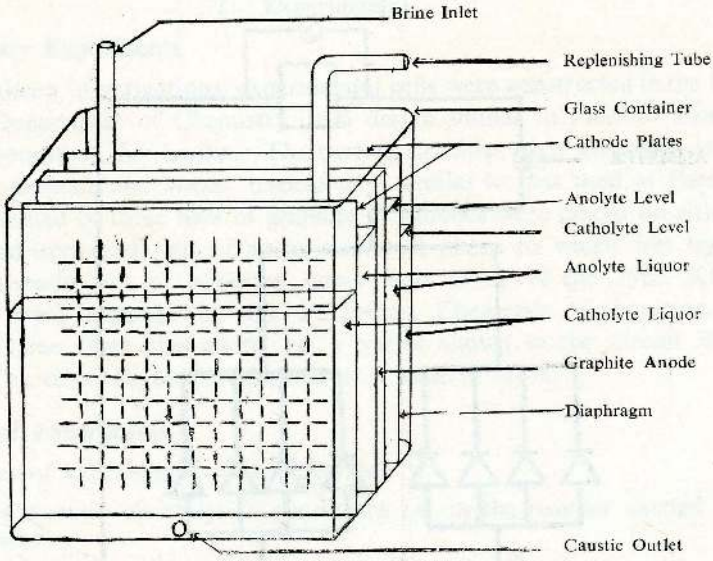


Figure 3. Diagramatic Section of the Cell

In this series of experiments we tried to derive the maximum replenishing rates that could be adopted by the cells in question to reduce the chlorate to the lowest possible value without reducing the efficiency of the cells. Increasing of temperature of feed-brine was limited to 55°C since P.V.C. pipes carrying brine cannot withstand a higher temperature. Normal electrolysis was carried out for 10 h maintaining the feed rate $40 \pm 2\,lh^{-1}$. Cell was thereafter subjected to a replenishing rates of anolyte liquor $18 \pm 2\,lh^{-1}$, $60 \pm 1\,lh^{-1}$ and $66 \pm lh^{-1}$, at the latter replenishing rate a drop in the anolyte temperature being recorded. As a result we were not able to increase the replenishing any further.

3. Analytical

For all quantitative analysis the following procedure was adopted :

$NaOH$—10.00cm³ of a sample diluted with an equal volume of water was titrated against 0.1000N hydrochloric acid.

$NaClO_3$—10.00cm³ of a sample was warmed with ferrous ammonium sulphate in the presence of 5N sulphuric acid. The remaining ferrous ammonium sulphate was titrated against standard 0.1000N potassium dichromate.

$NaCl$—5.00cm³ of a sample was diluted upto 250cm³ of water and 10.00cm³ of the latter solution titrated against 0.100N silver nitrate.

4. Discussion

4.1. Relationship of Anolyte and Catholyte Chlorate

In experiments of category A as the catholyte level was lowered and hence flow rate increased, there was observed a decrease in anolyte chlorate (Figure 4). This could be attributed to a decrease in the back diffusing hydroxyl ions[4] caused by the low sodium hydroxide concentration in the effluent. Back diffused hydroxyl ions contribute to the chemical formation of chlorate in the anolyte liquor. Reference to Figure 5 shows that the anolyte chlorate is higher than the catholyte chlorate and the magnitude of the catholyte chlorate is determined by the anolyte chlorate. Figure 5 also indicates a possible cathodic reduction of chlorate during the passage of the anolyte liquor through the cathode plates.

$$ClO_3^- + 3H_2O + 6e \longrightarrow Cl^- + 6OH^-$$

$$ClO_3^- + 6H^+ + 6e \longrightarrow Cl^- + 3H_2O$$

In experiments done under category D at 15 cm and 12 cm catholyte levels it was observed that with an increased anolyte sodium chloride concentration there was a decrease in the anolyte chlorate ; however, a reduction in the catholyte chlorate was not observed as expected. The anolyte chlorate concentration fell below the catholyte chlorate concentration and the difference in concentration increased with increasing flow rate ; therefore, the presence of catholyte chlorate cannot be attributed solely to chlorate formation in the anolyte. It is partly due to a process of chlorate formation in the catholyte. Dissolved chlorine in the anolyte liquor which passes through the diaphragm undergoes reaction with hydroxyl ions in the catholyte to give rise to additional chlorate in the catholyte. The series of reactions leading to catholyte chlorate formation is thought to be as follows :—

$$Cl_{2(aq)} + OH^- \longrightarrow Cl^- + HClO$$

$$HClO + OH^- \longrightarrow ClO^- + H_2O$$

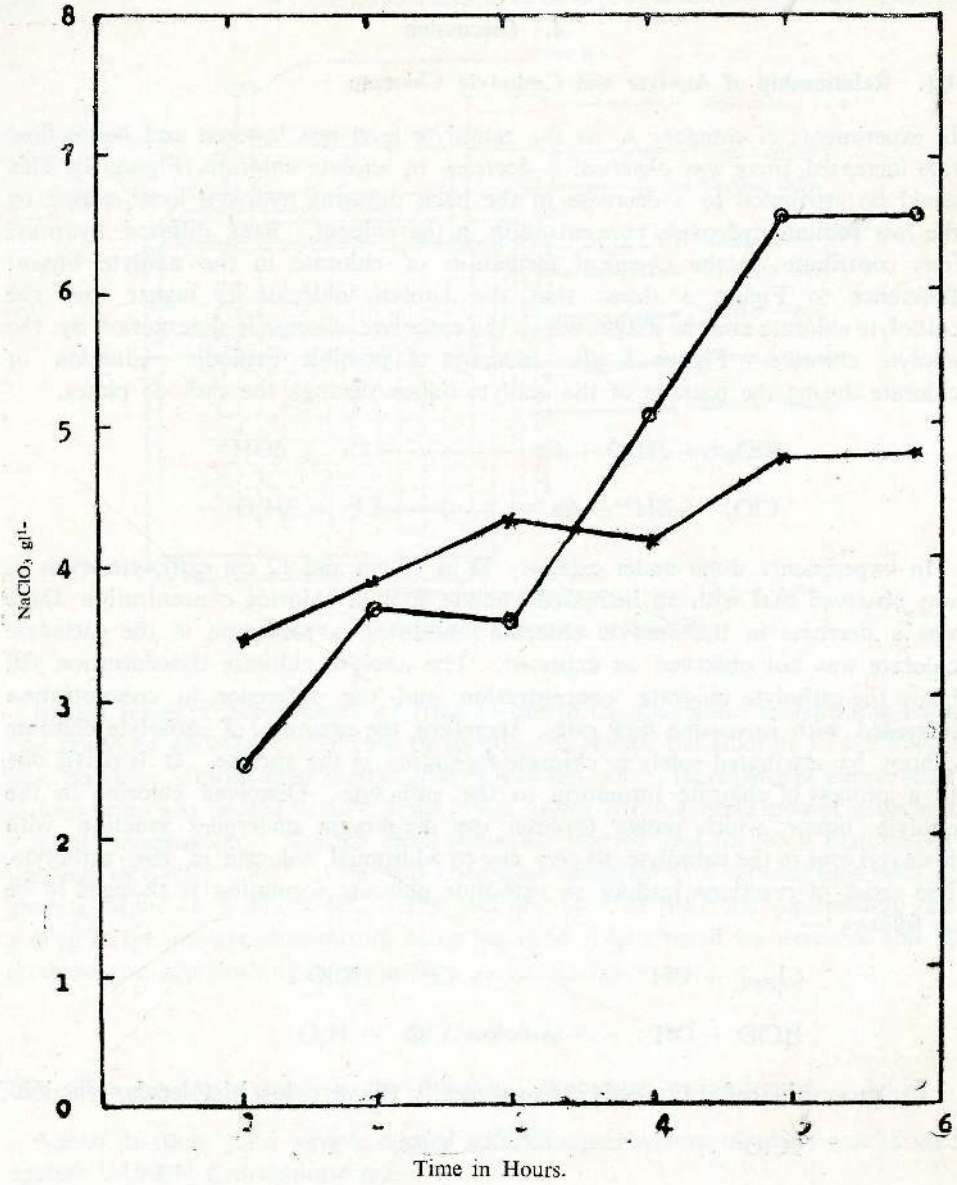
The process hereafter proceeds in two stages : the very slow bimolecular reaction

$$2ClO^- \longrightarrow ClO_2^- + Cl^-$$

being followed by the fast reaction

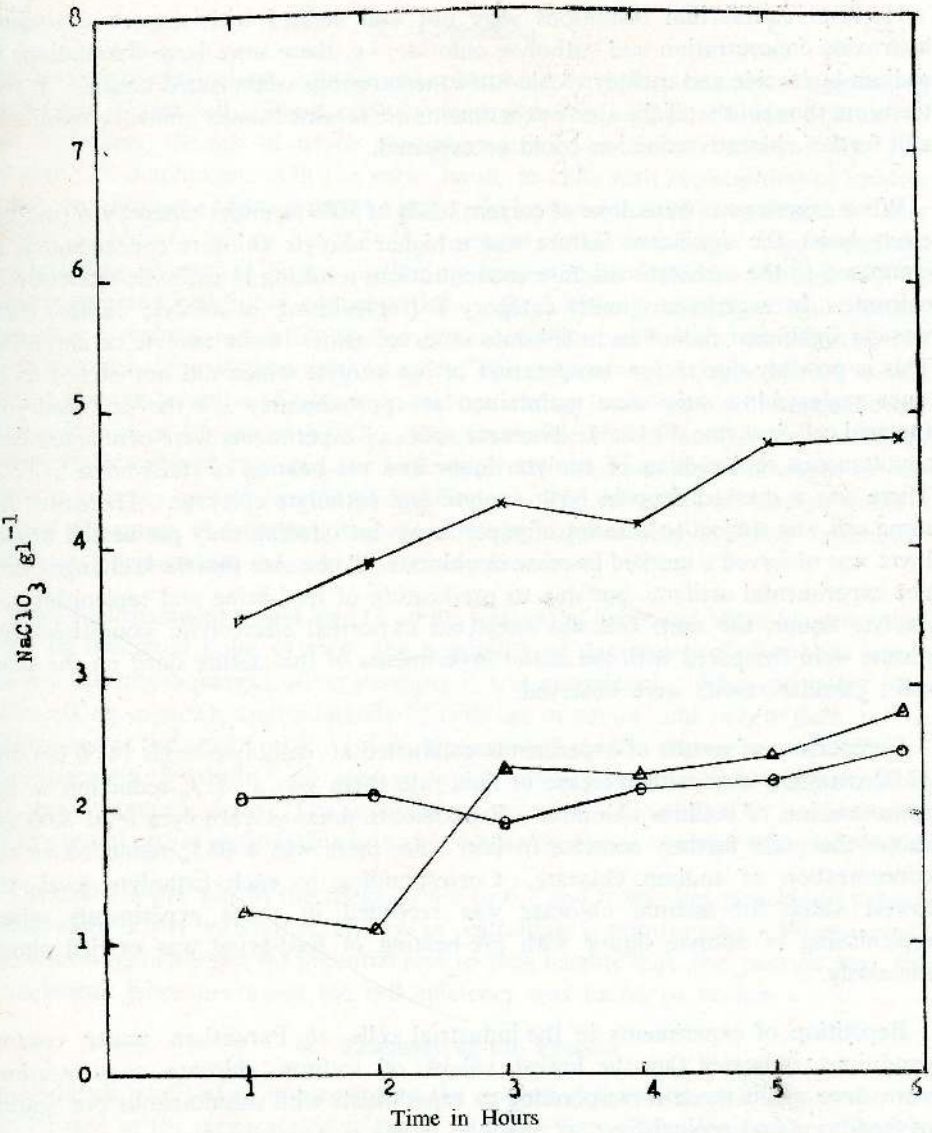
$$ClO_2^- + ClO^- \longrightarrow ClO_3 + Cl^-$$

In those experiments (category D) where replenishing of anolyte liquor and pre-heating of cell feed-brine was carried out reduction in anolyte chlorate, took place



o Anolyte Chlorate (catholyte level 15cm)
× Anolyte Chlorate (catholyte level 12cm)

Figure 4. — Variation of anolyte chlorate during normal electrolysis



× Anolyte $NaClO_3$
o Right Cell Effluent $NaClO_3$
Δ Left Cell Effluent $NaClO_3$

Figure 5. Variation of anolyte and catholyte chlorate during normal electrolysis at catholyte level of 12cm.

However equilibrium conditions were not well defined with respect of sodium hydroxide concentration and catholyte chlorate, i.e. there were large fluctuations in sodium hydroxide and catholyte chlorate concentrations when tested hourly. It was therefore thought that if the above experiments are repeated under control conditions* still further chlorate reduction could be expected.

When experiments were done at current loads of 3000 A under category A (normal electrolysis), the significant feature was a higher anolyte chlorate concentration as compared to the catholyte chlorate concentration, resulting in cathodic reduction of chlorate. In experiments under category B (replenishing of anolyte liquor) there was no significant reduction in chlorate observed either in the anolyte or catholyte. This is possibly due to low temperature of the anolyte which did not exceed 65°C. since replenishing rates were maintained at approximately 1/3 the cell feed rate (normal cell feed rate 40 $1h^{-1}$). The next series of experiments were conducted with simultaneous replenishing of anolyte liquor and pre-heating of feed-brine at 55°C There was a marked drop in both anolyte and catholyte chlorate. Thereafter the same cell was subject to a series of experiments introducing only pre-heated brine ; there was observed a marked increase in chlorate. To be sure that these changes were not experimental artifacts but due to pre-heating of feed-brine and replenishing of anolyte liquor, the same cell was subjected to normal electrolytic conditions and results were compared with the initial experiments of this nature done on the same cell ; similar results were observed.

Comparison of results of experiments conducted at catholyte levels 14.50 cm and 12.00 cm show that with increase in flow rate there was a 53% reduction in the concentration of sodium chlorate. Experiments done at catholyte level 8.00 cm shows that with further increase in flow rate, there was a 68% reduction in the concentration of sodium chlorate. Corresponding to each catholyte level, the lowest value for sodium chlorate was recorded in those experiments where replenishing of anolyte liquor with pre-heating of feed-brine was carried simultaneously.

Repetition of experiments in the industrial cells at Paranthan under control conditions, indicated that the lowest values of sodium chlorate concentrations were once again those corresponding to experiments with simultaneous pre-heating of feed-brine and replenishing of anolyte liquor.

Results[8] indicate that at high replenishing rates (approximately 66 $1h^{-1}$) chlorate has reduced to values of 0.08 g of sodium chlorate per 100 g of sodium hydroxide.

*Equilibrium conditions—an instance where variable parameters such as temperature, sodium hydroxide and sodium chlorate concentrations remain almost constant., i.e. cells to be run for a longer period from the commencement of the experiment.

5. Conclusion

During normal electrolysis, only limited control can be maintained over the operating conditions of the cell. These include decomposition voltage, brine concentration and feed rates, the last of which depending largely on the porosity and flow rate through the diaphragm. On the other hand, in cells with replenishing of anolyte liquor, equilibrium conditions of the cell could be so adjusted for it to operate under desired conditions of anolyte Cl^-, temperature and cell liquor concentrations. Replenishing of anolyte liquor further maintains an uniform distribution of Cl^-, temperature and cell liquor concentrations. Replenishing of anolyte liquor further maintains a distribution of Cl^- within in the anolyte and inhibits the deplection of Cl^- within the pores of the graphite anodes. This reduces the discharge of OH^- which should give rise to active O_2 attack on carbon, leading to shortening of anode life and contamination of Cl_2 gas with CO_2. The present method of anolyte replenishment substantially reduced the need for individual cell attention due to changes in diaphragm porosity and hydroxide back diffusion. The cell could be worked under a desired pH range, if necessary, thereby attaining high catholyte NaOH concentration and hence reduce the cost of evaporation.

Since replenishment would lead to undue wastage of brine and hence uneconomical from an industrial point of view, the possibility of re-circulation of anolyte liquor via the saturators instead of replenishing it was considered. When the plant is at full working capacity, approximately 55 cells are in circuit and when each cell is replenished at the rate of 60 lh^{-1} ($1\frac{1}{2}$ the normal feed rate) a volume corresponding to approximately 3300 lh^{-1} of anolyte liquor has to be delivered to the saturators through a pumping device. The possibility of recontamination of ClO_2^- concentration at the present rate of replenishing is shown to be in the region of about 0.08 g of NaOH.

The anolyte pH was in the range of 4.8 to 6.7 and it was not possible to draw a relationship of pH with either anolyte or catholyte concentrations. When current densities were increased, the potential rose to such heights that the process was not economical; when decreased the cell efficiency was found to be low.

6. Economy of the Process

Expenditure involved in implementing the process industrially, would comprise the capital cost of the construction of the P.V.C. pipe line (150m long with a diameter of 10 cm) from the cell plant via a storage tank of capacity of 150 cm^3 to the saturators. Motors would be needed to pump anolyte from the storage tank to the saturators at an approximate velocity of 80m min^{-1}, to a height of 15 m.

A dechlorination plant before the introduction of anolyte liquor to the saturators was not considered to be necessary, since dissolved Cl_2 in the anolyte liquor would tend to decrease with re-saturation. The industrial implementation of the above

technique (pre-heated cell feed brine and re-circulation of anolyte liquor) is found to be satisfactory and has been recommended. The proposed method, in addition to the reduction of ClO_3^- in NaOH, is also expected to improve the working conditions of the cells and give better quality NaOH and purer Cl_2 gas.

Acknowledgement

This project was sponsored by a grant from the National Science Council of Sri Lanka, to whom we express our grateful thanks. Thanks are also due to Mr. V. Edwis and Mr. K. Amerasinghe of the Physical Chemistry Laboratories of the Department of Chemistry for the valuable (technical) services rendered to this project.

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Economically Useful Plants of Sri Lanka

II* Commercially Important Steroidal Sapogenins from Sri Lanka Plants†

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(*Paper accepted :* 21 *August* 1978)

Abstract : Several species of *Dioscorea, Costus, Agave, Yucca* and *Furcrea* growing in Sri Lanka have been assayed for saponins with a view to identifying suitable species and cultivars for commercially useful steroidal sapogenins. Rhizomes of *Costus speciosus* and the leaves of *Agave americana* have been identified as the best available materials in Sri Lanka for diosgenin and hecogenin, respectively.

1. Introduction

Sapogenins are hydrolysis products of saponins which are phytoconstituents widely distributed in the plant kingdom. Some sapogenins containing the steroid nucleus are useful starting materials in the commercial synthesis of physiologically and pharmacologically active steroids[1] such as corticosteroids, sex hormones and oral contraceptives. Commercially important steroidal sapogenins are present as saponins in some tubers of *Dioscorea*,[8] leaves of *Agave*,[8] and *Yucca*[8] species. Diosgenin (I) isolated from *Dioscorea* species is at present the principal starting material for the synthesis of the steroidal hormones *viz*., testosterone, estradiol and progesterone.[5] The world requirement of diosgenin was estimated in 1973 to be around 1,000 tons per year.[1] Though this may be on the high side, there was in fact a world shortage in 1974.[1] Mexico was the world's leading producer of diosgenin and in 1968 it produced 500 tons.[5] India's contribution of diosgenin in 1968 was 30 tons. Chief sources of diosgenin in India were the tubers of *Dioscorea deltoidea* Wall and *Dioscorea prazeri* Prain & Burk.[5] The purchase price[5] of diosgenin in 1969 ranged from US $ 12/50 per kg to US $ 17 per kg. Whilst in 1976, Datta quoted[3] a price of Rs. (Indian) 1000/- per kg.

J. Natn. Sci. Coun. Sri Lanka, 1976, **4**(2) : 163-166 is now considered as Part 1 of this series.

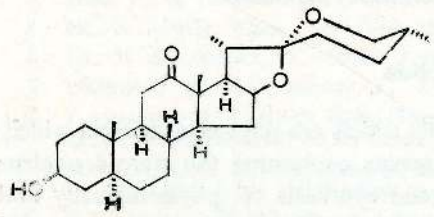
†Preliminary Communication : *Proc. Sri Lanka Assoc. Adv. Sci.*, 1977, **33** : 72.

This paper is dedicated to late Mr. A. W. Senanayake of the C.A.R.I., Gannoruwa, for his valuable contribution to the studies on the cultivation of *Dioscorea* species in Sri Lanka.

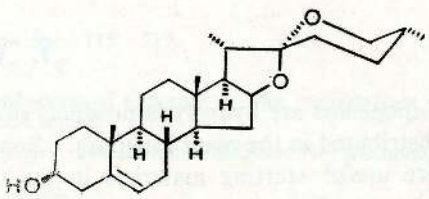
Hecogenin (II), a 12-keto steroidal sapogenin, though unsuitable for the manufacture of oral contraceptives is satisfactory for corticosteroid synthesis.[1] In fact 6% of steroid precursors used by the pharmaceutical industry is hecogenin.[1] The leaf of *Agave sisalana* Perrine, which is widely grown in Kenya and Tanzania for obtaining fibre, gives a juice from which hecogenin is extracted. The chief hecogenin producer in 1968 was Africa (40 tons).[6]

An alternative source for diosgenin (I) was discovered in 1970 by Das Gupta and Pandey[2] who showed that from the rhizomes of *Costus speciosus* (Koen.) Sm. growing in India about 2.1% of diosgenin could be obtained. In 1974, Sarin *et al.*[7] reported further studies on the rhizomes of *C. speciosus*. They found that the diosgenin content of these rhizomes varied from 0.58 to 2.63%.

Some *Dioscorea*, *Costus*, *Agave* and *Yucca* species are found growing wild and/or are cultivated in Sri Lanka. With the view to commercial exploitation for steroidal precursors we have screened these and some related species *viz.*, *Furcrea foetida* and *F. watsonia*, for their saponin content.



(I) Diosgenin



(II) Hecogenin

2. Experimental

2.1. Froth test for Saponins

The plant part (100 mg) was chopped and was shaken with water in a test tube. If a persistent froth of 3 cm length existed for 1/2 h, then the test was considered to be positive.[4]

2.2. Extraction of Saponins

The plant part (0.5 kg) which showed positive froth test was chopped and was immediately extracted in a soxhlet with rectified spirit (1 l.) for 24 h. The residue obtained after evaporation of solvent was extracted in a soxhlet with light petroleum (40–60°) (250 ml) and the defatted residue was partitioned between *n*-butanol and water. The *n*-butanol layer was dried (Na_2SO_4) and evaporated. The weight percentage of the butanol soluble residue (saponin) was calculated. Haemolysis test[4] was performed on this residue as described below.

2.3. Haemolysis test[4]

A medium double layered plate of 5% bovine red cell suspension in isotonic phosphate buffer (pH 7.4) in 1.5% agar-buffer overlaid on 1.5% agar-buffer was used. A disc of filter paper saturated in the appropriate solution of the test substance dissolved in phosphate buffer and diluted serially two-fold in the same buffer was placed on the surface of the well dried plate. Another disc containing digitonin in place of the test substance was placed on the same plate. The plate was left for 24 h and haemolytic zone, if any, was observed.

2.4. Hydrolysis of Saponins for TLC assay

The saponin (100 mg) was treated with rectified spirit (10 ml) and 10 ml of 10% HCl. The mixture was heated under reflux for 4 h. Solvent was evaporated under reduced pressure and the residue was taken up in chloroform, washed with water and the organic layer was dried (Na_2SO_4). The organic layer after concentration was subjected to TLC analyses using chloroform or chloroform-methanol (9 : 1) as developing solvents and ceric sulphate spray as the locating reagent.

The above single hydrolysis was sufficient for the assay of diosgenin. However, for detection of hecogenin a double hydrolysis (see section 2.6. below) was employed.

2.5. Isolation of Diosgenin (I) from *Costus Speciosus*

The rhizomes (25 g) of *C. speciosus* were cut into small pieces and were heated (80°) with 50 ml of 10% HCl (w/w) for 4 h. After cooling, the hydrolysis product was extracted with chloroform (2 × 25 ml). The organic layer was dried ($Na_2 SO_4$) and solvent evaporated. The residue was extracted with light petroleum (60°–80°) (10 ml). The light petroleum extract on concentration gave a solid (0.3 g) whose TLC analysis indicated diosgenin to be the major sapogenin. Preparative TLC of the above solid gave pure diosgenin (0.2 g, 0.8% from undried rhizomes) which was identified by m.p., mixed m.p. and co-TLC.

2.6. Isolation of Hecogenin (II)

2.6.1. *Hydrolysis of Agave americana leaf saponin*

Fresh *A. americana* leaves (1 kg) were cut into pieces and extracted in a soxhlet with rectified spirit (4 l) for 12 h. Solvent was evaporated under reduced pressure and the residue was refluxed for 2 h with ethanolic HCl (1M, 300 ml). The reaction mixture was filtered, solvent was evaporated and the residue was treated with 10% alcoholic KOH until solution was alkaline. The mixture was refluxed for 30 min, cooled and extracted with ether. The ethereal layer was dried (Na_2SO_4) and evaporated. The residue was crystallised from acetone to give pure hecogenin (1g, 0.1%), m.p. 258°–260°. The hecogenin isolated was found to be identical with an authentic sample (co-TLC and mixed m.p.).

2.6.2. *Direct hydrolysis of Agave leaves*

Fresh *Agava americana* leaves (1 kg) were chopped and ground in a mortar. The slurry thus obtained was transferred into a flask and heated with 60% H_2SO_4 at 150° for 4 h. Hot filtration gave a precipitate which was further heated for 2 h with 20% H_2SO_4. The residue from hot filtration was washed with water, with 1% NaOH and again with water. It was dried and the residue was extracted with chloroform. The chloroform extracts on concentration gave hecogenin (II) (0.5g, 0.05%), m.p. 259°–261°, identical with an authentic sample (co-TLC and mixed m.p.).

3. Results and Discussion

3.1. Commercial source for Diosgenin (I)

3.1.1. *Screening of the Dioscorea species of Sri Lanka*

Eleven different samples of underground tubers or aerial bulbils of *Dioscoreas* distributed amongst eight different species were collected from different parts of the country (see Table 1). The saponins were extracted by the method given in Section 2.2. The weight percentages of the *n*-butanol soluble residues (saponins) are presented in Table 1. The *n*-butanol solubles were subjected to haemolysis test only if the yield was $\geqslant 1\%$, since the underground tubers or aerial bulbils with a lower percentage will not be of economic importance. Those residues showing positive haemolysis test were subjected to hydrolysis. The hydrolysates were compared on TLC with authentic samples of diosgenin (I) and hecogenin (II). The results are given in Table 1. Out of the *Dioscorea* species assayed, only *angili ala* can be considered as a source for the commercially useful diosgenin. However, because of the low percentage of diosgenin, this *Dioscorea* species would not be of economic importance.

The two *Dioscorea* species, *D. deltoidea* and *D. prazeri* have been exploited in India. It is estimated that from these species growing at an altitude of 3000 to 8000 ft., 90 kg of diosgenin per acre per year could be obtained.[3] Two other species growing in the plains, *D. composita* Hemsl. and *D. floribunda* Mart. & Gal. have also been exploited[3] in India for diosgenin. According to trials carried out in India, the net profit from one acre of plantation per year, after extraction of diosgenin has been estimated to be around US $ 7,000/-. However, there is no record of these high diosgenin yielding *Dioscorea* species in Sri Lanka. Our results indicate that since the local *Dioscoreas* assayed for diosgenin, which included some wild types, are not of economic importance, attempts should be made to introduce the Indian varieties, at least as intercrops in tea, rubber or coconut plantations. Since the saponin content could vary with locality and climatic conditions (see Table 2), prior to large scale cultivation, it may be necessary to estimate the saponin content of the Indian species once introduced to Sri Lanka.

TABLE 1. % Saponins of some *Dioscorea* species growing in Sri Lanka

Species	Place of Collection	Plant part	Yield of Saponin (%)	Haemolysis Test†	Sapogenin
D. alata L (Jaffna purple)	Gannoruwa	Tubers	1.0	—	
D. alata L (*Sin.* Kahata ala)	Gannoruwa	Tubers	0.38		
D. alata L (*Sin.* Kahata ala)	Atabage	Tubers	1.0	—	
D. bulbifera L (*Sin.* Udala)	Atabage	Aerial bulbils	0.75		
D. bulbifera L (*Sin.* Udala)	Atabage	Tubers	2.2	+	No diosgenin, No hecogenin
D. bulbifera L	Jaffna	Tubers	1.65	+	No diosgenin, No hecogenin
D. esculenta (Lour) Burk. (*Sin.* Kukulala)	Gannoruwa	Tubers	1.0		
D. esculenta (Lour) Burk. (*Sin.* Kiriala)	Atabage	Tubers	0.20		
D. pentaphylla (*Sin.* Katuala)	Atabage	Tubers	0.88		
Dioscores sp.* (*Sin.* Angiliala)	Atabage	Tubers and aerial bulbils	1.0	++	Very small amount of diosgenin.
Dioscorea sp.* (*Sin.* Java ala)	Atabage	Tubers	0.32		

*The botanical names of these species are not available.

†No haemolysis, — ; weak haemolysis, + ; strong haemolysis, ++.

3.1.2. *Screening of the Costus species of Sri Lanka*

Two different species of *Costus*, *viz.* *C. speciosus* and *C. afer* have been identified as growing in Sri Lanka. Several specimens of these were collected from different parts of the country. Saponins from the rhizomes were isolated using the method given in Section 2.2. The haemolysis test did not yield satisfactory results. Since the saponin content of most of the rhizomes studied were $> 1\%$ the extracts were subjected to hydrolysis. The sapogenins were first assayed by TLC and the results indicated that all saponins of the *Costus* rhizomes studied had diosgenin as the major steroidal sapogenin (see Table 2). The presence of diosgenin in the hydrolysate was further confirmed by isolation. Diosgenin was also isolated in good yield from the *Costus* rhizomes by a direct hydrolysis route (see 2.5). The *Costus* species, especially *C. speciosus*, which grows wild in Sri Lanka is a good source of diosgenin in Sri Lanka. According to the economics of its cultivation in India[3], one acre of land can give about 4000 kg of the dried rhizomes of *C. speciosus* per year. This on processing can yield 15 to 30 kg of diosgenin even if the yield of saponin is only 1%. According to the 1976 purchase price[3] this would fetch US $ 1875 to $ 3750. Considering this to be an annual turnover for an acre plot cultivated, the foreign exchange earning would be in the region of Rs. (Sri Lanka) 28,725 to Rs. 57,450 per year. The cost of cultivation and extraction of diosgenin has not been considered in this computation. Considering the cheap labour available and the possibility of extracting diosgenin from the rhizomes by a direct hydrolysis procedure which could be employed (see 2.5), the total cost of labour and cost of extracting diosgenin in Sri Lanka cannot be much more than the Rs. (Indian) 12,000 estimated in India[3] for a 1.0% yield of saponin from the rhizomes. As an initial experiment, we suggest that *Costus speciosus* should be cultivated as an intercrop in rubber estates.

TABLE 2. % Saponins from the *Costus* species growing in Sri Lanka

Species	Place of Collection	Yield of Saponin (%)	Haemolysis Test	Froth Test
C. speciosus (Koen.) Sm.	Gilimale	1.4	+*	+
C. afer	Kandy	0.3	—	+
C. speciosus	Kandy	0.7	—	+
C. speciosus	Deraniyagala	2.5	—	+

*Weakly positive.

Note : Diosgenin (I) has been shown to be present in the hydrolysates of all the saponin extracts by TLC and from the sample of *C. speciosus* from Deraniyagala, (I) has been isolated and identified. In all the cases, rhizomes contained saponins.

3.2. Commercial source of hecogenin (II)

Phytochemical screening of the *Agave*, *Yucca* and *Furcrea* species growing in Sri Lanka was undertaken with the view to identifying the best source of hecogenin. The species studied are listed in Table 3. *Agave americana* was found to be the best source of hecogenin. The fresh leaves contain *ca.* 1.5% of saponin. Hydrolysis of this gave hecogenin in a reasonable yield. The conventional method involving extraction of saponin using solvents is too expensive and is not economically viable. The economically feasible route would be to chop the leaves and heat with 60% H_2SO_4 and effect the hydrolysis before extracting hecogenin (see *2.6.2.*).

TABLE 3. Results of the screening of *Agave*, *Yucca*, and *Furcrea* species of Sri Lanka for their saponin contents.

Species*	Plant part†	Yield of Saponin (%)	Haemolysis test‡	TLC of sapogenin mixture	
				No. of spots	Hecogenin
Agave americana L Var. Variegata	leaves	1.5	++	4	+††
A. angustifolia Haw.	fruits	1.1	++	6	+
A. franzosoni Baker	fruits	0.6**			
A. rigida Mill Var, Sisalana Engl.	leaves	1.1	—		
A. toquilana Wood	leaves	0.3**			
Yucca aloifolia L	leaves	2.3	+	3	+
Y. gloriosa L	leaves	7.2	+	3	+
Furcrea foetida (L) Haw. (= *F. gigantia* Vent.)	leaves	1.0	++	4	+
F. watsonia Hort.	fruits	0.5**			

* All the plant parts were collected in and around Peradeniya.

† Fresh plant parts were used in the extraction.

‡ No haemolysis, — ; weak haemolysis, + ; very strong haemolysis, ++.

** No further analysis was performed as the saponin yield was low (< 1%)

†† Isolated and identified by comparison with an authentic sample.

4. Conclusion

The results indicate that none of the locally growing *Dioscorea* species including some wild ones studied is suitable as a commercial source of diosgenin. If diosgenin rich Indian *Dioscorea* species, *viz. D. deltoidea*, *D. prazeri*, *D. composita* and *D. floribunda* prove to be good sources of diosgenin under local conditions, steps should be taken to introduce them for commercial exploitation.

Costus species growing wild in Sri Lanka which are shown to be rich in diosgenin should be cultivated on an organised scale preferably in the rubber growing districts.

Agave americana is a good source of hecogenin in Sri Lanka. Cultivation of this should be encouraged in semi-arid and agriculturally unproductive areas.

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Development of Local Raw Materials for the Rubber Industry

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Abstract : The rubber industry in Sri Lanka imports annually a considerable amount of rubber compounding ingredients. A programme of research has been initiated at the Ceylon Institute of Scientific and Industrial Research to find local substitutes for these imported ingredients. Suitable local substitutes for antioxidants, stearic acid and tackifiers have been successfully worked out.

1. Introduction

It is now over hundred years since the rubber tree was first introduced to Sri Lanka. The rubber industry in Sri Lanka has developed much over these hundred years and 136×10^6 kg (about 300 m. lbs) of natural rubber are produced in the country now. The amount of rubber consumed by the local rubber industry is about 7×10^6 kg, while the balance is exported. About 65 wt % of the rubber used locally is for the manufacture of tyres, tubes and for retreading.

Although rubber forms the major portion (about 65 wt %) of a rubber compound, the compounding ingredients or the rubber chemicals play a more important role in the evaluation of the physical and mechanical properties of the rubber products and they also exercise a considerable control over the cost. Most of the rubber compounding ingredients are imported into the country and they are products of the petroleum industry. In recent times, much attention has been drawn to replacing these oil derived products with materials derived from either source renewable natural raw materials or source destructive, but, tacitly more plentiful, inorganic products.[1] It is very encouraging that Sri Lanka has in abundance materials belonging to both these categories and therefore the Ceylon Institute of Scientific and Industrial Research (CISIR) has initiated a programme of research to develop these local raw materials for the benefit of the rubber industry. This paper describes work that has already being carried out at the CISIR, the work that is in progress and outlines the other possibilities that are worth investigating.

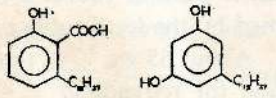
2. Experimental

2.1. Development of antioxidants

The presence of unsaturation in natural rubber makes it particularly vulnerable to autoxidation and therefore antioxidants are essentially incorporated into the rubber products to prevent or retard the degradative process.[15] Phenyl-beta-naphthylamine (Nonex D, ICI) and polymerised 2, 2, 4-trimethyl-1-2-dihydroquinoline (Flectel H,

Monsanto Chem. Co.) are the two most commonly used general purpose antioxidants in Sri Lanka, the latter has become more popular in the recent years. Both of them belong to the amine type of chain breaking antioxidants, in which category the hindered phenolic type of antioxidants are also classified.[15] It is generally accepted that the amine antioxidants are superior to the phenolic antioxidants, specially in black loaded vulcanizates.[16]

A survey of the naturally occuring hindered phenols in Sri Lanka has indicated that Cashew-Nut-Shell Liquid (CNSL) should occupy the first place in the list of local raw materials as prospective antioxidants. CNSL consists mainly of two phenols, namely anacardic acid and cardol, each with a bulky unsaturated alkyl group (C_{15}) at the meta position. Anacardic acid has a carboxyl group, ortho to the phenolic group and is present to an extent of about 80 wt %. Cardol is a dihydroxy alkyl phenol, the two OH-groups being at meta positions with respect to each other and is present to an extent of about 20 wt %. Figure I illustrates the structures of these two compounds.



(1) (2)

Figure 1. Structure of the main constituents of CNSL.
(1) — anacardic acid
(2) — cardol.

Laboratory scale investigations have proved conclusively that CNSL, after being subjected to a heat treatment,[11] shows high antioxidant activity in black loaded natural rubber vulcanizates. Its antioxidant activity, when used in 2 parts per hundred rubber (phr) as evaluated in a series of vulcanizates, based on conventional, semi-efficient vulcanization (semi—E V) and efficient vulcanization (E V) curing systems, has been found to be comparable with that of 1 phr Nono × D and Flectol H. For example, Table 1 contains the retention of tensile strength and elongation at break of rubber vulcanizates, containing CNSL, Nonox D, and Flectol H, based on a conventional vulcanizing system, on ageing in an air circulating oven at $70^0 \pm 1^0$C. Evaluation of antioxidants in natural rubber[2] is commonly done by studying the retention of the tensile properties of the vulcanizates on ageing in an air circulating oven at $70^0 \pm 1^0$C. The results included in Table 1 indicate that 2 phr of heat treated CNSL has antioxidant activity much similar to that of 1 phr of Nonox D and Flectol H. The high antioxidant activity of CNSL could be qualitatively explained as being due to formation of high molecular weight antioxidants and network bound antioxidant during vulcanization with sulphur.[13] Synergistic mixtures of CNSL and Nonox D and Flectol H, have shown to be even more powerful antioxidants than Nonox D and Flectol H.[13]

TABLE 1. Retention of tensile strength and elongation at break of the vulcanizates with different antioxidants on air oven ageing at 70° ± 1°C

Antioxidant	Retention of tensile strength		Retention of elongation at break	
	After 7 days (%)	After 14 days (%)	After 7 days (%)	After 14 days (%)
Nonox D (1 phr)	69	47	70	60
Flectol H (1 phr)	63	41	60	50
CNSL (Raw) (2 phr)	40	25	56	40
CNSL (Heated) (2 phr)	69	42	63	51
Nil	33	17	48	33

Formulation of the base mix

Rubber	100
ZnO	4
Stearic acid	6
Dibenzthiazyl disulphide	0.75
Sulphur	3.5
Carbon black (HAF)	40
Antioxidant	1 or 2

Cure time 30 minutes at 140°C.

2.2. Local substitutes for stearic acid

In rubber compounding, one to four parts per hundred parts of rubber of a high molecular weight monobasic organic acid or a mixture of such acids (fatty acids) is used to promote the solubility of zinc oxide in rubber through the formation of organic zinc salts. In recent times, the fatty acids mixture of the Oils and Fats Corporation has partly replaced the imported stearic acid. The possibility of using Pitch oil, the residue from the fatty acid manufacture at Oils and Fats Corporation, in place of imported stearic acid has been investigated by us. Pitch oil has been found to contain about 40 to 45 wt % of free fatty acids, lauric acid being present upto an extent of about 45%, myristic acid to an extent of 21%, palmitic to an extent of 11% and stearic to an extent of 10.5%. It has been established, using a standard tyre tread formulation that pitch oil can replace stearic acid, but a quantity equivalent to $1\frac{1}{2}$ times the amount of stearic acid in a particular formulation has to be used,[12] as illustrated by Table 2. According to the Oils and Fats Corporation about 300 tons of pitch oil are available annually and its cost is about one fifth that of the fatty acid mixture.

A possible source of stearic acid in Sri Lanka is rubber seed oil. Hydrogenation of the fatty acids from rubber seed oil should yield about 80% (w/w) of stearic acid.

Table 2. Tensile properties of the vulcanizates with pitch oil and stearic acid and their ageing characteristics (3 days at 100°C)

Property	Stearic acid (3 phr)	Pitch oil (4.5 phr)
Tensile strength kg/cm²	262	259
Elongation at break %	563	588
Modulus at 300% elongation kg/cm²	111	100
Permanent set %	26	28
Tear resistance kg	129	102
% tensile strength retained on ageing	86.2	88
% Increase in modulus on ageing	16.6	23
% elongation at break retained on ageing	84	88
% Tear resistance retained on ageing	71	71

Formulation of the base mix

Rubber (RSS)	100
ZnO	5
Sulphur	1.6
2-(4-morphohnyl mercapto) benzthiazole	1.3
Carbon black (ISAF)	45
Flectol H	0.5
4-isopropylamino-diphenylamine	1
Dutrex R	8
Fatty acid	3 or 4.5

Cure time 50 minutes at 143°C.

2.3. Local resins in rubber compounding

Resinous materials have long being used to aid in the processing of rubber and to impart special properties to the vulcanized product.[9]

Coumarone-indene resins made from coal tar and gas tar distillates and other synthetic resins from petroleum are widely employed with rubber. They improve the tack properties of rubber and also act as softeners to a certain extent. Investigations carried out at the CISIR have shown that the local resin Kekuna (*Canarium zeylanicum*) could be used as a substitute for the imported synthetic resins,[14] as illustrated by the results in Table 3. Investigations are in progress on the use of CNSL-formaldehyde thermoplastic resins (with low ratio of formaldehyde) as tackifiers and CNSL-formaldehyde thermosetting resins (with high ratio of formaldehyde) to improve the physical and mechanical properties of the vulcanizates. It has been observed that the presence of CNSL-formaldehyde resin in natural rubber vulcanizates improves their resistance to mineral oils. Chlorinated paraffin and chlorinated waxes have been used with rubber to impart flame resistance.[9] Chlorinated natural rubber could impart flame resistant characteristics to rubber, for example in rubberized coir products.

TABLE 3. Physical properties of natural rubber mixes and their vulcanizates with Kekuna and coumarone indene resin as tackifiers

Property	With Kekuna resin	With Coumarone Indene resin	Control
Tackiness (Wallace)	260	230	110
Tensile strength (kg/cm²)	265	274	320
Modulus at 300% longation (kg/cm²)	85	88	107
Abrasion (cc/500 rev.)	0.12	0.17	0.16
Hardness (°IRHD)	60	60	63

Formulation of the base mix

Rubber (RSS)	100
ZnO	5
Stearic acid	1
Dibenzthiazyl disulphide	1
Diphenyl guanidine	0.5
Sulphur	2.5
HAF black	45
Nonox D	1
Dutrex R	5
Resin	5

Cure time 30 minutes at 140°C

2.4. Local materials as reinforcing fillers

Carbon black occupies a unique place in rubber technology as a reinforcing filler, but its supplies depend solely on the oil industry. During the last few years, when the oil-crisis was at its peak, a considerable number of publications appeared in rubber journals reporting work on improvements of the reinforcing effect of the non-black fillers like clays, silicas, cellulose, corn starch and paddy hull ash, so that these naturally occurring raw materials could be substitutes for carbon blacks.[1, 6, 8, 19]

2.4.1. *Paddy Hull Ash*

A cheap source of pure silica in Sri Lanka is paddy hull. At present paddy hull finds only limited commercial applications. It contains about 18 to 30 wt % of pure silica. According to Haxo and Mehta, in a paper presented at the ACS Conference in 1974,[6] if you burn paddy hulls at the right rate and temperature, and then grind the residues, you end up with an amorphic silica material which comes out at something like the price and performance of a medium thermal black. To obtain the correct type of silica combustion conditions are the key to success. The carbon containing materials must be burned away, but too high a temperature or too long a residence time will give a fused crystalline mass, with no useful properties at all.

At the CISIR, preliminary investigations have been carried out to evaluate the optimum combustion conditions. The temperature of combustion was varied between 700°C and 800°C and the residence time between $\frac{1}{2}$ h and 1 h. Although

silica obtained under these different conditions showed different reinforcing properties, it was not possible to work out the optimum conditions. Further investigations are now in progress in our laboratories to work out these conditions. It is also reported in literature[6,7] that precipitated silica modified with silanes, e.g. about 2 wt % of gamma-mercaptopropyltrimethoxysilane, imparts similar physical and mechanical properties to passenger vehicle treads as reinforcing blacks.

2.4.2. *Clays as reinforcing fillers*

Clay occupies the number two position after carbon black as a filler in rubber compounding, when the use pattern for all fillers is considered. In the rubber industry, clays are classified as 'hard clay' and 'soft clay'. 'Hard clay' gives a higher modulus or a stiffer stock than the 'soft clay' at the same loading. Nearly every soil contains clay, but all clays are not good enough to be used by the rubber industry.[8] The particle size, nature of the particle surface and purity are vital factors in the use of clay as a compounding ingredient. The particle size and purity are parameters to be controlled during processing of clay from the mine. Nature of particle surface which controls its capacity to absorb accelerators and activators and thus the rate of cure can be improved by the use of activators. Triethanolamine and high molecular weight polyethylene glycols are found to be useful activators.[8]

Silane modification of fine particle (mean diameter $< 1\ \eta$) hydrous clay is reported to improve its reinforcing characteristics greatly and this modified clay offers the opportunity to replace substantial proportions of carbon black in many compounds.[1]

A study of the local clays, e.g. particle size, distribution, surface properties and purity, for the rubber industry is to be initiated in collaboration with the Minerals Technology Section of the Ceylon Institute of Scientific and Industrial Research.

2.4.3. *Lignin reinforcement of rubber*

Considerable work has been done in an attempt to use lignin as a reinforcing filler for rubber. Vulcanizates with satisfactory properties have been obtained in introducing lignin into rubber at the latex stage.[7, 10]

Commercial dry lignin, milled into rubber, produces vulcanizates with little, if any improvement, in their physical properties. However, it has been reported that precipitating alkali lignin solutions in the presence of emulsifiers yielded dry lignin products with good reinforcing properties.[17,18] Reinforcement has also been obtained using reprecipitated lignin where the final finely divided product has surface areas in the range of 36 m^2/g to 52 m^2/g.[17,18]

In Sri Lanka, the source of lignin would be the black liquor from the National Paper Mills Corporation. Investigations to use lignin in the form of lignin-rubber latex copreeipitates (using black liquor itself) as well as dry lignin recovered from black liquor, as a reinforcing filler for rubber are to be initiated.

2.5. Rubber Chemicals from CNSL

In recent years, attempts have been made to synthesise rubber chemicals, namely accelerators and antioxidants from CNSL, in India.[3,4,5] The antioxidant activities of the chemical derivatives of CNSL as reported in these publications,[3,4] are not very much superior to the activity of heat treated CNSL developed at CISIR. The accelerator of the sulphenamide type, which has been developed modifying CNSL chemically, is reported to perform well as an accelerator[5] in efficient vulcanization systems. Therefore, at the CISIR efforts will be concentrated on the development of accelerators through chemical modification of CNSL.

3. Conclusion

The intention of this paper has been to deal with a reasonably wide variety of topics to illustrate research at the CISIR in the field of evaluation of local raw materials for the rubber industry. The paper will not be complete without the mention of possible recovery of sulphur from the flue gases at the Ceylon Petroleum Corporation.

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A Study of the Effect of Nitrogen Fertilization and Intensity and Frequency of Defoliation on Yield, Chemical Composition and Feeding Value of Guinea A Grass

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Abstract : Two experiments were carried out to investigate the influence of intensity and frequency of defoliation and N application on dry matter yield, chemical composition and feeding value of Guinea A grass, found abundantly in the low and mid-country of Sri Lanka. In Experiment I, the effect of three cutting heights on dry matter yield, crude protein percentage and digestibility, were investigated. When harvested at 30 day intervals under a fertilizer regime of 336 kg N/ha/year, the height of cutting had a significant influence on herbage dry matter yield and leaf : stem ratio. It had no effect however, on crude protein percentage and *in vitro* organic matter digestibility. In the second experiment, the influence of three levels of N, on changes in composition and feeding value, when harvested at 15, 30 and 45 days, was studied. N application up to 84 kg N/ha/year had no significant effect on dry matter yield but the crude protein content increased with age up to 30 days and declined thereafter. An inverse relationship was seen between herbage dry matter yield and its feeding value. It is concluded that Guinea A grass shows no response to N application up to 84 kg N/ha/year and that highest dry matter yields can be achieved when defoliated to a height of 6'' above ground level at 30 day intervals ; the harvested material having 13 to 14% crude protein and an organic matter digestibility of 53%.

1. Introduction

Guinea grass, also known as Guinea A (*Panicum maximum*, ecotype A) found abundantly in low and mid country of Sri Lanka, is extremely resistant to drought and prolific in growth. Despite recommendations for the use of improved varieties, dairy farmers in these areas utilize Guinea A as the main source of roughage for their cattle. The recent trend has therefore been to treat Guinea A as a useful source of fodder rather than attempting to eradicate and replace it with improved varieties.

It is now well established that high nitrogen application increases herbage dry matter yields and enhances herbage quality.[1,7,8,9] Recently, Jayawardene[6] demonstrated that Guinea A responds well to the application of 250 kg N/ha by producing 26,000 kg dry matter/ha having a crude protein content of 11%, when harvested at six weekly intervals. High nitrogen application to grass-land would, however, be uneconomical in view of the rising cost of fertilizers and shortages experienced from time to time.

The intensity and frequency of defoliation has also been demonstrated to influence the rate of regrowth and hence the output of herbage dry matter/unit of land.[1,4,5,10]

This paper reports the results of two field experiments designed to study the influence of low levels of nitrogen and intensity and frequency of defoliation on dry matter yield, composition and feeding value of Guinea A grass. The experiments were conducted at the Pasture Research Unit of the Department of Animal Husbandry, University of Sri Lanka, Peradeniya Campus, during February to July 1977.

2. Materials and Methods

Experiment I.

Guinea A grass was established in the field about six months prior to the commencement of the trial. The layout of the trial was a completely randomized block design with four replications. The size of the main plot was 10′ × 6′ and each sampling sub-plot measured 6′ × 4′. Grass was planted giving a spacing of 2′ × 2′. Prior to the actual commencement of the trial all plots were fertilized uniformly with a basal application of 112 kg K_2O and 56 kg P_2O_5/ha.

Three cutting heights, namely 1″, 3″ and 6″ above ground level, were studied. The plots were harvested at monthly intervals to estimate the herbage yield. The total period of sampling was 90 days. At the beginning and after each harvest, nitrogen was applied in the form of urea at the rate of 336 kg nitrogen/ha/year and worked into the soil by forking. The experiment commenced on the 28th April 1977.

At each sampling herbage was cut to the appropriate height as at the commencement, mixed thoroughly, weighed on the spot and two sub-samples were removed to the laboratory. One sub-sample was entirely used to determine the leaf : stem ratio and the Leaf Area Index (LAI). The other sample was used for dry matter determination.

Experiment II.

Guinea A grass was established in the field about 3 months prior to the actual commencement of the trial. The experiment was laid out as a 3 × 3 factorial with four replications. Each main plot measured 10′ × 6′ and the sampling sub-plot measured 6′ × 4′. The plants were evenly spaced at a distance of 2′ × 2′. Prior to the commencement of the trial all plots were uniformly cut to a height of 6″ above ground level. In addition all plots were fertilized uniformly with a basal application of 112 kg K_2O and 56 kg P_2O_5/ha.

Nitrogen was applied in the form of urea. Three rates of application, namely 0, 56 and 84 kg Nitrogen/ha/year were compared. The appropriate quantity of nitrogen fertilizer was placed around each plant after harvest and incorporated into the soil by forking.

Since the main purpose of the study was to observe the changes in composition and feeding value during uninterrupted growth within a cutting cycle of 45 days, sampling was done at 15, 30 and 45 days, each time removing the cumulative growth from the time of previous sampling. At each sampling, the herbage was cut to 6" from ground level as at the commencement, mixed thoroughly and a sub-sample removed to the laboratory for dry matter determination. The experiment commenced on the 18th February 1977.

Laboratory Methods

For both experiments the dry matter determination was carried out by drying the sub-sample in an unitherm oven at 100°C for 6 hours. A representative sample from each of these was used for the determination of crude protein by Kjeldhal method and *in vitro* organic matter digestibility by the method of Tilley and Terry.[11]

3. Results

Experiment I

The influence of height of cutting, on the composition and feeding value of Guinea A is shown in Table 1.

TABLE 1. The influence of height of cutting on composition and feeding value of Guinea A. (The values are the mean of three harvests).—Experiment I.

Height of cutting (inches)	1	3	6	S.E. of difference for comparing means.
The mean herbage dry matter yields (kg/plot)	1.05	1.18	1.29	± 0.06
Percentage dry matter	19.4	19.5	20.2	± 0.34
Crude protein content (g/100 g dry matter)	12.9	14.4	14.1	± 0.63
Leaf : stem ratio	1.34	1.68	2.20	± 0.18
Leaf area index (LAI)	4.9	5.5	5.7	± 0.34
In vitro organic matter digestibility (%)	51.1	47.7	49.5	± 1.52

The height of cutting appeared to have a significant effect upon the herbage dry matter yield. Increasing the height of cutting from 1 "to 6" increased the herbage dry matter yields significantly ($P < 0.05$). Although it had no influence on the dry matter percentage, it increased the leaf : stem ratio significantly ($P < 0.05$). The cutting height of 6" gave the highest leaf : stem ratio of 2.2 at 30 days of growth.

With the increase in the leaf : stem ratio the LAI also increased ; however, beyond the cutting height of 3" there was no further significant ($P < 0.05$) increase in the LAI.

Even though the height of cutting influenced the dry matter yield, it had no effect on the crude protein percentage and the *in vitro* organic matter digestibility.

Experiment II

The mean yields of herbage dry matter at each sampling date (mean cumulative growth) for the 45 days of growth are shown in Table 2. Nitrogen application up to 84 kg/ha had no significant ($P < 0.05$) effect upon the yield of dry matter. However increasing the cutting frequency increased dry matter yields significantly ($P < 0.01$) at all levels of nitrogen.

TABLE 2. Mean herbage dry matter yields in grams per plot—(cumulative growth)—Experiment II.

Days of growth	15	30	45
Nitrogen application (kg/ha)			
0	157	431	729
56	184	477	609
84	197	438	531

S.E. of difference for comparing any two nitrogen levels at the same harvesting date ± 58.9

S.E. of difference for comparing any two harvesting dates at the same nitrogen level ± 58.9

S.E. of difference for comparing interactions ± 144.2

Table 3 shows the mean crude protein percentage in herbage dry matter at each sampling date. The crude protein percentage increased significantly with age up to 30 days and thereafter showed a rapid decline. Increasing the dosage of nitrogen from 0 to 56 kg nitrogen/ha increased the crude protein percentage ; beyond 56 kg nitrogen there was no further increase. As could be expected, the mean herbage dry matter percentage increased with advancing maturity but nitrogen application had no significant effect. (Table 4).

TABLE 3. Mean crude protein percentage in herbage dry matter—Experiment II.

Days of growth	15	30	45
Nitrogen application (kg/ha)			
0	10.67	13.17	9.92
56	11.72	13.20	11.67
84	11.67	13.12	10.47

S.E. of difference for comparing any two nitrogen levels at the same harvesting date ± 0.26

S.E. of difference for comparing any two harvesting dates at the same nitrogen level ± 0.26

S.E. of difference for comparing interactions ± 0.64

TABLE 4. Mean herbage dry matter percentage—Experiment II.

Days of growth	15	30	45
Nitrogen application (kg/ha)			
0	25.19	24.33	28.81
56	24.69	27.23	28.85
84	22.76	24.64	30.10

S. E. of difference for comparing any two nitrogen levels at the same harvesting date ± 2.19

S.E. of difference for comparing any two harvesting dates at the same nitrogen level ± 2.19

S.E. of difference for comparing interactions ± 5.36

The relationship between dry matter yield (DMY) and *in vitro* organic matter digestibility (IVOMD) with increasing maturity of the herbage is shown in Figure 1. There was an inverse relationship between herbage yield and its feeding value. As the plants progressed towards maturity, herbage yield increased but the organic matter digestibility declined.

4. Discussion

Pasture management is aimed at securing the highest output/unit of land of good quality herbage, that can be used for the successful raising of livestock. Intensive pasture management therefore involves the production of high yields/unit of land of herbage of high feeding value and the efficient use of the herbage produced. In this context increasing attention has been paid in recent years to the study of the influence of intensity of defoliation on herbage growth. The results of the present experiments clearly demonstrate that Guinea A fodder yields the highest quantity of herbage dry matter when defoliated to a height of 6″ above ground level and at 30 day intervals.

The variation in yields with the intensity of defoliation can be attributed to two main factors. As claimed by Watson[12,13] it could be primarily due to changes in leaf area, which would operate directly by altering the photosynthetic area and indirectly by changing the net assimilation rate. The relationship between leaf area and pasture yields was clearly demonstrated by Brougham,[3] who reported that the height of defoliation markedly influenced the rate of regrowth. The stage at which 95% of the incident light energy was intercepted and hence a maximum rate of regrowth attained, corresponded to a leaf area index of 5 and following defoliation to a height of 5″ above ground level, this was achieved approximately 4 days after cutting, whereas regrowth did not reach a maximum rate until 16 and 24 days following defoliation to 3 inches and 1 inch, respectively. Beyond this point the rate of increase in leaf area and the increment in dry matter was maintained at a maximum rate. Thus it seems that defoliation to a height of 6″, induced Guinea A grass to attain the optimum LAI very rapidly resulting in the maximum rate of regrowth producing the highest dry matter yields.

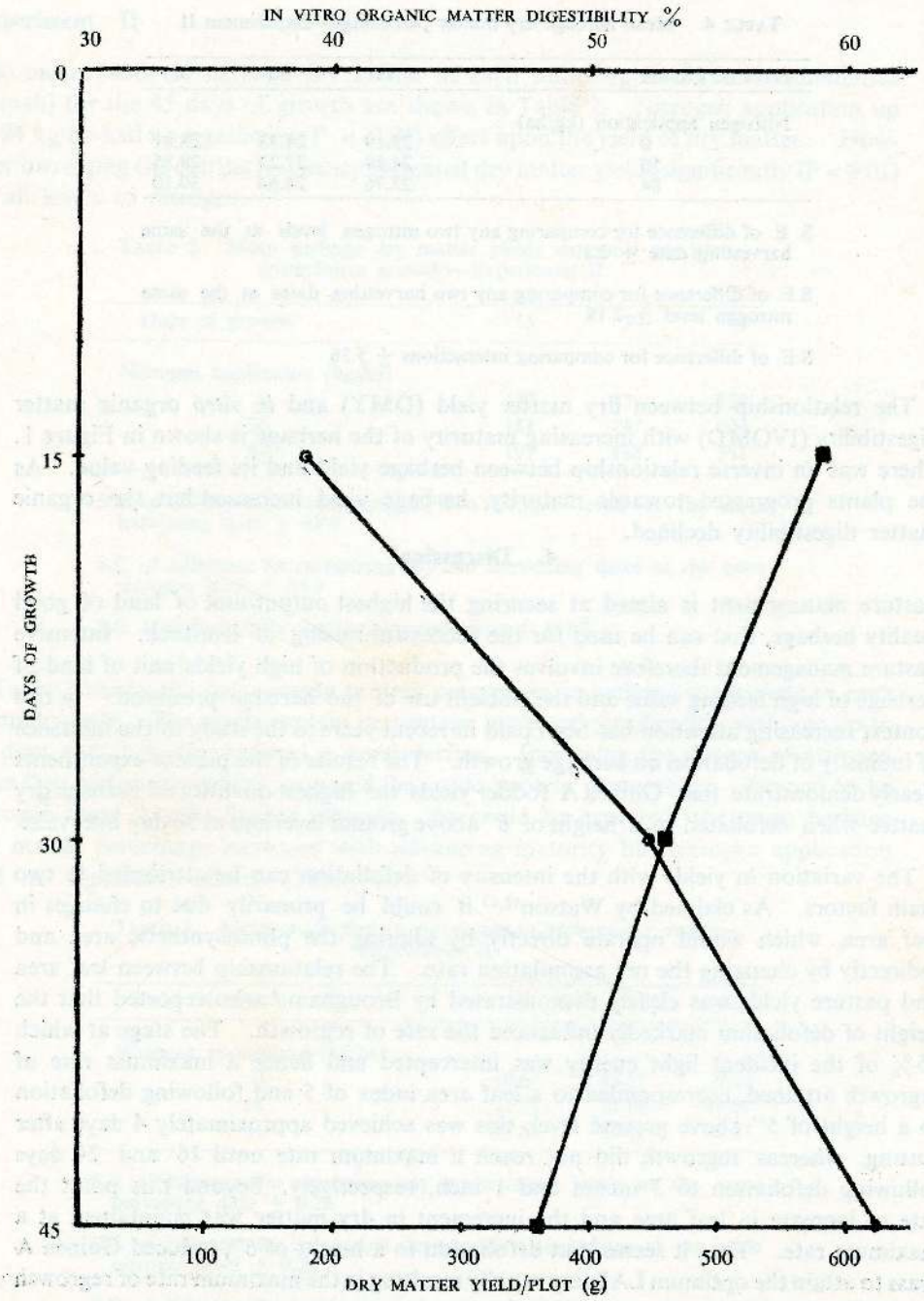

Figure 1. The relationship between dry matter yield and *in vitro* organic matter digestibility of Guinea A grass.

■——■ IVOMD

o——o DMY

The effect of defoliation on water absorption could have also influenced the high dry matter production at the 6" cutting height. According to Army and Kozlowski,[2] the effect of soil moisture is more severe on closely defoliated plants than on lax defoliated plants. In lax defoliated plants, transpiration occurs and causes a diffusion pressure deficit in the leaves, which may be transmitted as a tension to the roots and helps to absorb water. If the plants are closely defoliated, however, they will have to depend only on the absorption mechanism of their roots for the water supply, thus limiting rate of regrowth.

Pure stands of grass are known to respond readily to applied nitrogen. However, the results of the present investigation indicate that Guinea A grass does not respond to applied nitrogen up to 84 kg/ha. It may be possible that the quantities investigated in the reported trial were too low to produce any significant response. On the other hand, microorganisms associated with the root rhizosphere of Guinea grass could have influenced nitrogen utilization. It has been clearly demonstrated that microorganisms associated with root hairs of most tropical grasses are capable of fixing atmospheric nitrogen similar to legumes.[14] The equal response in dry matter production at 0, 56 and 84 kg/ha in the present trial is strongly indicative of such an association between the plant and the soil borne microorganisms.

Rainfall enhances the rapid growth of pasture grasses. Drought conditions on the other hand, results in reduced rate of growth, early maturity and early flowering. This is often reflected in the feeding value of the pasture herbage especially in the rate of decline of crude protein content and nutritive value. The more suitable climate conditions (Appendix Table 1) experienced during the experimental period could have therefore been responsible for the high crude protein and the dry matter yields recorded.

Appendix Table 1. Weather Data (January—July 1977)

Month	Monthly rainfall (mm)	Temperature (°F)		Relative Humidity (%)	
		Minimum	Maximum	Morning	Evening
January	2.8	61.7	84.2	72.9	53.6
February	6.7	67.1	86.0	73.8	55.2
March	123.1	69.8	87.8	75.6	60.6
April	291.1	68.9	89.6	84.0	73.5
May	450.8	69.8	83.3	82.6	83.3
June	174.0	68.9	81.5	80.8	73.4
July	76.5	68.9	84.2	81.6	73.8

(Source—CARI—Department of Agriculture, Gannoruwa)

The present investigation confirms the inverse relationship that exists between dry matter production and feeding value of pasture herbage (Figure 1). The choice of the optimal stage of defoliation would involve a compromise between these two factors. A late defoliation would result in a higher dry matter production but low feeding value while the reverse would be true for early defoliation. Thus the compromise between yield and quality of Guinea A when defoliated to a height of 6" above ground level, appears to be around the 30th day at which time it yields around 24,000 kg dry matter/ha, having a crude protein content of 13 to 14% and an *in vitro* organic matter digestibility of 53%.

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The Maximal Oxygen Uptake of Sri Lankan Athletes

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Abstract : The maximum oxygen uptake (VO_2 max) which is regarded as the best criterion of cardio-respiratory fitness, was measured using sub-maximal workloads in 214 Sri Lankan athletes chosen from the national pools. The steady state heart rate (Fh) was determined electrocardiographically at the end of the sixth minute of a stepping exercise and the VO_2 max was predicted using the Astrand Ryhming Nomogram. The aerobic capacity (physical fitness) of the Swimmers, Footballers, Gymnasts, Hockey Players, Netball Players and the Rugby players was inferior to accepted international standards. Among the Athletes, the Army endurance runners and sprinters had an oxygen uptake of international standards, although the All Ceylon Athletes who were non-service personnel showed a significantly lower uptake. It was further found that the average duration of training of army athletes was almost double that of other athletes when their respective training schedules were analysed.

1. Introduction

It seems strange that Asians who constitute half of the world population have only a 2% chance of winning prizes at the Olympic games. There are several reasons for this anomaly, and diet, body build, training schedules, state aid, physical fitness are all contributory factors. But there is no doubt that the use of sophisticated research techniques to assess and improve physical fitness is a major factor which enables the developed countries to sweep the board at international athletic meets.

Although much work has been done in other countries regarding the physical assessment of their athletes, very little work has been done in Sri Lanka, regarding the assessment of physical fitness of Sri Lankan athletes.

Cullumbine[4] measured the fitness index in 7000 Ceylonese subjects using post-exercise pulse rates. This method is, however, inaccurate[7] and these recovery tests are seldom used now for assessing physical fitness. Other than for this work of Cullumbine and of Koch[5] who assessed the vital capacity of University students, there has been no significant research done in this field for the past three decades.

Although many tests of physical fitness have been proposed, it is now recognised that the maximal oxygen uptake is the absolute criterion of cardio-respiratory fitness.[2,9] The objective of this project was to determine the physical fitness of Sri Lankan athletes using the maximal oxygen uptake as an index of physical fitness, to compare them with international standards and to suggest methods of improving the physical fitness of these athletes.

2. Materials and Methods

The maximal oxygen uptake was predicted from the heart rate using the nomogram proposed by Astrand and Ryhming[3] which was constructed on the postulate that the oxygen consumption and pulse rate are linearly related. A correction factor was applied for age as suggested by Astrand.[1]

The workload used was a submaximal one which involved the climbing of steps (40 cm high for males and 33 cm high for females) at the rate of 20 ascents per minute for males and 15 ascents per minute for females, the rate being controlled by a metronome. Care was taken to see that the athletes stood erect at each ascent and placed both heels on the ground with each descent. The heart rate was recorded electrocardiographically throughout the duration of the exercise, which lasted six minutes.

As the pulse rate shows a pronounced circadian rhythm,[6] the tests were carried out between 7 a.m. and 10 a.m. in a room where the temperature varied between 26°C and 28°C and the relative humidity varied between 60% and 70%.

The athletes chosen were from the national training pools and consisted of those who had or were representing the country in their respective sports or those who had taken part in the Ceylon Nationals. They were tested at the peak of their training schedules, a day or two prior to a meet.

The athletes were tested on an empty stomach, bare-bodied and bare-footed, clad only in physical training shorts and were advised to avoid unusually strenuous exertion the day prior to testing and to completely abstain from any strenuous activity on the day of testing.

They were rested supine on a bed for half an hour after which their resting pulse rates, systolic and diastolic blood pressures were recorded.

They were then asked to perform the stepping exercise without a preliminary warm-up period. The heart rate was calculated from the ECG, by measuring the distance between 7 R—waves (i.e. six intervals). Two consecutive heart rate recordings after the fifth minute which differed by no more than $\pm$ 5 beats was the criterion used to define the steady state.

The sports these athletes participated in were athletics (track and field), swimming, hockey, football, gymnastics, netball and rugger. They were all between 15 and 35 years of age.

3. Results

The physical fitness of the participants is calculated separately for each event.

3.1. Swimming

A total of seven males and seven females were examined. They were Ceylon's best swimmers and were examined just prior to the Indo-Ceylon meet. The details of their physical characteristics are shown in Table 1 (males) and Table 2 (females). In the swimming events, as bodyweight is supported, it is customary to express maximal oxygen uptake in litres per minute rather than in ml/kg/min.

TABLE 1. Swimming — Males (N = 7)

	Range	Mean	S.D.
Age (yrs)	13 — 24	16.4	3.6
Body Wt. (kg)	49 — 73	59.4	8.8
Rest. Ht. Rate/min	57 — 84	65.4	11.0
6tl. min Ht. Rate/min.	130.4—166.7	148.9	14.1
R.S.B.P. (mm Hg)	110 —130	120	7.1
R.D.B.P. (mm Hg)	68 — 85	75.9	6.1
VO_2 Max (L/min)	2.1— 3.8	2.8	0.55

TABLE 2. Swimming — Females (N = 7)

	Range	Mean	S.D.
Age (yrs)	13 — 16	14.1	1.2
Body Wt. (kg)	39 — 64.5	50.6	7.9
Rest. Ht. Rate/min	51 — 82.0	74	11.6
6th min. Ht. Rate/min	128.6—173.6	157.9	15.8
R.S.B.P. (mm Hg)	104 —130	114.3	8.4
R.D.B.P. (mm Hg)	68 — 84	72.3	5.8
VO_2 Max (L/min)	1.6— 3.4	2.2	0.68

As all of them were students, their training was restricted to $1\frac{3}{4}$ hours of swimming in the evenings. There were no body building or ground exercises included in their training schedules.

3.2. Hockey

36 hockey players from the national hockey pool were examined. There were 17 males and 19 females. The results of the 17 male players are shown in Table 3, while those of the female players are shown in Table 4.

TABLE 3. Hockey — Males (N = 17)

	Range	Mean	S.D.
Age (yrs)	17 — 21	18.3	0.99
Body Wt. (kg)	45 — 63	52.9	6.03
Rest. Ht. Rate/min	48 — 83	62.5	8.1
6th min Ht. Rate/min	129.6—154.4	142.5	7.3
R.S.B.P. (mm Hg)	100 —128	114.1	8.3
R.D.B.P. (mm Hg)	64 — 90	73	5.6
VO_2 Max (ml/kg/min)	43.7 — 63.7	52.5	5.9

TABLE 4. Hockey — Females (N = 19)

	Range	Mean	S.D.
Age (yrs)	15 — 30	19.4	4.03
Body Wt. (kg)	36 — 61	46.7	5.5
Rest. Ht. Rate/min	58 — 96	77.0	12.7
6th min Ht. Rate/min	133.3 —168.8	154.9	8.8
R.S.B.P. (mm Hg)	94 —146	111.8	10.3
R.D.B.P. (mm Hg)	52 — 84	71.6	8.9
VO_2 Max (ml/kg/min)	32.8 — 55.7	44.0	6 3

The average duration of training of these male players was $2\frac{1}{2}$ hours per day of which two hours was spent in playing hockey and acquiring its skills, while half an hour was spent in running and doing exercises. The females trained for $1\frac{1}{2}$ hours each day, of which one hour was spent in playing hockey while $\frac{1}{4}$ hour was spent each in running and doing exercises.

Except for four players, they were all students, many of them from Jaffna schools.

3.3. Football

12 Navy football players who had reached the semi-finals of the Ceylon Football Association cup were investigated at the end of the football season. The details of their measurements are shown in Table 5. The average duration of training per day was 3 hours, of which two hours were spent in playing football while $\frac{1}{2}$ an hour was spent in running and doing exercises.

TABLE 5. Football (N = 12)

	Range	Mean	S.D.
Age (yrs)	22 — 34	26.3	3.8
Body Wt. (kg)	50 — 68.5	60.3	4.9
Rest. Ht. Rate/min	50 — 64	58.5	4.1
6th min Ht. Rate/min	117.6—157.9	140.6	12.8
R.S.B.P. (mm Hg)	90 —124	103.5	9.7
R.D.B.P. (mm Hg)	50 — 76	67.3	8.7
VO_2 Max (ml/kg/min)	41.1— 76.7	53.4	11.2

3.4. Gymnastics

13 male gymnasts from the pool were examined prior to the Indo-Ceylon meet (Table 6). The average duration of training per day was 3 hours, of which two hours were spent in running and doing body-building exercises.

TABLE 6. Gymnastics (N = 13)

	Range	Mean	S.D.
Age (yrs)	17 — 25	20	2.4
Body Wt. (kg)	40 — 65	52	6.5
Rest. Ht. Rate/min	52 — 72	61.8	6.1
6th min. Ht. Rate/ min	130.4—166.7	148.6	9.8
R.S.B.P. (mm Hg)	96 —137	115.3	11.4
R.D.B.P. (mm Hg)	60 — 80	69.8	6.2
VO_2 Max (ml/kg/min)	37.9— 61.1	48.5	6.8

3.5. Netball

Twenty-five girls who formed the pool for the Sri Lanka netball team were examined (Table 7) just prior to their international match against Seychelles. Their average duration of training per day was two hours, of which about quarter of an hour was spent in doing exercises.

TABLE 7. Netball (N = 25)

	Range	Mean	S.D.
Age (yrs)	15 — 35	23.2	5.4
Body Wt. (kg)	40 — 60	48.6	5.4
Rest. Ht. Rate/min	48 — 84	67.9	8.2
6th min. Ht. Rate/min	136.4—184.9	160.2	11.6
R.S.B.P. (mm Hg)	90 —126	109.3	10.4
R.D.B.P. (mm Hg)	50 — 80	69.9	5.7
VO_2 Max (ml/kg/min)	29.1— 60.5	40.2	8.0

3.6. Rugger

A total of 17 rugby players were examined. Of these, 9 players represented Sri Lanka in the International seven-a-side rugby tournament in Hong Kong. The remaining 8 players represented a leading Colombo rugby club—the Colombo Hockey and Football Club (C.H. and F.C.).

3.6.1. *Seven-a-Side-Rugger*

Their physical assessment is shown in Table 8. The average duration of training was $1\frac{1}{4}$ hours per day. These players were mainly executives and staff officers.

TABLE 8. Rugger—Seven a side (N = 9)

	Range	Mean	S.D.
Age (yrs)	21 — 27	23.4	1.7
Body Wt. (kg)	56 — 76	64.6	7.2
Rest. Ht. Rate/min	54 — 82	61.1	8.7
6th min. Ht. Rate/min	121 —161.5	139.2	14.3
R.S.B.P. (mm Hg)	100 —125	112.8	7.4
R.D.B.P. (mm Hg)	68 — 75	71.9	3.8
VO_2 Max (ml/kg/min)	38.9— 70	54.1	11.2

3.6.2. *Club Rugger*

The physical characteristics of these 8 players is shown in Table 9. The average duration of training per day was 1½ hours. Four of these players were employed while the other four came from upper middle-class families.

TABLE 9. Rugger — Club rugger (N = 8)

	Range	Mean	S.D.
Age (yrs)	18 — 29	21.5	4.2
Body Wt. (kg)	52 — 73.5	61.5	8.8
Rest. Ht. Rate/min	62 — 72	67.5	10.5
6th min. Ht. Rate/min	136.4—163.1	151	10.3
R.S.B.P. (mm Hg)	90 —116	101.3	10.2
R.D.B.P. (mm Hg)	60 — 78	67.3	7.2
VO_2 Max (ml/kg/min)	37.8— 55	44.3	6.0

3.7. Athletes

A total of ninety-seven athletes were examined. These included 86 male athletes and 11 female athletes. Of these 97 athletes, 8 had participated in field events like the Javelin, Discus and Puttshot. Out of the 89 athletes who participated in track events, 67 (58 males and 9 females) were sprinters who had as their favoured event the 100m, 200m, 400m, 800m flat or hurdles.

22 athletes (20 males and 2 females) were long distance runners, who specialized in either the 1500m, 3000m, 5000m, 10,000m or the marathon road race—26 miles. Many had represented Sri Lanka in international meets, some held Ceylon records, others were winners of the Amateur Automobile Association (AAA) meet, the Junior Nationals, the Ceylon schools or the army meet.

The sprinters, army athletes, public school athletes, female athletes, long distance runners, and those athletes who participated in field events are considered separately.

3.7.1. *Field Events*

A total of 8 athletes fell into this group. They were males. Their characteristics are shown in Table 10.

TABLE 10. Male Athletes — Field events (N = 8)

	Range	Mean	S.D.
Age (yrs)	21 — 30	23.5	2.8
Body Wt. (kg)	59.6— 80	68.3	8.1
Rest. Ht. Rate/min	54 — 71	61.4	6.1
6th min. Ht. Rate/min	123.1—159.6	142.9	11.9
R.S.B.P. (mm Hg)	95 —112	107.1	5.4
R.D.B.P. (mm Hg)	60 — 96	70	11.7
VO_2 Max (ml/kg/min)	38.8— 68.8	49.8	10.2

Their average duration of training per day was one and a quarter hours of which $\frac{1}{4}$ hour was spent doing weight-lifting exercises.

3.7.2. *Female Athletes*

There were 11 female athletes, 2 long distance runners and 8 sprinters. Their details are shown in Table 11. Their average duration of training per day was $1\frac{1}{2}$ hours in the evenings.

TABLE 11. Female Athletes (N = 11)

	Range	Mean	S.D.
Age (yrs)	16 — 29	24.3	4.1
Body Wt. (kg)	40 — 67.5	49.4	8.6
Rest. Ht. Rate/min	56 — 82	67.5	9.6
6th min Ht. Rate/min	128.6—158	151	13.2
R.S.B.P. (mm Hg)	95 —116	106.5	7.0
R.D.B.P. (mm Hg)	60 — 90	73.3	7.6
VO_2 Max (ml/kg/min)	33.3— 63.2	44.4	10.4

3.7.3. *Army Sprinters*

Twenty of the top sprinters from the army athletic pool were examined. They had all won their events either at the Army meet or at the Nationals. The results of their examination are shown in Table 12. The average duration of training per day was $2\frac{1}{2}$ hours.

TABLE 12. Army sprinters (N = 20)

	Range	Mean	S.D.
Age (yrs)	20 — 27	22.8	2.1
Body Wt. (kg)	51 — 66	58.4	4.3
Rest. Ht. Rate/min	52 — 72	56.6	5.8
6th min Ht. Rate/min	111.1—150	133.3	11.7
R.S.B.P. (mm Hg)	90 —120	110.3	8.7
R.D.B.P. (mm Hg)	50 — 80	66.4	7.7
VO_2 Max (ml/kg/min)	45.8— 90.4	60.4	13.3

3.7.4. *National Sprinters*

A total of 17 sprinters were examined (Table 13). All of them were placed either in the Nationalised Services, AAA or Mercantile athletic meets, and some had represented Sri Lanka in the Indo-Ceylon Athletic meet.

TABLE 13. National sprinters (N – 17)

	Range	Mean	S.D.
Age (yrs)	19 — 31	24.4	3.4
Body Wt. (kg)	44 — 66	56.2	6.2
Rest. Ht. Rate/min	46 — 80	58.7	9.9
6th min Ht. Rate/min	120 —162.2	143.7	11.1
R.S.B.P. (mm Hg)	85 — 118	102.9	9.3
R.D.B.P. (mm Hg)	60 — 76	68.7	4.8
VO_2 Max (ml/kg/min)	38.5— 62.1	48.8	6.9

The average duration of training of these athletes was only $1\frac{1}{2}$ hours each day.

3.7.5. *Public School Sprinters*

21 students who had won or who had been placed in the Public School or the Junior Nationals were examined. (Table 14).

TABLE 14. Public School sprinters (N = 21)

	Range	Mean	S.D.
Age (yrs)	15.4	18.5	2.1
Body Wt. (kg)	42.5— 60	49.7	4.2
Rest. Ht. Rate/min	48 — 80	62.8	9.1
6th min Ht. Rate/min	126.9—190.6	153.6	14.4
R.S.B.P. (mm Hg)	90 —130	105.7	10.1
R.D.B.P. (mm Hg)	60 — 78	68.4	4.5
VO_2 Max (ml/kg/min)	29.8— 67.8	46.5	0.6

The average duration of training per day of these schoolboys was $1\frac{1}{2}$ hours.

3.7.6. *Army Long Distance Runners*

13 long distance runners who had won or had been placed in the 1500, 5000, 10,000 metres or marathon road race were investigated (Table 15).

The average duration of training per day was 3 hours.

TABLE 15. Army Long Distance runners (N = 13)

	Range	Mean	S.D.
Age (yrs)	22 — 29	25.2	2.2
Body Wt. (kg)	43 — 58.5	51.1	4.0
Rest. Ht. Rate/min	41 — 70	54.7	9.8
6th min Ht. Rate/min	95.5—152	121.4	19.7
R.S.B.P. (mm Hg)	100 —130	111.7	9.0
R.D.B.P. (mm Hg)	50 — 85	67.7	10.1
VO_2 Max (ml/kg/min)	50 — 96.2	74.9	18.9

3.7.7. *Long Distance Runners—Non-Service Personnel*

7 long distance runners who were non-service personnel but who had been placed in one of the events at the Nationals were examined. Their results are shown in Table 16. The average duration of training per day was two hours.

TABLE 16. Long Distance runners — non-service personnel (N = 7)

	Range	Mean	S.D.
Age (yrs)	17 — 25	20.6	3.0
Body Wt. (kg)	45 — 63.5	52.6	6.5
Rest. Ht. Rate/min	47 — 90	62.4	13.9
6th min Ht. Rate/min	117.2—170.7	143.7	23.2
R.S.B.P. (mm Hg)	94 —130	106.9	12.2
R.D.B.P. (mm Hg)	60 — 80	69.9	6.4
VO_2 Max (ml/kg/min)	34.7— 78.9	55.1	18.0

4. Discussion

The assessment of physical fitness of Sri Lankan athletes using maximal oxygen uptake as an index of physical fitness has not been performed earlier.

It has been shown by direct measurements of maximal oxygen uptake that the best physically trained athletes in endurance events have a maximal oxygen uptake in the region of 70 ml to 75 ml/kg/min for males and between 50 ml to 60 ml/kg/min for females. A maximal oxygen uptake of less than 42 ml/kg/min for a healthy young adult is a sign of poor physical fitness.[8]

Low resting heart rates and low sixth minute heart rates during submaximal exercise are also recognized criteria of physical fitness.

The physical fitness of the participants is calculated separately for each event.

4.1. Swimming

A total of seven males and seven females were examined. They were Ceylon's best swimmers and were examined just prior to the Indo-Ceylon meet. The details of their physical characteristics are shown in Table 1 (males) and Table 2 (females).

In the swimming events, as body weight is supported, it is customary to express maximal oxygen uptake in litres per minute rather than in ml/kg/min.

Their duration of training of $1\frac{3}{4}$ hours per day is inadequate. There were no body-building or ground exercises included in their training schedules.

4.2. Hockey

36 hockey players from the national hockey pool were examined. There were 17 males and 19 females. The results of the 17 male players are shown in Table 3, while those of the female players are shown in Table 4.

The average duration of training of these male players was $2\frac{1}{2}$ hours per day of which two hours was spent in playing hockey and acquiring its skills while half an hour was spent in running and doing exercises. The females trained for $1\frac{1}{2}$ hours each day of which one hour was spent in playing hockey while $\frac{1}{4}$ hour was spent each in running and doing exercises.

The uptake of these hockey players was fairly satisfactory compared to international standards and none of the male players had an uptake below 40 ml/kg/min. This could probably be attributed to their rigid training schedules and strict supervision by the coaches.

4.3. Football

12 Navy football players who had reached the semi-finals of the Ceylon Football Association (F.A.) cup were investigated at the end of the football season. The details in their measurements are shown in Table 5.

The average duration of training per day was 3 hours, of which two hours was spent in playing football while $\frac{1}{2}$ hour was spent in running and doing exercises. In spite of a three hour training schedule, their mean maximum oxygen uptake was low (53.4 ± 11.2 ml/kg/min) though none were below the unfit mark of 40 ml/kg/min.

4.4. Gymnastics

13 male gymnasts from the pool were examined prior to the Indo-Ceylon meet (Table 6). The average duration of training per day was 3 hours, of which two hours were spent in running and doing body-building exercises.

Although their duration of training was long, their uptakes were relatively low indicating a low endurance fitness. Two of them had uptakes below 40 ml/kg/min.

4.5. Netball

Twenty-five girls who formed the pool for the Sri Lanka netball team were examined (Table 7) just prior to their international match against Seychelles. Their average duration of training per day was two hours.

The mean age of these players (23.2 ± 5.4 years) was greater than those in other events and many of them were working mothers who had very little time for serious training.

4.6. Rugger

A total of 17 rugby players were examined. Of these, 9 players represented Sri Lanka in the International Seven-a-Side rugby tournament in Hong Kong. The remaining 8 players represented a leading Colombo rugby club—the C.H. and F.C.

4.6.1. *Seven-a-side Rugger*

Their physical assessment is shown in Table 8. The average duration of training was only $1\frac{1}{4}$ hours per day.

There were no schoolboys in this event and all players were employed, six of them being executives.

Although they constituted the best rugger players in the country, their mean maximum oxygen uptake was low (54.1 ± 11.2 ml/kg/min). This rugger team was unplaced in the international meet and their lack of physical fitness may account for their poor performance.

4.6.2. *Club Rugger*

The physical characteristics of these 8 players is shown in Table 9. Their average duration of training per day was $1\frac{1}{4}$ hours.

These players had a mean oxygen uptake of 44.3 ± 6.0 ml/kg/min which was far inferior to that of the seven-a-side players.

4.7. Athletes

A total of ninety-seven athletes were examined. These included 86 male athletes and 11 female athletes. Of these 97 athletes, 8 had participated in field events like the Javelin, Discus and Puttshot. Out of the 89 athletes who participated in track events, 67 (58 males and 9 females) were sprinters who had as their favoured event the 100m, 200m, 400m, 800m flat or hurdles.

22 athletes (20 males and 2 females) were long distance runners, who specialized in either the 1500m, 3000m, 5000m, 10,000m or the marathon road race—26 miles.

Many had represented Sri Lanka in international meets, some held Ceylon records, others were winners of the AAA meet, the Junior Nationals, the Ceylon Schools or the army meet.

The sprinters, army athletes, public school athletes, female athletes, long distance runners and those athletes who participated in field events are considered separately.

4.7.1. *Field Events*

A total of 8 male athletes fell into this group, their characteristics are shown in Table 10. Their average duration of training per day was $1\frac{1}{4}$ hours of which $\frac{1}{4}$ hour was spent doing weight-lifting exercises.

These athletes were among the heaviest examined (mean wt 68.3 $\pm$ 8.1 kg), their bigger muscle mass probably accounting for the reason why they had a higher mean oxygen uptake than the sprinters.

4.7.2. *Female Athletes*

There were 11 female athletes, 2 long distance runners and 8 sprinters. Their details are shown in Table 11. Their average duration of training per day was $1\frac{1}{2}$ hours in the evenings.

Two of these athletes were outstanding and had oxygen uptakes of 62.8 and 63.2 ml/kg/min. They were two of Ceylon's best female athletes who had represented Ceylon in several international athletic meets.

4.7.3. *National Sprinters*

A total of 17 sprinters were examined (Table 13). Their oxygen uptake was low (mean 48.8 ml $\pm$ 6.9 ml/kg/min).

Their average duration of training was only $1\frac{1}{2}$ hours each day.

4.7.4. *Public School Sprinters*

21 students who had won or who had been placed in the Public Schools or the Junior nationals were examined (Table 14).

Their average duration of training per day was $1\frac{1}{2}$ hours.

4.7.5. *Army Sprinters*

Twenty of the top sprinters from the army athletic pool were examined. They had all won their events either at the army meet or at the Nationals. The results of their examination are shown in Table 12.

The mean oxygen uptake of these sprinters was 60.4 ml/kg/min—a relatively high value for Ceylonese athletes, significantly higher than the national and public school sprinters. Seven of these had an uptake of over 60 ml/kg/min and none were below the 40 ml/kg/min mark.

Their duration of training per day was almost double that of the other sprinters.

4.7.6. *National Long Distance Runners*

Seven long distance runners who were non-service personnel but who had been placed in one of the events at the nationals were examined. Their results are shown in Table 16. The average duration of training per day was two hours.

Their mean oxygen uptake (55.1 ml $\pm$ 18.0 ml/kg/min) was lower than that of the army sprinters. Three of them had an uptake below 40 ml/kg/min indicating the poor physical endurance of these national runners.

4.7.7. *Army Long Distance Runners*

13 long distance runners who had won or had been placed in the 1500m, 5000m, 10,000m or marathon road race were investigated (Table 15). The average duration of training per day was 3 hours.

These athletes had the lowest resting heart rates in this series (mean 54.7 $\pm$ 9.8 per minute), five were below 50/min. Their mean sixth minute heart rates were also the lowest (121.4 $\pm$ 19.7 per minute) in this series. These are good indices of physical fitness. They had the highest mean oxygen uptake (74.9 $\pm$ 18.9 per minute) of all athletes examined. Nine had an uptake of over 60 ml/kg/min and none were below 40 ml/kg/min.

These army endurance runners also had the lowest mean body weight (51.1 $\pm$ 4.0 kg) of all the male athletes examined. It is well known that among athletes the lowest bodyweight is among endurance runners.

Their duration of training was at least three hours each day, which was double that of their non-service counterparts.

These results show the superiority of the army sprinters and army long distance runners over their non-service counterparts and stresses the importance of endurance training for the improvement of physical fitness of athletes.

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රාජගුරු, ඒ. එස්. බී., රවීන්ද්‍රන්, වී. සහ ඩයස්, ඊ. ඒ.

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වැඩෙන හා වැඩි අවසන්වන අවයියේ පසුවන ඌරන්ගේ ආහාරය සඳහා මංඤ්ඤක්කා පිටි උපයෝගී කර ගැනීම සම්බන්ධයෙන් පවත්වන ලද පරීක්ෂණ දෙකකදී බඩ ඉරිහු වෙනුවට ආදේශයක් වශයෙන්, කෑම වේලක 40% ප්‍රමාණය දක්වා, HCN රහිත මංඤ්ඤක්කා පිටි සාර්ථක ලෙස යොදාගත හැකි බව පෙනී ගියේය. එසේ වුවද පිරියැකසුම් නොකළ මංඤ්ඤක්කා පිටි යොදා ගැනීම නිසා වැඩුම් අනුපාතිකය හා පෝෂක කාර්යක්ෂමතාවද අඩුවිය. පිරිසැකසුම් නොකළ මංඤ්ඤක්කා පිටි ආහාරය දුන් අවස්ථාවේදී ඇති වූ බඩයාම මංඤ්ඤක්කා පිටිවල විෂ හරණය කිරීමෙන් සම්පූර්ණයෙන්ම වලක්වා ගත හැකිය. සංඛ්‍යාලේඛන දත්ත අනුව එතරම් ගණන් ගත නොහැකි වූවද, මංඤ්ඤක්කා පිටි සහිත ආහාර දුන් අවස්ථාවලදී මාංශ කලේවර ප්‍රකෘති ස්වභාවයට පැමිණීමේ ප්‍රතිශත තරමක් පහත වැටුණ බව දක්නා ලදී. මාංශ කලේවර විශ්ලේෂණය සඳහා යොදු ගන්නා ලද්දේ එකම සතෙක් පමණක් බැවින් මෙහි දී ඇති දත්ත අවසාන නිගමන වශයෙන් ගත නොහැකිය. HCN රහිත මංඤ්ඤක්කා ආහාරය නිසා පිටේ මේදයෙහි ඝනකම වෙනස්නොවුවද පිරිසැකසුම් නොකළ ආහාරය නිසා පිටේ මේද ප්‍රමාණයට හානිකර බලපෑම් ඇති විය. ශක්ති උපයෝජනය කෙරෙහිද HCN බලපාන බව මෙයින් පැහැදිලි වේ.

බහුවක්‍රිය හයිඩ්‍රොකාබන කිපයක සගන්ධතාව (ඇරෝමැටිකතාව)

කුරෙයිසිංහම්, ආර්. ඒ.

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සම ඒකාන්තරික හයිඩ්‍රොකාබන කිපයක් වික්ෂෝභ අණුක කක්ෂීය (PMO) පදනම යටතේ ගණන් බලා සොයා ගන්නා ලද එක්තරා ''ඇරෝමැටික සූචකයක්'' ගැන මෙයින් විස්තර කරනු ලැබේ. කාබන් වළල්ලේ එක්තරා සීමිත ස්ථානයක හෝ මුළු වළල්ල පුරාම හෝ පවතින සගන්ධතාව මැන ගැනීමට මෙම සූචකයෙන් හැකි වන්නේය. මෙම සූචකය එකී හයිඩ්‍රොකාබනවල සගන්ධතාව සංසන්දනය කර බැලීමට ද එම සංයෝගවල අඩංගු දැකැමි ගුණ ලක්ෂණ තේරුම් ගැනීමටද උපකාරී වන්නේය. කාඩිනෝජනක බහුවක්‍රිය හයිඩ්‍රෝකාබනවල K-ප්‍රදේශයට අයත් ඇරෝමැටික සූචකය 0.3 ට වඩා අඩුබව අවධානය කරනු ලැබිය. මේ සූචකය ගණන් කරන ක්‍රමය අනුව තවත් ඉතා ප්‍රයෝජනවත් ප්‍රතික්‍රියතා සූචකයක්වන ''දේවාර් අංකය''ද ගණන් කළ හැකි වේ.

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ශ්‍රී ලංකාවේ කෝස්ටික් සෝඩා නිෂ්පාදනය සඳහා භාවිතා කරන ඩෙ-නෝරා වර්ගයේ විද්‍යුත් විච්ඡේද ප්‍රාචීර කෝෂවල ක්ලෝරේට් ප්‍රමාණය අඩු කිරීම.

පෙරෙයිරා, ඩබ්ලිව්. පෙර්ලින් ඩී., ප්‍රනාන්දු, ජේ. එන්. ඩී. සහ ජයමාන්න, ඩී. වී.

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ශ්‍රී ලංකාවේ පරන්තන් රසායන සංස්ථාවේ ඩෙ-නෝරා ප්‍රාචීර කෝෂවල නිෂ්පාදනය කරනු ලබන සෝඩියම් හයිඩ්‍රොක්සයිඩ්වල සෑම ග්‍රෑම් 100 කම ගෑම් 1.30 සිට 1.50 දක්වා වූ සෝඩියම් ක්ලෝරේට් ප්‍රමාණයක් ඇන්තේය. ක්ලෝරේට් අවම ප්‍රමාණයක් ඇතිව සෝඩියම් හයිඩ්‍රොක්සයිඩ් උපරිම ප්‍රමාණයක් නිෂ්පාදනය කිරීමට හැකිවන සේ ලුණු දියර විද්‍යුත් විච්ඡේදනයට භාජනය කිරීමට සුදුසු ප්‍රගස්ත අවස්ථා නිර්ණය යන්න විමර්ශනය කිරීමේ අදහසින්, කාබන් ඇනෝඩ එකකින් හා වානේ කැතෝඩ දෙකකින් ද යුක්ත වූ නියමු කෝෂ එක්තරා සංඛ්‍යාවක් පරීක්ෂණාගාරයේදී සාදන ලදී. කැතෝලයිට් අවටම පහත් කොට ගැලුම් අනුපාතය වැඩි කිරීමට සැලැස්වීමෙන් ක්ලෝරේට් දූෂකයේ අනුපාතය අඩුකළ හැකි විය. හයිඩ්‍රොක්සයිඩ්වල පල්වාත් විසරණය මෙයින් අඩුවූ නිසා ඇනොලයිටයේ ක්ලෝරේට් සෑදීමද අඩුවිය. එසේ වුවද, මේ නිසාම හයිඩ්‍රොක්සයිඩ් සාන්ද්‍රණයවීමද අඩුවිය. ඇනොලයිට් දියරය ප්‍රතිපූරණය කිරීම හා පෝෂක ලුණු දියරය පූර්ව-තාපනයට බඳුන් කිරීමද එකවර සිදුකොට කරන ලද අත්හදබැලීම්වලින් ඇනොලයිට් ක්ලෝරේට්වල අඩුවීම නිසා කැතොලයිට් ක්ලෝරේට් ප්‍රමාණයද අඩුවන බව පෙනී ගියේය. 3000 ක ප්‍රත්‍යාවර්තන විද්‍යුත් ධාරාවක් යටතේ ඇනොලයිට් දියරය ප්‍රතිපූරණය කිරීම හා පෝෂක ලුණු දියරය පූර්ව-තාපනයට බඳුන් කිරීමද එකවර සිදු කරමින් පරන්තන් රසායනාගාර සංස්ථාව තුළද මෙම පරීක්ෂණ නැවත අත්හද බැලුවිට ක්ලෝරේට් ප්‍රමාණය තවත් අඩු කරගත හැකි බව පෙනී ගියේය. සෙන්ටිග්‍රේඩ් අංශක 55 ක උෂ්ණත්වයකදී පෝෂක ලුණු දියර නිරතුරුව ගලා ඒමට සලස්වා එකින් එක වැඩිවන ප්‍රතිපූරණ අනුපාත යොදා ගෙනද අත්හද බැලීම් කරන ලදී. මේ අනුව සෝඩියම් හයිඩ්‍රොක්සයිඩ් ග්‍රෑම් 100 ක් තුළ පවතින ඇනොලයිට් ක්ලෝරේට් ප්‍රමාණය ග්‍රෑම් 0.1 සිට 0.08 දක්වා පහත මට්ටමට කට ගෙන ඒමට හැකි විය. ලුණු දියර අපතේ යාම වලක්වා ගැනීමේ මගක් වශයෙන් ප්‍රයෝජනයට ගත් ඇනොලයිට් දියරය සංතර්පණ නළ මහින් නැවතත් කෝෂ කරා යැවීමද හැකි බවද පෙන්වා දී ඇත.

ශ්‍රී ලංකාවේ ආර්ථික වශයෙන් ප්‍රයෝජනවත් ශාක – 2 වන කොටස.
ශ්‍රී ලංකාවේ ශාකවලින් ලැබෙන වාණිජමය වශයෙන් වැදගත් ස්ටෙරොයිඩිය සැපොජෙනින් වර්ග

ගුණතිලක, ඒ. ඒ. එල්., සෝදිස්වරන්, එස්. සහ බාලසුබ්‍රමණියම්, එස්.

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වාණිජමය වශයෙන් ප්‍රයෝජනවත් වන ස්ටෙරොයිඩිය සැපොජෙනින් රසායනික ද්‍රව්‍ය ලබා ගැනීමට හැකි ශාකයන් හා වගාශාක හඳුනා ගැනීමේ අටියෙන් ශ්‍රී ලංකාවේ වැවෙන ඩියෝස්කෝරියා, කොස්ටුස්, ඇගවේ, යුක්කා සහ ට්‍රිපර්ක්‍රියා වැනි ශාකවර්ගවල ඇති සැපොනින් පිළිබඳ රසායනික ඇගයීමක් කොට ඇත. ශ්‍රී ලංකාවේ වැවෙන කොස්ටුස් ස්පෙසියෝසුස් ශාකයේ රෙසෝම (මූල්වර්ගයක්) කොටස් ඩියෝස්ජෙනින් ලබා ගැනීමට ඉතා හොඳ අමු ද්‍රව්‍යයක් ලෙසද ඇගවේ ඇමෙරිකානා ශාකයේ කොළ හෙකොජෙනින් ලබා ගැනීමට ඉතා හොඳ අමුද්‍රව්‍යයක් ලෙසද හඳුනාගෙන ඇත.

රබර් කර්මාන්තය සඳහා දේශීය අමුද්‍රව්‍ය නිෂ්පාදනය කර ගැනීම

රාජපක්ෂ, ආර්. ඒ.

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ශ්‍රී ලංකාවේ රබර් කර්මාන්තකරුවන් විසින් අවුරුදු පතා රබර් මිශ්‍රණ ද්‍රව්‍ය විශාල තොගයක් ආනයනය කරනු ලැබේ. මෙසේ පිටරටින් ගෙන්වනු ලබන මිශ්‍රණ ද්‍රව්‍ය වෙනුවට භාවිත කළ හැකි දේශීය අමුද්‍රව්‍ය සොයා ගැනීමට ලංකා විද්‍යාත්මක හා කාර්මික පර්යේෂණ ආයතනය මගින් පර්යේෂණ වැඩසටහනක් ආරම්භකොට ඇත. ප්‍රතිඔක්සිකාරක, ස්ටියරික් අම්ලය සහ ආසක්තීකාරක වලට ආදේශ කළ හැකි යුදුසු දේශීය රසායන ද්‍රව්‍ය සාර්ථක ලෙස නිපදවා ඇත.

නෛට්‍රජන් පොහොර යෙදීම, තණකොළ කැපීමේ නිවුනාව හා සංඛ්‍යාතය යන මේ කරුණු, ගිනියා තණවල පලදුව, රසායනික සංයුතිය සහ පෝෂණ අගය කෙරෙහි බලපාන අන්දම ගැන අධ්‍යයනයක්.

ඉණ්ඩිතරත්න, එස්., ජයසූරිය, එම්. සී. එන්., රංජිත්, ඩබ්ලිව්. ජේ. කේ. ටී. සහ නිමාවිතාන, එස්. සී.

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ශ්‍රී ලංකාවේ පහත රට හා මධ්‍යම ප්‍රදේශය පුරාම බහුල ලෙස වැවෙන ගිනියා තණ වර්ගයට අදළ වියලි තණ පලදුව, රසායනික සංයුතිය සහ පෝෂණ අගය කෙරෙහි නෛට්‍රජන් යෙදීම, තණ කොළ කැපීමේ නිවුනාව හා සංඛ්‍යාතය බලපාන හැටි දැන ගැනීමට පරීක්ෂණ දෙකක් පවත්වන ලදී. 1 වන පරීක්ෂණයේදී වියලි තණ පලදුව, දළ ප්‍රෝටීන් ප්‍රතිශතය සහ ජීරණතාව කෙරෙහි තුන් ආකාරයක තණ කැපීමේ උස බලපාන අන්දම ගැන සොයා බලනු ලැබීය. වර්ෂයකට/නෙළීම්/තෙ. කි. ග්‍රෑ. 336 යන පොහොර යෙදීමේ ක්‍රමය අනුව දින 30 කට වරක් තණ කපා ගන්විට කැපීමේ උස, වියලි තණ පලදුව කෙරෙහිත් කොළ: දඬු අනුපාතය කෙරෙහිත් සැහෙන දුරට බලපාන බව සොයා ගන්නා ලදී. එහෙත් දළ ප්‍රෝටීන් ප්‍රතිශතය කෙරෙහි හා පිරික්සුම් නළ ඵෙන්ද්‍රික ද්‍රව්‍ය ජීරණතාව කෙරෙහි එයින් කිසිම බලපෑමක් ඇති නොවිය.

දෙවන පරීක්ෂණයේදී, දින 15, දින 30, දින 45 යන කාල වකවානු ඇතුළත අස්වනු නෙලීමේදී ඇතිවන රසායනික සංයුතිය හා පෝෂණ අගය කෙරෙහි නෛට්‍රජන් මට්ටම් තුනේ බලපෑම් පිළිබඳව අධ්‍යයනය කරන ලදී. වර්ෂයකට/නෙලීම්/තෙ. කි. ග්‍රෑ. 84 දක්වා නෛට්‍රජන් යෙදීම කරණකොට ගෙන වියලි තණ පලදුව කෙරෙහි සැලකිය යුතු බලපෑමක් ඇති නොවූණද දළ ප්‍රෝටීන් ප්‍රතිශතය දින 30 සීමාව දක්වා වැඩි වී ඉන්පසුව අඩුවන්නට පටන්ගත්තේය. වියලි තණ පලදුව හා පෝෂණ අගයෙහි ප්‍රතිලෝම සම්බන්ධයක් ඇති බව දක්නට ලැබුණි. නෙළීම්/තෙ.කි. ග්‍රෑ. 84 අනුපාතයට අඩුවෙන් නෛට්‍රජන් යෙදීමෙන් ගිනියා තණකොළ වල කිසියම් ප්‍රතිවාරයක් දක්නට නොතිබුණ අතර දින 30 කට වරක් පොළවේ සිට අඟල් 6 කට උඩින් කැපීමෙන් උපරිම වියලි තණ පලදුවක් ලබාගත හැකි බවද එසේ නෙළා ගන්නා ලද තණකොළ වල 13–14% දක්වා දළ ප්‍රෝටීන් ඇති බවද, ඒවායෙහි ඵෙන්ද්‍රික ද්‍රව්‍ය ජීරණතාව 53%ක් බවද අවසාන වශයෙන් නිගමනය කරනු ලැබේ.

ශ්‍රී ලංකා මලල ක්‍රීඩකයන්ගේ උපරිම ඔක්සිජන් උද්දනය

ඩයස්, ජී. එල්. ආර්. සහ රවීන්ද්‍රන්, ඩබ්ලිව්.

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දේශීය ක්‍රීඩා කණ්ඩායම්වලින් තෝරා ගන්නා ලද ශ්‍රී ලංකා ක්‍රීඩකයින් 214 දෙනකු තුළ පැවති උප-උපරිමා ශ්‍රම දූරුම් ශක්තිය ආධාර කරගෙන හෘද් ශ්වසන යෝග්‍යතාව පිළිබඳ ඉතා හොඳ ආමානය වශයෙන් සැළකෙන උපරිම ඔක්සිජන් උද්දනය (VO_2max) මැන බලන ලදී. පියගමන් අභ්‍යාසයක හයවන විනාඩිය අවසානයේදී විද්‍යුත් කන්තුකරේඛකයේ ආධාරයෙන් අචල ස්පීතික හෘද්ශීස්‍රතාව (Fh) නිර්ණය කරන ලද අතර ඇස්ට්‍රන්ඩ් රයිමීන් නියාමරේඛය උපයෝගි කරගෙන උපරිම ඔක්සිජන් උද්දනය (VO_2 max) ගණන් බලන ලදී. පිහිනුම් කරුවන්, පාපන්දුකරුවන්, හරඹ ක්‍රීඩකයන්, හොකි ක්‍රීඩකයන්, දැල්පන්දු ක්‍රීඩකයන සහ රගර් ක්‍රීඩකයන්ගේ සවායු ධාරිතාව (ශාරීරික යෝග්‍යතාව) පිළිගත් ජාත්‍යන්තර ප්‍රමිතිවලට වඩා ඉතා අඩු බව පෙනී ගියේය. මලල ක්‍රීඩකයන් ගැන සොයා බැලීමේදී යුදහමුදු දුර දුවන්නන්ට හා කෙටිදුර දුවන්නන්ට ජාත්‍යන්තර මට්ටමේ ඔක්සිජන් උද්දනයක් තිබුණ අතර හමුදුවලට අයත් නොවූ සමස්ත ලංකා මලල ක්‍රීඩකයන්ට තිබුණේ ඊට වඩා අඩු ඔක්සිජන් උද්දනයකි. මේ දෙවර්ගයටම අයත් ක්‍රීඩකයන්ගේ මධ්‍යක පුහුණු කාලය විභාග කර බැලීමේදී හමුදුවලට අයත් ක්‍රීඩකයන්ට වෙනත් මලල ක්‍රීඩකයන් පුහුණුවන කාලය මෙන් දෙගුණයක පමණ පුහුණු කාලයක් ඇති බවද පෙනී ගියේය.

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இந்த இதழின் கட்டுரைகளின் சுருக்கங்கள்

பன்றி உணவாக மரவள்ளிக்கிழங்கின் மாவைப் (மனிகொற் எஸ்குயுலானரு கிருனற்ஸ்) பயன்படுத்துதல்.

ராஜகுரு, ஏ. எஸ். பி., இரவிந்திரன், வீ., டயஸ், ஈ. ஏ.

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வளரும் பருவத்துப் பன்றிகளினதும் வளர்ச்சி நிறைவுபெறும் பருவத்துப் பன்றிகளினதும் உணவாக மரவள்ளிக் கிழங்கின் மாவைப் பயன்படுத்துதல் பற்றி மேற்கொள்ளப்பட்ட இரண்டு பரிசோதனைகளின் போது, சோளத்துக்குப் பதிலாக HCN அற்ற மரவள்ளிமாவை ஒரு வேளை உணவின் 40 வீதம் வரை பயனுறு வகையில் பயன்படுத்தலாமென்பது கண்டறியப்பட்டது. ஆயினும் பதனிடப்படாத மரவள்ளிக் கிழங்கு மாவைப் பயன்படுத்தியவிடத்து வளர்ச்சிவீதமும் ஊட்டல் திறனும் குறைந்து செல்லல் நிரூபணமாயிற்று. பதனிடப்படாத மரவவள்ளிக் கிழங்கு மாவை உணவாக அளித்தபோதெல்லாம் ஏற்பட்ட வயிறுகழிதலே மரவள்ளிக் கிழங்கு மாவிலுள்ள நஞ்சினை அகற்றுதலால் முழுமையாகவே தவிர்த்துக் கொள்ளலாம். புள்ளிவிவரத் தரவுகளின்படி ஒரு முக்கிய நிகழ்வாகக் கருதவியலாததாயினும், மரவள்ளிக் கிழங்குமாவு கலந்த உணவு அளிக்கப்படும் சந்தர்ப்பங்களில் விலங்கின் உடற்கூண்டுமீட்பின் நுற்று வீதம் ஓரளவு குறையும் இயல்புடைத்தாகும். உடற் கூண்டுப் பகுப்பாய்வுக்கு ஒரே ஒரு விலங்கு மாத்திரம் பயன்படுத்தப்பட்டமையால் இப்பரிசோதனைத் தரவுகளை முடிந்த முடிவாக்க கொள்ளலாகாது. HCN அற்ற மரவள்ளிக் கிழங்கு மாவுகலந்த உணவின் விளைவாக முதுகுக் கொழுப்பின் அடர்த்தி மாற்றமுறவில்லையாயினும் பதனிடப்படாத உணவின் காரணமாக முதுகுக் கொழுப்பின் அளவிற் பாதிப்பு ஏற்பட்டது. எனவே, சக்திப் பயன்பாட்டிலும் HCN குறுக்கிடுமென்பது புலனாகும்.

பல் சக்கர ஐதரோகாபன் சிலவற்றின் அரோமற்றிக்கியல்பு

துரைசிங்கம், ஆர். ஏ.

J. Natn. Sci. Coun. Sri Lanka 1978 **6** (2): 103—108

சில சம இடமாறி ஐதரோகாபன்களின் கலக்க மூலக்கூற்றெழுக்குக் (PMO) கணிப்பின் அடிப்படையிலமைந்த "அரோமற்றிக்குச் சுட்டி" ஒன்று இங்கு விளக்கப்பட்டுள்ளது. இச்சுட்டியைக் கொண்டு காபன்வளையத்தின் குறிப்பிட்டவோரிடத்தில் அல்லது அவ்வளையம் பூராவும் நிலவுகின்ற அரோமற்றிக்கியல்பினை அளவிடலாம். இச்சுட்டி அந்த ஐதரோகாபன்களின் அரோமற்றிக்கியல்பினை ஒப்பு நோக்கவும் அச்சேர்வைகளிலுள்ள

பண்பியல்புகளோத் துணிந்துக் கூறவும் துணைபுரிகின்றது. காசினேசனிக்குப் பல்சக்கர ஐதரோகாபன்களின் K பிரதேசத்துக்குரிய அரோமற்றிக்குச் சுட்டி. யானது 0.3 நிலையினின்றும் தாழ்வாக உளதென்பதும் அவதானிக்கப்பட்டுள்ளது. இச் சுட்டியைக் கணிக்கும் அதே முறையினைக் கொண்டு பயன்மிகு வேறு தாக்குத்திறன் முறையான ''தேவார் எண்'' ணையும் கணித்துவிடலாம்.

இலங்கையில் எரிசோடா உற்பத்திக்குப் பயன்படுத்தப்பட்டுவரும் டேநோரா மினபகுப்பு மென்தகட்டுக் கலங்களில் குளோரேற்று அளவினைக்குறைத்தல்.

பெரேரா, டபிள்யு. பர்லின், டீ., பெர்ணாந்து, ஜே. என். ஒ., ஐயமான்ன, டீ. ரீ.

J. Natn. Sci. Coun. Sri Lanka 1978 **6** (2): 109—120

இலங்கையில் பரந்தன் இரசாயனப் பொருள் யாக்கத்தில் டேநோரா மென்தகட்டுக் கலங்களில் உற்பத்தி செய்யப்படும் ஒவ்வொரு 100 கிராம் சோடியமைதரொட்சைட்டிலும் 1.30 கி. முதல் 1.50கி. வரையான சோடியம் குளோரேற்று அடங்குகின்றது. குளோரேற்றளவு மிகக் குறைவாக அடங்கப் பெற்ற சோடியமைதரொட்சைட்டை அதிக அளவில் உற்பத்தி செய்தற்கு உவர்நீரை மின்பகுப்புக்குட்படுத்தக் கூடிய மிகச் சிறந்த வாய்ப்புகள் உளவாவென்பதைக் கண்டறியும் நோக்கில், காபன் அனோட்டு ஒன்றையும் உருக்குக் கதோட்டு இரண்டையும் கொண்ட முன்னோடிக்கலங்கள் பரிசோதனைக்கூடத்தில் தயாரிக்கப்பட்டன. கதோட்டுப் பகுப்பொருள் மட்டத்தைத் தாழ்த்துப் பாய்ச்சல் வீதம் அதிகரிக்கச் செய்தலால் குளோரேற்று மாசுப்பொருள் வீதத்தைக் குறைக்கமுடிந்தது. அதன் விளைவாக ஐதரொட்சைட்டின் பின் பரவுகை குறைதலுற்றதனால் அனோலிற்றில் குளோரேற்று உருவாதலும் குறைதலுற்றது. எனினும், அதன் காரணமாகவே ஐதரொட்சைட்டின் செறிவாதலும் குறைந்தது. அனோலிற்று நீரை மீள-நிறைவாக்கலையும் ஊட்டல் உவர்நீரை முற்-சூடாக்கலுக்குட்படுத்தலையும் ஒருங்கே அமையச் செய்து மேற்கொள்ளப்பட்ட பரிசோதனைகளின் மூலம், அனோலிற்றுக் குளோரேற்றில் ஏற்பட்ட குறைதலால் கதோலிற்றுக் குளோரேற்றும் குறைதலுறுதலைக் காணமுடிந்தது. 3000 மின்வலு கொண்ட ஆடலோட்டத்தைப் பயன்படுத்தி அனோலிற்று நீரை மீள-நிறைவாக்கலையும் ஊட்டல் உவர்நீரை முற்-சூடாக்கலுக்குட்படுத்தலையும் ஒருங்கே அமைவுறுமாறு இப்பரிசோதனைகள் பரந்தன் இரசாயனப் பொருள் யாக்கத்திலே மேற்கொள்ளப்பட்ட பின்னர், குளோரேற்றின் அளவு மேலும் குறைக்கப்படலாமென்பது உறுதியாயிற்று. 55 சென்டிகிரேட் பாகை வெப்பநிலையில் ஊட்டல் உவர்நீரை இடைவிடாது செலுத்தி ஒவ்வொன்றிலிருந்து அதிகரித்துச் செல்லும் பல மீள நிறைவாக்கல் வீதங்களைப் பயன்படுத்தியும் சில பரிசோதனைகள் மேற்கொள்ளப் பெற்றன. அதன்வண்ணம் 100 கிராம் சோடியமைதரொட்சைட்டில் அடங்கும்

அனைலேற்றுக் குளோரேற்றின் அளவு 0.1 கி. முதல் 0.08 கி. வரை குறைக் கப்படல் சாத்தியமாயிற்று. உவர்நீர் வீணுதலைத் தடுக்குமோர் உபாயமாக, பயன்பட்ட அனைலேற்று நீரை நிரப்பிகளின் வழியாக மீண்டும் கலங்களுக்குச் செலுத்தக்கூடிய முறையும் விளக்கப்பட்டுள்ளது.

பொருளாதார வகையில் பயனிகு இலங்கைத் தாவரங்கள்—பாகம் 2.

இலங்கைத் தாவரங்கள் அளிக்கும் வர்த்தக அடிப்படையிலான பயனிகு தெரோயிட்டுச் சப்போசனின் வகைகள்

குணதிலக்கா, ஏ. ஏ. எல்., சோதீஸ்வரன், எஸ்., பால சுப்பிரமணியம், எஸ்.

J. Natn. Sci. Coun. Sri Lanka 1978 **6** (2) : 121—128

வர்த்தக அடிப்படையில் பயன்மிக்க தெரோயிட்டுச் சப்போசனின் வகைகளை அளிக்கும் தாவரங்களையும் தாவரவளரிகளையும் கண்டறியும் பொருட்டு, இலங்கையில் வளருகின்ற டியோசுகோரியா, கொஸ்டுஸ், அகவே, யூக்கா, பூர்கிரியா ஆகிய தாவர இனங்களில் உள்ள சப்போனீன்களைப் பற்றியவோர் இரசாயன மதிப்பீடு மேற்கொள்ளப்பட்டுள்ளது. இலங்கை யில் வளருகின்ற கொஸ்டுஸ் சுபேசியோசுசுத் தாவரத்தின் வேர்த்தண்டுகள் டியோசுசனின் அளிக்கும் அதிசிறந்த மூலப்பொருளாகவும் அகவே அமெரி காணு தாவரத்தின் இலைகள் எக்கோசனின் அளிக்கும் அதி சிறந்த மூலப் பொருளாகவும் இருக்கின்றன வென்பது கண்டறியப்பட்டுள்ளது.

இரப்பர் கைத்தொழிலுக்கு உதவும் உள்ளூர் மூலப் பொருள்களின் அபிவிருத்தி.

ராஜபக்சா, ஆர். ஏ.

J. Natn. Sci. Coun. Sri Lanka 1978 **6** (2) : 129—136

இலங்கையிலுள்ள இறப்பர் தொழிலதிபர்களால், வருடாவருடம் ஏராள மான இறப்பர்ச் சேர்வைப்பொருள்கள் இறக்குமதி செய்யப்படுகின்றன. இவ்வாறு வெளிநாடுகளிலிருந்து தருவிக்கப்பெறும் சேர்வைப் பொருள்க ளுக்குப் பதிலாகப் பயன்படுத்தத் தக்க உள்ளூர் மூலப் பொருள்களைக் கண்டு பிடிக்கும் நோக்கில், இலங்கை விஞ்ஞான, கைத்தொழில் ஆராய்ச்சி நிறுவகத்தால் ஆராய்ச்சித் திட்டமொன்று துவக்கப்பட்டுள்ளது. ஓட்சியேற்ற வெதிரிகள், தியரிக்கமிலம், ஒட்டுப்பிசின்கள், ஆகியவற்றிற்குப் பதிலாக பயன்படுத்தக்கூடிய உள்ளூர்ப் பொருள்களைத் தயாரிப்பதில் வெற்றி கண்டுள்ளனர்.

நைதரசன் இரசாயன உரங்களை உபயோகித்தல், புல்வெட்டுதற் செறிவு, மீடிறன் ஆகியன கினிப்புல்லின் விளைச்சல், இரசாயன அமைப்பு, ஊட்டற் பெறுமானம் என்பவற்றின் மீது ஏற்படுத்தும் தாக்கம் பற்றிய ஆய்வு.

பண்டிதரத்தினை, எஸ்., ஜயசூரியா, எம். கி. என்., ரஞ்சித், டபிள்யு. ஜே. கே. வீ., திரிமாவித்தான, எஸ். சி.

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இலங்கையில் தாழ் பிரதேசங்களிலும் மலைநாட்டுப் பிரதேசங்களிலும் பரவலாக வளருகின்ற கினிப்புல்லினம் பற்றிய உவர்புல் விளைச்சல் இரசாயன அமைப்பு, ஊட்டற் பெறுமானம், ஆகியவற்றின் மீது நைதரசன் பசளைகளை உபயோகித்தல், புல்வெட்டுதற் செறிவு, புல்வெட்டுதல் மீடிறன் என்பன ஏற்படுத்தும் தாக்கத்தை அறிதற்பொருட்டு இரண்டு பரிசோதனைகள் மேற்கொள்ளப் பெற்றன. 1 ஆம் பரிசோதனையில் போது உலர்ப்புல் விளைச்சல், செப்பமுறுப் புரத வீதம், செரிமானம் ஆகியவற்றின் மீது மூவகைப்பட்ட புல்வெட்டுதல் உயரம் ஏற்படுத்துகின்ற தாக்கம் ஆராயப்பட்டது. ஆண்டொன்றுக்கு அறுவடை நை. கி. கிரா. 336 என்ற பசளையிடல் திட்டத்தின்படி 30 நாள்களுக்கு ஒருமுறை புல்லை வெட்டிய விடத்து, வெட்டல் உயரம், உலர்புல் விளைச்சல் வீதம் இலை தண்டு வீதத்தின் மீதும் குறிப்பிடத்தக்கவாறு தாக்கம் ஏற்படுத்தியதென்பது கண்டு பிடிக்கப்பட்டது. ஆயினும் செப்பமுறுப் புரத வீதத்தின் மீதும், பரிசோதனைக் குழாய்ச் சேதனவுறுப்புச் செரிமானத்திறன் மீதும் அதனால் எதுவித தாக்கமும் ஏற்படவில்லை.

இரண்டாம் பரிசோதனையின் போது, 15 நாள், 30 நாள் 45 நாள் ஆகிய கால எல்லைக்குட்பட்டு அறுவடைசெய்யும் காலை ஏற்படும் இரசாயன அமைப்பு, ஊட்டற் பெறுமானம் என்பவற்றின் மீது மூன்று நைதரசன் நிலைகள் ஏற்படுத்தும் தாக்கம் ஆயப்பட்டது. ஆண்டொனறுக்கு அறுவடை / நை.கி.கிரா. 84 வரை நைதரசன் உபயோகித்தலால், உலர் புல் விளைச்சலில் குறிப்பிடத்துக்க மாறுதல் எதுவும் ஏற்பட வில்லையாயினும் செப்பமுறுப் புரதவீதம் 30 நாள் எல்லைவரை அதிகரித்து அதன் பின்னர் குறைதலுற்றது. உலர்புல் விளைச்சலுக்கும் ஊட்டப்பெறுமானத்துக்கு மிடையில் நேர்மாறுன தொடர்பொன்று இருந்ததென்பது கண்டறியப்பட்டது. அறுவடை / நை.கி.கிரா. 84 என்ற வீதத்திற்குக் குறைவாக நைதரசன் பசளையிடுதலால் கினிப்புல்லில் எதுவிதத் தூண்டற்பேறும் ஏற்படவில்லை என்பதோடு 30 நாள்களுக்கு ஒருமுறை நிலத்திலிருந்து 6 அங்குலத்துக்கு மேலே வெட்டுதலால் மிகச் சிறந்த உலர்ப்புல் விளைச்சலைப் பெற முடியுமென்பதும் அவ்வாறு அறுவடை செய்த புல்லில் 13 — 14% வரையான செப்பமுறுப்புரதம் உண்டென்பதும் அவற்றின் சேதனவுறுப்புச் செரிமானத்திறன் 53% என்பதும் இப்பரிசோதனையின் கண்கண்ட முடிபுகளாம்.

இலங்கையின விளையாட்டு வீரர்களது பெரும ஒட்சிசன பற்றுத்திறன்.

டயஸ், பி. எல். ஆர்.; இரவீந்திரன், டபிள்யு.

J. Natn. Sci. Coun. Sri Lanka 1978 **6** (2): 145–158

தேசிய விளையாட்டுக் குழுமங்களிலிருந்து தேர்ந்தெடுக்கப்பட்ட, 214 இலங்கை விளையாட்டு வீரர்களது உப—பெரும உழைப்பு ஆற்றலைப் பயன் படுத்திக் கொண்டு இருதய சுவாசிப்பு ஏற்பமைதியைத் துணிந்துகூறும் மிகச் சிறந்த அளவுக்கட்டளையாகக் கொள்ளப்படுகின்ற பெரும ஒட்சிசன் பற்றுத்திறன் (VO_2max) அளவிடப்பட்டது. அடிபெயர்வுப் பயிற்சியொன் றின் ஆரும் நிமிடத்தின் இறுதியில் மின் இதயக் காட்டி மூலம் அசைவில் நிலையான இதய விழுக்காடு கணக்கிடப்பட்டதுடன் அஸ்ரண்ட் ரைமின் வழக்குவரிப்படத்தின் மூலம் பெரும ஒட்சிசன் பற்றுத்திறன் (VO_2 max) அறுதியிடப்பட்டது. நீச்சல்காரர், உதைப்பந்தாட்டக்காரர், உடற்பயிற்சி வீரர், கொக்கி ஆட்டக்காரர், வலைபந்தாட்டக்காரர், கூற்பந்தாட்டக்காரர் ஆகியோர்களின் உயிர்வளிக்கொள்திறம் (உடற் கட்டு ஏற்பமைதி) ஏற்றுக் கொள்ளப்பட்ட சருவதேசக் கட்டளைகளினின்றுக் குறைந்த நிலையில் உள்ள தெனக் கண்டறியப்பட்டது. விளையாட்டு வீரர்களைப் பற்றி ஆய்ந்தகாலை, தரைப் படையைச் சேர்ந்த தொலைவு ஓட்டக் காரர்களும் அணிமை ஓட்டக் காரர்களும் சருவதேச தரத்துக் கொப்பான ஒட்சிசன் பற்றுத்திறன் கொண் டவர்களாக விளங்கினர்கள். படைதாங்குசேவைகளிற் சேராத அனைத் திலங்கை விளையாட்டு வீரர்கள் அதனின்றும் குறைந்த ஒட்சிசன் பற்றுத்திறன் கொண்டவர்களாக விருந்தனர். இவர்களது பயிற்சிக்காலங்களை ஆய்ந்த பின்னர் ஏனைய விளையாட்டு வீரர்களது பயிற்சிக் காலத்தைவிடபட தாங்கு சேவைகளைச் சேர்ந்தோரின் சராசரிப் பயிசிக் கலம் சுமார் இரு மடங்கு அதிகமென்பதும் கண்டறியப்பட்டது.

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