STUDIES ON THE NUTRITIONAL REQUIREMENTS OF THE INDIAN ELEPHANT

THESIS

Submitted to the

KERALA AGRICULTURAL UNIVERSITY

in fulfilment of the requirements

for

the degree of Doctor of Philosophy

(Faculty of Veterinary & Animal Sciences)

Department of Nutrition

COLLEGE OF VETERINARY & ANIMAL SCIENCES

Kerala Agricultural University

Mannuthy :: TRICHUR

January, 1979.

C. R. ANANTHASUBRAMANIAM, B.V.Sc., M.S.

ACKNOWLEDGEMENTS

The Author is indebted to:

Dr. K. Chandra Menon, G.M.V.C., B.V.Sc., M.Sc., Ph.D., Professor of Animal Husbandry (Retired) under whose guidance this investigation was carried out,

Dr. P.G. Nair, B.Sc., B.V.Sc., M.Sc., Ph.D., Dean, Faculty of Veterinary and Animal Sciences, Kerala Agricultural University, Mannuthy, Trichur for permission to conduct the investigation and for valuable advise given from time to time,

Dr. C.T. Peter, B.Sc., G.M.V.C., B.V.Sc., M.Sc., Ph.D., Dean (Retired), Faculty of Veterinary and Animal Sciences, Kerala Agricultural University, Mannuthy, Trichur for encouragement,

Sri. N. Kaleeswaran, I.A.S., Vice-Chancellor, Kerala Agricultural University for the interest evinced in the study,

Sri. T.C. Balakrishnan Nair, Administrator, Guruvayur Devaswom for making available the experimental elephants and for affording facilities for carrying out the balance trials,

Authorities of the Thiruvambadi, Paramekavu and Kuttankulangara Devaswoms, Trichur; Manager, Bharat Circus; Sri. M. Bhaskara Menon, B.M. Transport, Trichur and Kizhakuveetil Balakrishna Menon, Trichur for providing elephants for determining body measurements - body weight relationship,

Sri. M.A. James, M.Sc., Dip. Food Tech. (U.K.), Scientist, Central Institute of Fisheries Technology, Matsyapuri, Cochin for the help extended in the assay of Vitamin B_{12} in blood Plasma,

Dr. T.R. Sahasranam, M.B.B.S., D.C.P., Pathologist and Sri. M.N. Kasinathan, M.Sc. (MED), F.A.G.E., Microbiologist, Medical Centre, Trichur for help in the estimation of glucose, creatinine and cholesterol in blood,

Dr. P.V. Rao, Ph.D., Director, Central Training Institute for Poultry Production and Management, Hessergatta, Bangalore, for providing laboratory facilities for determining gross energy values,

Dr. R.C.D. Olivier, Ph.D., Co-Chairman, IUCN/SSC Asian Elephant Group, Department of Applied Biology, University of Cambridge, for providing literature on the ecology of the Asian elephant,

Authorities of The Tanjore Maharaja Serfoji's Saraswati Mahal Library, Tanjore for providing library facilities for the perusal of ancient literature on the elephant,

Dr. P.U. Surendran, M.A., Ph.D., Professor of Statistics, College of Veterinary and Animal Sciences, Mannuthy for statistical analyses of the results,

Dr. K. Chandrasekharan, B.V.Sc., M.Sc., Ph.D., Assistant Professor and Dr. K. Radhakrishnan, M.V.Sc., Professor, College of Veterinary and Animal Sciences, Mannuthy for the help rendered in the collection of blood and in the taking of body measurements of the elephants.

Members of Staff of the Nutrition Department and of the Co-ordinated Project on Agricultural Bye-products, College of Veterinary and Animal Sciences, Mannuthy for the active co-operation and help extended to the timely execution of the work, and

The Indian Council of Agricultural Research, New Delhi for meeting part of the expenditure involved in the investigation.

C O N T E N T S

		Page
INTRODUCTION	..	1-2
RESUME OF LITERATURE	..	2-17
Ancient history	..	2
Conservation status and distribution	..	4
Ecology	..	6
Habitat and habits	..	8
Distinguishing features of the digestive tract and rate of passage of feed and feed residue	..	10
Defecation and character of the faeces	..	12
Micturition and urinary constituents	..	12
Feeds and feeding	..	13
Nutrient allowances	..	16
PRESENT INVESTIGATION	..	18-19
EXPERIMENTAL	..	20-56
Material	..	20
Animals	..	20
Procedure	..	21
Methods	..	23
Gross energy determination	..	24
Determination of cobalt in palm leaf	..	26
Estimation of calcium in urine	..	26
Estimation of total phosphorus in urine	..	28
Estimation of haemoglobin	..	30
Determination of blood calcium	..	33
Determination of inorganic phosphate in blood	..	35

		Page
Estimation of urea in blood	..	38
Estimation of creatinine in blood	..	42
Estimation of glucose in blood	..	44
Estimation of cholesterol in serum	..	47
Estimation of chloride in serum	..	50
Assay of Vitamin B_{12} in blood plasma	..	53
RESULTS	..	57-60
TABLES	..	61-119
DISCUSSION	..	120-145
Prediction of body weight from body measurements.	..	120
Balance trials	..	125-139
Feed intake	..	125
Dry matter consumption	..	126
Defecation and dung dry matter	..	126
Micturition and urinary total solids	..	127
Digestion coefficients of nutrients in palm leaf	..	128
Nutritive values of palm leaf	..	128
Nutrient intake	..	129
Nitrogen balance	..	130
Calcium balance	..	131
Phosphorus balance	..	132
Digestible energy	..	132
DE as determined and TDN as determined and as calculated	..	133
Metabolizable energy	..	135
Energy values	..	135
Values obtained for Dry matter intake, DCP and TDN in Kodanad and Guruvayur trials	..	139-140

		Page
Dry matter, DCP, TDN, DE and ME requirements for maintenance and growth	..	140-141
Requirements of calcium, phosphorus and cobalt for maintenance and growth	..	141-144
Haematological values	..	144-145
SUMMARY	..	146-150
Summary of summary	..	149
REFERENCES	..	151-155
APPENDIX	..	i-xiii

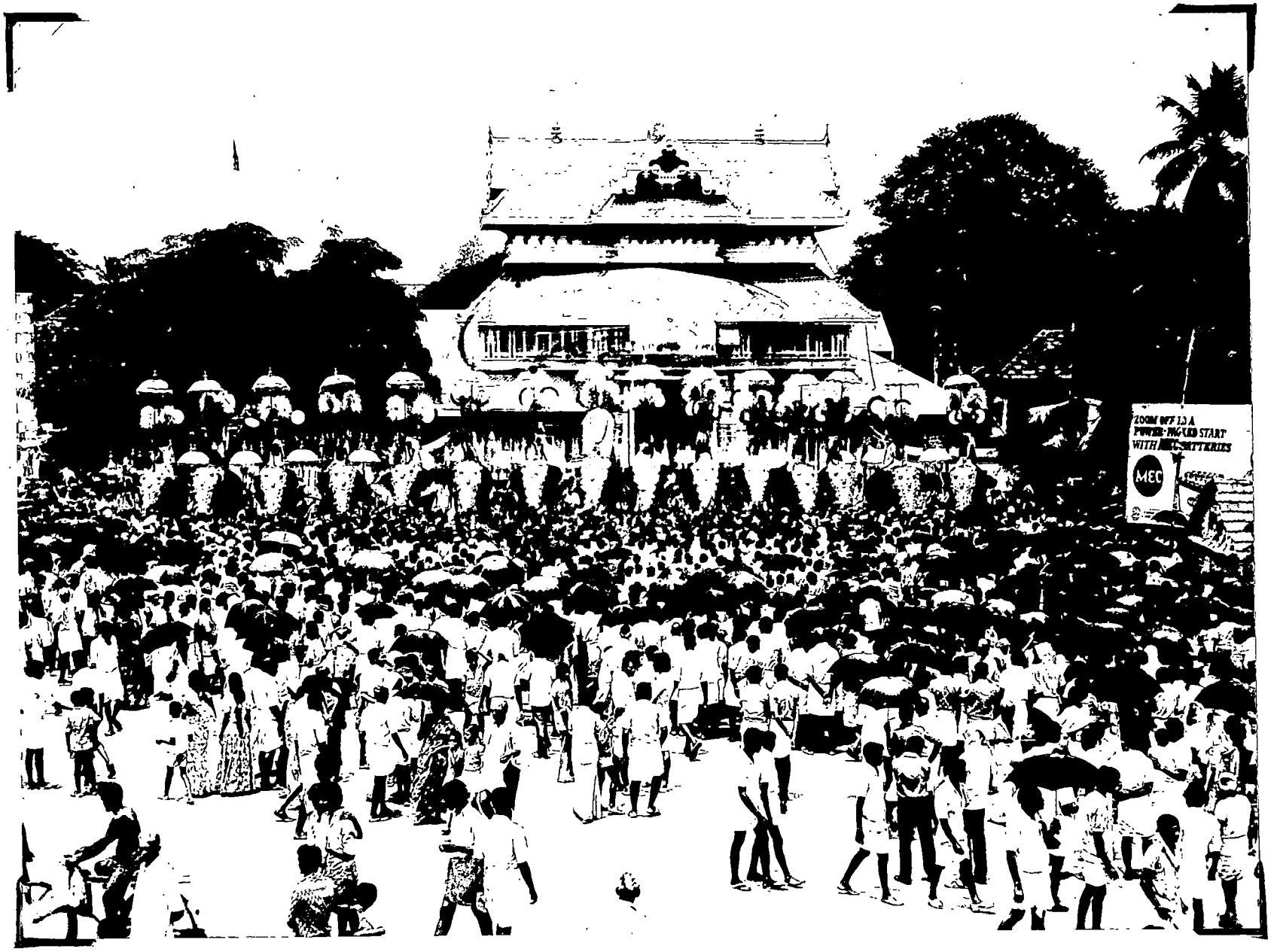
---oOo---

INTRODUCTION AND RESUME OF LITERATURE

INTRODUCTION

Nestling amidst the tall ranges of the western ghats in the east and the blue waters of the Arabian Sea in the West, Kerala State, a thinly long stretch of coastal territory covering an area of 38,864 sq. km, occupies a strategic position in the map of the Indian Union. With a coast line of 580 km, 41 out of 44 rivers flowing towards the west and with an annual rainfall of 3003.8 mm, the State represents 1.03 per cent of the Indian Union. Out of the total geographical area of 38,85,000 hectares, forests, mostly tropical deciduous type, occupy 1,08,200 hectares. Inseparable with the forest are the wild game. Of this, the elephant assumes utmost importance (Plate I). Elephants, though a symbol of pomp and glory of the medieval aristocracy, are now employed mainly for forest work such as dragging, heaping and piling of timber as also for ceremonial purposes (Plate II). Kerala possesses a good share of the elephant population of the Indian Union and elephants form an integral part of the State's forest wealth, a true recognition of which has been depicted in the official symbol of the State. The State's hill products such as honey, ivory and timber contribute substantially to India's foreign exchange earnings. The importance of the elephant in enriching national wealth is thus evident. It is surprising, therefore, that of the husbandry processes of the elephant, nutrition which is the most important has received only little attention. It is all the

PLATE II - TRICHUR POORAM FESTIVAL


MEC

more so because feeds and feeding of elephants, as evidenced from records available with the forest departments of the various states in the Indian Union, account for a major share of the total expenditure incurred towards their maintenance. Besides the work reported by Benedict (1936), there is no evidence in literature of any other investigation carried out to determine the nutrient requirements of the elephant for maintenance or for growth. A feeding standard in terms of Digestible crude protein, Total digestible nutrients or Metabolisable energy, as in the case of cattle, pigs and poultry, is yet to be evolved for this species of animal. Accomplishment of this need has been the object of the study under report.

RESUME OF LITERATURE

Ancient history

The unique relationship between men and elephants, as it exists today in India, probably dates back to the third millenia B.C., since when records of tamed elephants are available. According to the Hindu Mythology, the elephant is considered as the incarnation of Lord Ganesh or Ganapathy - the elephant headed God - who is the first to be invocated in all religious functions. Tamed elephants in years as far back as 2500 B.C. are depicted as archaeological evidences in engravings in Mohanja Daro on the

lower Indus. Fossil studies have provided information on the nature, feeding and geographic distribution of the elephants in prehistoric times; so also the Vedas (20-15th centuries B.C.) and Upanishads (9-6th century B.C.). Chandogya Upanishad gives a classification of mammals, the animals being divided into eight groups on the basis of habitat and feeding behaviour. The elephant is seen placed in the Anupa group - the marsh land or river bank dwellers. The 'Gajasastra' of Palakapya Muni, the 'Bhasha Prabundha' of Raja Serfoji - the 18th century Maratha Ruler of Thanjavoor and the innumerable books in Sanskrit attributed to such ancient 'Rishis' as Vyasampayana, Vyasa, Palakapya and Nakula, all preserved in the Saraswathy Mahal Library, Thanjavoor, throw considerable light on the various aspects of elephant husbandry with special reference to the origin and development of this species as the winged decendants of the divine 'Airavata' and other 'Dig-gajas'. Reference has been made in the Tamil Sangham literature to the elephant and it's interaction with men in ancient times in South India. There is ample evidence to show that Punjab was the domestic elephant centre of India right upto the Mughal era in 13th century A.D. (Olivier, 1978). In ancient literature such as 'Mathangaleela', 'Gajarakshathanthrum' and 'Hastyayurveda', diseases, 'Musth' and treatment of elephants are dealt with at length.

Armandi, as cited by Benedict (1936) gives a treatise on

the use of elephants in warfare. Reference has been made to the use of elephants in war in the epics 'Ramayana' and 'Mahabharata' written by Valmiki and Vyasan respectively in 5-7 centuries B.C. Indian elephants were used for the first time in war in the West in the battle of Arbela faught between Alexander the Great and Darius in 331 B.C.

It is an interesting revelation that the history of the elephant had been written centuries before the time of Christ. The elephant had then been referred to as 'Benemoth' (The Holy Bible. Job 40 : 15-24).

Conservation status and distribution

Olivier (loc. cit.) has presented a vivid picture of the conservation status and distribution of elephants in Asia. Estimation of the elephant population has been made on a regional basis, as the distribution of the animals is largely restricted to mountainous regions unhindered by human development and occurs mainly on interstate and international boundaries. Accordingly, the Indian sub-continent has been shown to consist of four divisions viz., (i) West sub-Himalayan foot hills, bounded by the Yamuna river in the west and the Sardar river in the east near Nepal border (ii) Central peninsular India constituting the states of Madhya Pradesh, Orissa, Bihar and Southern Bengal, (iii) North-Eastern India comprising of the East sub-Himalayan

foot hills extending to Bhutan, Arunachal Pradesh, Assam, North and South of Brahmaputra river covering part of Arunachal Pradesh, Meghalaya State, West of Nagaland and the States of Misoram and Tripura and (iv) Peninsular India comprising of the Western ghats. Besides, elephants are also reported in the Andaman Islands.

Included in the elephant ranges are the Corbett National Park and the Rajaji and Motichur sanctuaries (Uttar Pradesh), the Palamau National Park (Bihar), Similipal Tiger Reserve (Orissa), Manas wild life sanctuary (Assam), Mudumalai and Anamali wild life sanctuaries (Tamil Nadu), Bandipur National Park (Karnataka), and the Periyar wild life sanctuary (Kerala).

According to Olivier (loc. cit.), the number of elephants estimated to be in each of the four divisions is as follows: West Himalayan foot hills, 550; Central Peninsular India, 900-2000; North Eastern India, 4000-8000 and Peninsular India, 4500. The whole Indian sub-continent accounts for 9950-15050 elephants.

In view of the fact that the Asian elephant has been considered as 'endangered species' by the International Commission for Conservation of Nature and Natural Resources (cited by Olivier, loc. cit.), the entire Southern Peninsular area which is reported to hold nearly one third to half the number of elephants estimated to be present in the country is currently under survey by the South Indian Task Force of the IUCN/SSC Asian

Elephant Group. Enumerations in 15 out of 19 divisions in Kerala, covering an area of 7145 sq. km out of 9384 sq. km of reserve forest have shown the presence of 2243 elephants, the ratio of male to female being 1:2 (Pillai, pers. comm. 1978).

In respect of tame elephants, it is estimated that Kerala possesses 350 animals, the Guruvayur Temple alone maintaining 30 of them (Nair, pers. comm. 1978).

Ecology

Under the family Elephantidae established by Gray in 1821 (cited by Sikes, 1971) there are only two representative genera, each having only one surviving species viz., Elephas maximus (Linnaeus) and Loxodonta africana (Blumenbach). These species are readily distinguishable by geographic distribution, detailed anatomy and by general appearance.

Elephants by nature are gregarious animals and with their migratory tendency are surprisingly adaptable to a wide variety of environmental conditions, as evidenced by fossilised and frozen specimens. They were once distributed throughout the world with the exception of Australia and Antartica.

As an evolutionary strategy to deal with the structural plant parts high in cellulose, the ungulate and near ungulate mammals developed a capacity to utilise complex polysaccharides

with the aid of symbiotic bacteria in their fermentation chamber in the gut, the chamber being evolved either in the fore-stomach as in the ruminant ungulates (artiodactyl) or in the Caecum as amongst tne perissodactyl ungulates (rhinos and tapiers). The relative advantage or disadvantage of a ceacal fermentation site as possessed by the elephant is related to tne nature of it's diet and to it's ecological amplitude (Olivier, loc. cit.) in the light of Kleiber's law (Kleiber, 1961) that tne maintenance requirement of an animal per unit body weight decreases with increasing body weight. Absolute body size among herbivores assumes importance in the determination of tne bulk or fibre/protein ratios that tne animal will be able to tolerate. As regards the elephant, it has been reported (Sikes, loc. cit.) that it's tolerance of fibre in the diet is enhanced by the evolutionary change in it's dental characteristics, the premolars becoming indistinguishable from the molars. Further, in the absence of a Seive-like reticulo-omasal orifice and with a caecal fermentation chamber, the elephant is able to increase it's food intake, enhance the rate of passage of food through the intestinal tract and maintain a constant nutrient absorption per unit time without loosing efficiency of fibre digestion. Thus, the elephant appears to be in an advantageous position in exploiting tne food resources of variable seasonal quality. It may have some disadvantage in tne detoxification process. The anatomical disadvantage of the caecum together with tne urge to fulfil tne nutrient requirements

from large quantities of low quality forage might have influenced the inclusion of a varied variety of plants in the diet of perissodactyls in general and elephants in particular. Nettasinghe (1973) has attributed the variation in the diet of the Asian elephant partly to its habitat.

Habitat and habits

The habitat types in India are the tropical semi-evergreen and tropical deciduous forests as in the western ghats (Olivier, loc. cit.). Tropical deciduous forest is a formation of closed, high forest, occurring where water is periodically seriously limiting. The dominant and emergent trees are mostly deciduous; hence the name. The length of the leafless period, however, varies according to the nature of the dry period. In general, an evergreen component is larger in wetter areas and a deciduous component in drier areas. In the wetter area, woody climbers are abundant and bamboos and palms are scarce with practically no grass. In the drier areas, bamboos are common as seen in Bandipur and Mudumalai sanctuaries in South India. Alteration of land and shifting of cultivation at the hands of man for years have resulted in the occurrence of patches of deciduous forests in a mosaic of climax forest, savannah forest and grasslands providing a diversity of habitat for elephants. According to Sikes (loc. cit.), availability of water and food, environmental temperature, humidity, atmosphere, light, predators and competitors are all factors

affecting the shifting habitat of the elephants.

The life span of the elephant is similar to that of the human, the life expectency being 70 to 80 years which again is restricted by the molar progression, the 6th and last molar teeth beginning to wear by 45 years of age and thus interfering with food consumption (Gopalan, 1962). Possessing the largest brain among land animals and with its development only second to primates, elephants are highly intelligent with acute sense of hearing and smell. Although the functions of the pair of subcutaneous temporal glands observed in the elephants are yet to be elucidated, they are found to be apparently related to herd cohesion, communication and territory making (Sikes, loc. cit.). Sexual maturity is attained between 10 and 13 years of age and sexual activity continues in both sexes until extreme old age (Anon, 1958 and Sikes, loc. cit.). In a month long oestrous cycle, oestrus is seen for three days when the female shows frequent micturition and fondness for tuskers. Mating lasts for less than two minutes and takes place three or four times in a day. Parturition process lasts for 30 minutes, generally at night. The intercalving period is reported to be 36 to 47 months (Simon, 1962). Elephants make a variety of sounds by blowing out of the trunk and by muscular movements can modulate the sound to angry screams, playing squeals, laryngial rumbling and the trumpet. The Asiatic elephant makes a characteristic squeak in the distal part of the trunk apparently

indicating affection - a habit not seen in the African elephant. Anthony and Coupin (cited by Sikes, loc. cit.) have attributed this habit to a curious valve-like canal uniting the right and left nasal passages of the trunk of the Asiatic elephant. In it's migratory behaviour, water source plays a distinct role. The animal drinks first and then takes bath squirting systematically followed by the powder bath with soil. Benedict (loc. cit.) has reported that elephants sleep on an average for 4 hours in a day, mostly at night. The activity of the temporal gland is frequently associated with the sexual activity of the male called 'musth' which is characterised by restlessness and aggressiveness. Deraniyagala (1955) has suggested the cause for musth as liver disorder resulting from over nutrition. The increased secretion of the gland during 'musth' is sometimes accompanied by a yellowish appearance of skin. Sikes (loc. cit.) has stated that studies carried out by Fernando et al. (1963) have shown that temporin can be related to sexual activity. In the domesticated Asiatic elephant 'musth' has been and continues to be a problem in its control and management.

Distinguishing features of the digestive tract and rate of passage of feed and feed residue.

The prehensile organs of the elephant are the mouth, the proboscis and the lower lip. The stomach is a simple sac situated on the left side with the spleen attached and with number of

transverse, nearly circular, folds projecting inwards from the cardiac wall. The folds disappear when the stomach is distented. The small intestine begins at the pyloric orifice of the stomach and ends at the entrance of the caecum. The large intestine consisting of the caecum, the colon and the rectum and terminating at the anus is capacious and can be distinguished by its puckered appearance due to the presence of short longitudinal bands. Evans (1910) has referred to the measurements taken in a young Indian elephant about 7 ft at shoulder by Owan who observed a 38 ft long small intestine and a 21.5 ft long large intestine. The length of the entire intestinal tract as cited by Sisson and Grossman (1953) is about 167.5 ft in cattle, about 95 ft in horses and about 95 ft 10" in sheep. It is observed (Benedict, loc. cit.) that the length of the tract per unit weight is less in the case of the elephant as compared with that in the other herbivores and as such elephants eat incessantly throughout the 24 hours to satisfy their insatiable appetite which in turn is controlled to a certain extent by the caloric requirement and rate of passage of food through the intestinal tract. Enormous quantities of food pass through its alimentary canal and it is conceivable that the length of stay of food in the tract and the accompanying chemical transformation and absorption may not be the same as in other herbivora. It is also probable that wild animals in their natural state show a metabolism somewhat different from that of

domesticated animals. Lack of time for complete digestive action on account of rapid passage of food through the tract has been attributed as the factor responsible for the lowered digestibility of less easily digestible substances (Maynard and Loosli, 1969; Benedict, loc. cit.). From the results of feeding trials carried out in the elephant 'Jap', Benedict (loc. cit.) has concluded that the food residue of any given feeding begins to pass out of the body through the intestinal tract of the elephant in about 24 hours and completely disappears from the body in about 50 hours.

Defecation and character of the faeces

The faeces are formed in the rectal canal as boluses. Defecation occurs throughout the day, more or less hourly, except during four or five hours in the night when the animal sleeps. Defecation is usually withheld in startled animals. Tamed elephants pass large quantities of loose faeces prior to circus act, trucking or other anticipated exciting events. According to Benedict (loc. cit.), defecation occurs 14 to 18 times a day with a total out put of 110 kg, each bolus weighing 1 to 2 kg and measuring in diameter 111 to 168 mm and in length 79 to 178 mm. The faecal boluses are usually green to brown in colour. The boluses resemble those of the horse in texture and scent. They are held intact by a mucous seal.

Micturition and urinary constituents

A single discharge averages five litres, the total volume of

urine excreted being 50 litres per day (Benedict, loc. cit.). The frequency of micturition is more in the night than in the day and is increased following the drinking of water. The urine is ordinarly straw coloured with no pronounced odour (Benedict, loc. cit.). Simon (1958) has reported an average specific gravity of 1.03 for elephant urine.

According to Benedict (loc. cit.), a large elephant excretes over 2 kg of total solids in urine per day of which one fifth is mineral and four fifth organic matter. About 5 mg of nitrogen per cubic centimeter of urine were found excreted by 'Jap' (Benedict, loc. cit.), the total 24 hour out put being 235 g. The high percentage of total nitrogen in the form of urea, low percentage of ammonia nitrogen and a low creatinine coefficient led Benedict (loc. cit.) to conclude that the elephant has an extremely low endogenous nitrogen metabolism. Benedict (loc. cit.) observed detectable amounts of hippuric acid and about 160 g of sodium chloride per day in urine. Five to twenty mg of carbon were found excreted in one cubic centimeter of urine, the energy value of 1 ml of urine being 65 to 200 gram-cal. According to Simon (1959), urea ranged from 300 to 2500 mg, creatinine from 32 to 238 mg and uric acid from 11 to 106 mg per 100 ml of urine.

Feeds and feeding

The trunk being the main organ used for acquisition of food,

elephants feed mainly on arboreal plants and shrubs though in some places they are found grazing on grass land. According to Mckay (1973), Nettasinghe (loc. cit.) and Vancuylenberg (1974) the foods that can be consumed most rapidly by the Asiatic elephant are fruits that require little or no preparation. Fruits are followed by grasses, shrubs, leafy browse and barks in that order of preference. Olivier (loc. cit.) has suggested for the elephant a diet consisting of grasses and limited amount of palm and entailing minimum preparation cost. The physical defences as they exist in palms and the chemical defences like hydrocyanic acid in Manihot utilissima and latex in Hevea brasiliensis, Artocarpus heterophyllus and Ficus religiosa are effectively combated by the elephants (Olivier, loc. cit.).

Mckay (loc. cit.), Nattasingh (loc. cit.) and Vacuylenberg (loc. cit.) have given the average wet weight of an elephant mouthful of food, irrespective of type, as 150 g as against 190 g per mouthful with palm leaves reported by Olivier (loc. cit.). The ability to exploit palm nicne is so unique in elephants that it led Olivier (loc. cit.) to propose the term 'Palmivore' to distinguish this palm eating species of animal from other forms of herbivore such as browsing and grazing. Olivier (loc. cit.) has accordingly classified palm as a preferred food plant for the elephant.

Persistent references are seen in the ancient literature (Anon, 1945 and Anon, 1958) to the popular belief that elephants eat soil (salt licking) to get rid of worminous infestation. Sodium and calcium deficiencies in the diet have been implicated as the cause for the salt licking behaviour of the elephants (Peacock, 1935; Benedict, loc. cit.; Deraniyagala, loc. cit.; Shebbeare, 1958; Weir, 1969; Weigum, 1972; Laurie, 1978 and Olivier, loc. cit.).

Sanderson as indicated by Evans (loc. cit.) carried out numerous experiments to determine the quantity of fodder, elephants would eat and found that about 800 lbs of green fodder may be consumed by a full sized elephant in a day. The commissariat scale of ration for elephants in Bengal, Madras and Burma as cited by Evans (loc. cit.) includes 15 lbs of grain, 200 lbs dry fodder, 480 lbs green fodder, two ounces of salt and one ounce of oil for large elephants on command. The importance of giving different rations for idle and work animals, pregnant and lactating animals and calves has been stressed in 'Gajasastra'. Eight types of salt, grass, garlic, jaggery, gingelly oil, butter, curd, cooked and uncooked paddy, meat and alcohol have been mentioned as dietary ingredients in this ancient work. Elephants in the Forest Department of Tamil Nadu get bamboo leaves, grass and ficus twigs in an ascending order as per a scale based on height ranging from 3 ft 6" (calves) to over 9 ft (adults), weightage to the extent

of 50 per cent being given to wastage (Gopalan, loc. cit.). The concentrate, especially for work animals, is constituted by such grains as rice, pulses and millets. The concentrate is fed twice a day. Elephants are fed on class-war basis as calves, adults of varying height groups, working, pregnant and lactating animals (Krishnamoorthy, pers. comm. 1978). In Kerala, the concentrate part of the ration for elephants is constituted by rice, wheat, ragi and horsegram singly or in combination in a cooked form. The staple roughage fed is palm leaves (Caryota urens). The elephants maintained in the Forest Department of the State are fed on the basis of size assessed by height, work load and on other productive performances as growth, pregnancy and lactation (Nair, pers. comm. 1978).

Nutrient allowances

Benedict (loc. cit.) maintained 'Jap' on positive nitrogen balance and found that the apparent digestibility of nutrients in the hay fed to the elephant to be: Dry matter, 43.8%; Ash, 25.5%; Protein, 48.3%; Ether extract, 1.3%; Crude fibre, 37.7%; N.F.E., 50.6% and Energy, 40.0%. Benedict (loc. cit.) estimated the basal metabolism of 'Jap' weighing 3630 kg as 49000 kcal for 24 hours. Brody (1945) determined the basal metabolism of an elephant weighing 3833 kg and that of another weighing 1360 kg and found the same to be 30924 kcal/day and 16020 kcal/day respectively, after

deducting 30 per cent for standing and heat increment. In terms of metabolic body size, daily requirements of nutrients for warm blooded animals in general have been reported (Albritton, 1954) as follows: Protein, digestible 1666 mg; Calcium 29 mg; Phosphorus 59 mg; Calories utilizable with light muscular activity, 99 and calories utilizable for basal energy expenditure, 66.

No information other than that furnished by Benedict (loc. cit.) from his feeding trial with 'Jap' is available from literature on the nutrient requirements of the elephant for supporting or promoting any specific physiological process. In the absence of an acceptable feeding standard, elephants are now fed at random, hardly based on any scientific nutritional principle.

PRESENT INVESTIGATION

PRESENT INVESTIGATION

From the resume of literature given in the foregoing pages, it will be evident that although nutrition is the most important husbandry process of the elephant, only the least is known about it. Besides the work of Benedict (1936) in a single elephant 'the Jap', there is no other investigation on record, designed and carried out to determine the nutrient requirements of the elephant for maintenance or for promoting such a vital physiological function as growth. Consequently, there is no feeding standard for this species of animal. The present investigation was undertaken to make up this deficiency. As the initial study, a digestion trial was carried out in two adult and two young elephants with palm leaf fed ad lib. From the results of this study communicated for publication in the Indian Veterinary Journal (vide appendix), the following inferences were drawn:

1. The nutrients in general in palm leaf are well digested by elephants, the young animals digesting the nutrients better than the adults.

2. The dry matter consumption of elephant per 100 kg body weight is higher than the same of cattle.

3. A DCP and a TDN of around 2.8 kg and 47 kg respectively should satisfy the maintenance requirements of

the elephants but will be quite inadequate for promoting growth in the young.

4. A nitrogen balance trial is indicated.

The study under report which is a continuation of this enquiry is concerned with nitrogen, calcium, phosphorus and energy balance trials in two adult and two young animals, both fed palm leaf ad lib. at first (Trial I) and subsequently at a level of 75 per cent of the ad lib. intake (Trial II). Prior to the balance trials, the reliability of applying a formula based on body measurements to predict the body weights of elephants as accurately as possible for purposes of their scientific feeding and judicious treatment was explored. During the course of the balance trials, the nutritional status of individual animals was assessed in terms of concentrations of some of the well-known blood constituents.

EXPERIMENTAL

EXPERIMENTAL

Preliminary to the nitrogen, calcium, phosphorus and energy balance trials, the reliability of applying a formula based on body measurements to predict the body weights of elephants as accurately as possible was examined. Nitrogen, calcium, phosphorus and energy balances were determined in adult and young elephants fed palm leaf (Caryota urens) ad. lib. at first (Trial I) and subsequently at a level of 75 per cent of the ad lib. intake (Trial II). During the course of the feeding trials, the nutritional status of the experimental animals was assessed in terms of concentrations of some of the better known blood constituents.

Material

Leaf of Caryota urens collected from trees around Mannarghat, Palghat District, Kerala and supplied by the contractor of the Guruvayur Devaswam, formed the material for the study.

Animals

Twenty elephants of varying age, weight and sex were employed for the determination of the relationship between body measurements and body weight.

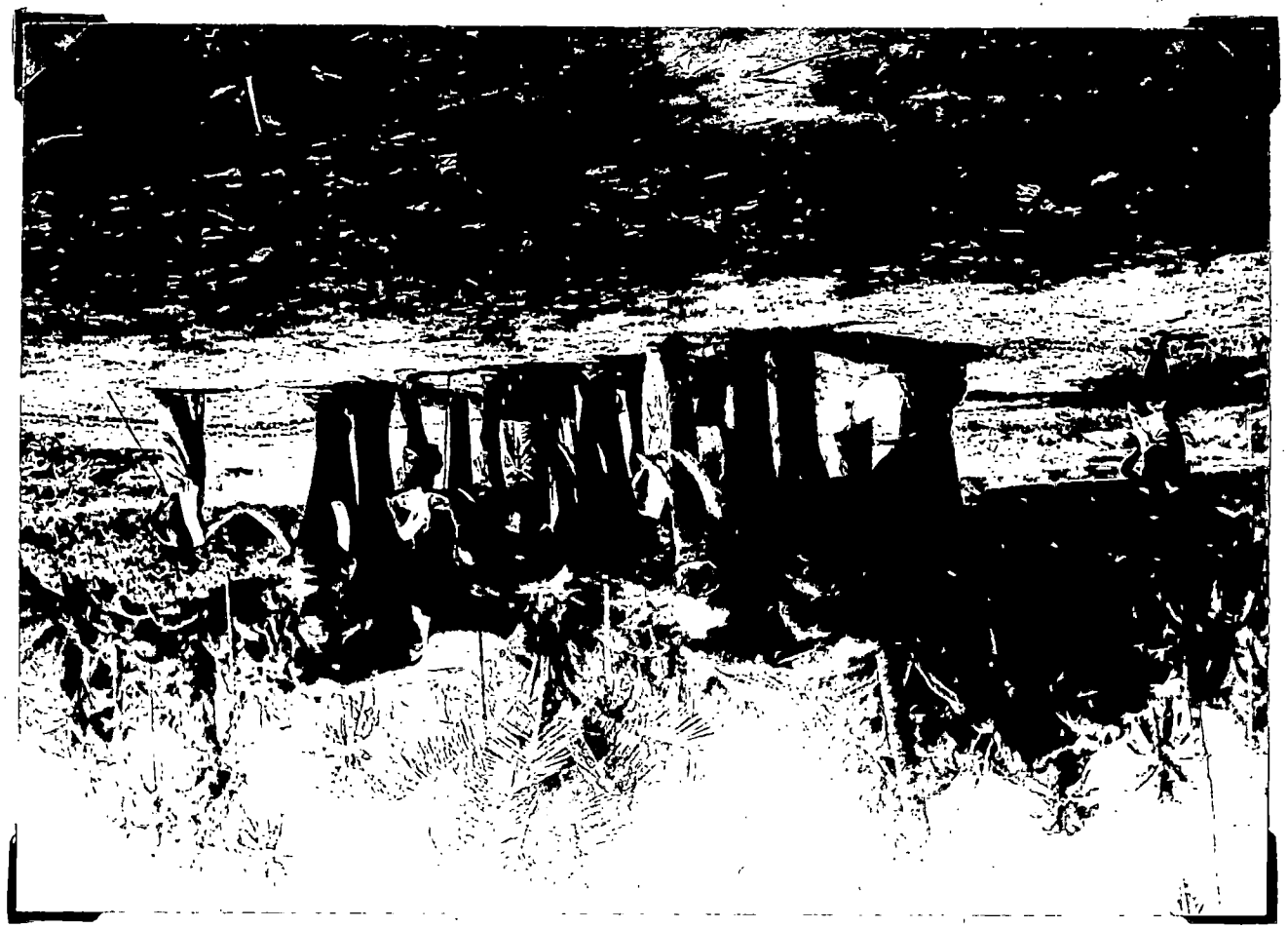
Two adult elephants named as Narayanan and Ravindran and two young elephants named as Sathyanarayanan and Kesavankutty belonging to the Guruvayur Devaswam and stationed at Punnathur palace ground,

36 km away from the Kerala Agricultural University, constituted the two groups of experimental animals for the balance trials (Plate III).

Procedure

The animals were weighed in a weigh-bridge available with the Indian Oil Agencies, 6 km away from the University campus. Body measurements of the elephants were taken simultaneously with a measuring tape in centimeters. Shoulder height at withers was measured by attaching the tape to the tip of a horizontally placed straight rod provided with a spirit level, the distance between the rod and the ground being taken as the height. Chest girth was measured by tightly encircling the body of the animal just behind the elbows by the measuring tape. Body length measurements were taken from the point of the shoulder to the point of the buttocks (P.S. to P.B.) and from the point of the shoulder to the point of the ilium (P.S. to P.I.). Neck girth was determined by tightly encircling the tape around the neck. All measurements were taken by keeping the animal stand squarely on all four legs in a level ground with the head straight and steady.

Ten leaves gathered at random from twenty leaves randomly selected from over 400 palm leaves supplied by the contractor were chopped to a size of 2 cm, mixed and quartered to obtain a 5 kg sample. Samples from this were taken for dry matter determination.



The rest of the material was air-dried, pulvarised in a key-orr mill, mixed and quartered and a 1 kg sample was made available for analyses.

The experimental animals were dewormed with phenothiazine three weeks prior to the commencement of the feeding trials. In the first trial, the animals were fed palm leaves ad lib. After a period of ten days, 24 hour collections of dung and urine were made for three days continuously (72 hours). The collection period was determined on the basis of results of a previous feeding trial carried out with rubber pieces in a separate group of three elephants. Dung and urine were collected quantitatively and mannually using plastic sheets and plastic buckets respectively. The second trial was conducted similarly except that the feeding of palm leaves was restricted to 75 per cent of the intake observed during Trial I. The animals were watered twice a day, at 10 A.M. and at 3 P.M. Records of feed intake and of dung and urinary outputs in respect of individual animals were maintained. For immediate analytical purposes, 10 per cent aliquots of the dung collected defecation-wise and bolus-wise were mixed and stored in air-tight polythene (polyvinyl compound) bags. Samples of 0.5 per cent of dung in 5 ml of a 10 per cent solution of thymol in chloroform were preserved in air-tight glass jars for any analysis at a later date. Five per cent aliquots of urine collected micturition-wise were pooled and of this lot one half was mixed with chloroform

containing 10 per cent thymol by weight and the other mixed with 20 ml of 25 per cent sulphuric acid. Both these samples were preserved in air-tight polythylene jars for analyses. The dung and urine samples were transported immediately after preservation to the Nutrition Laboratory of the College of Veterinary and Animal Sciences, Mannuthy for analyses.

For the determination of blood values, blood was always drawn from the ear vein. Wherever necessary, sodium citrate was used as the anticoagulant. Serum was obtained by allowing the blood to clot.

Methods

Analyses of palm leaf, dung and urinary total solids were carried out as per the methods described in A.O.A.C. (1970). Gross energy values of palm leaf, dung, and urinary total solids were determined in a Gallenkamp model CB 370 Ballistic bomb calorimeter. For the determination of cobalt in palm leaf, the method described by Sandell (1950) was followed.

Calcium and phosphorus in urine were estimated by the methods described by Tisdall and Kramer (1921) and Fiske and Subha Row (1925) respectively.

Red cell counts were made using improved Neubauer counting

chamber with 1:200 dilution of blood, using Hayem's fluid as the diluting fluid. W.B.C. counts were made by using Thomas fluid as the diluting fluid with 1:20 dilution of blood. Packed cell volume was determined by the Wintrobe method and erythrocyte sedimentation rate by the Westergren method. Plasma protein (Plasma N x 6.25) was determined by the Kjeldahl method. Haemoglobin was estimated by the method of Wong (1928) as described by Hawk et al. (1954).

Calcium concentration in blood serum was determined by the Clark and Collip (1925) modification of the Kramer and Tisdall (1921) method. Inorganic phosphate in whole blood was determined by the method of Fiske and Subha Row (1925). The methods of Folin and Svedbrg, Folin and Wu and Nelson-Somogyi described by Hawk et al. (1954) were used for the estimation of urea, creatinine and glucose respectively in whole blood. For the estimation of cholesterol and chloride in blood serum, the methods of Abell et al. and Schales and Schales respectively were used as described by Hawk et al. (1954). Vitamin B_{12} in blood plasma was assayed following the method described by Kavanagh (1963).

Gross energy determination

The gross energy values of the dried and ground samples of palm leaf, dung and urinary total solids were determined in a Gallenkamp model CB 370 Ballistic bomb calorimeter as follows:

The instrument was standardised using thermochemical grade benzoic acid (Calorific value-6.32 kcal/g). Exactly 0.7 g of banzoic acid was weighed in the firing crucible. The crucible was then mounted on the firing stand and using a firing thread, the sample was connected to firing pin. The bomb was closed and oxygen at 25 atm. was let in. The instrument was checked for any leakage. The sample was then fired and the heat released as indicated by the galvanometer deflection was recorded. Blank firings under identical conditions using only the firing thread were conducted and the galvanometer deflections recorded. The length of the firing thread used was maintained uniform for all determinations. The difference between the galvanometer deflection with benzoic acid and the blank gave the actual galvanometer reading due to benzoic acid. Five firings were made with benzoic acid and the galvanometer readings so obtained were used to arrive at the caliberation constant which is the relation between the galvanometer deflection and amount of heat released by combustion of benzoic acid. The mean value of caliberation was used as caliberation constant throughout the study.

The samples for the determination of gross energy were subjected to the same procedure and the heat released in each case in terms of galvanometer deflection was recorded. Using the caliberation constant, the heat released (gross energy) per gram of sample was calculated. Triplicate determinations were made

for each sample and the mean value was taken as the gross energy of the sample.

Determination of cobalt in palm leaf (Sandell, 1950)

The air dried sample of palm leaf ground in a porcelain mortar and pestle was used for the determination of cobalt. Ashing of the sample (65 g) was done at 750°C in a platinum dish in a muffle furnace. The whit ash was then dissolved in a mixture of Hcl and HNO_3 (dilute 1:1) boiled and filtered. The filtrate was treated with H_2So_4, boiled, cooled and filtered. The cobalt was determined in the filtrate (25 ml) by using nitroso-R-salt as the colorimetric reagent. Measurements were made at pH 8 using citrate-phosphate-borate buffer and at 420m/^{u} using Unicam SP 500 spectrophotometer.

Estimation of calcium in urine (Tisdall and Kramer, 1921)

Principle

Calcium is precipitated as oxalate and titrated with potassium permanganate.

Reagents

1. A 10-fold dilution of ammonium hydroxide (10 ml of concentrated ammonia solution diluted to 100 ml).

2. A 50-fold dilution of ammonium hydroxide.

3. Sulphuric acid (approximately 1N) : diluted 30 ml of concentrated sulphuric acid to a litre.

4. Oxalic acid (1N) : Dissolved 45 g of oxalic acid in water and diluted to a litre.

5. A filtered saturated solution of sodium acetate.

6. Potassium permanganate (0.01 N) : Standardised each day against a 0.01N solution of sorensen sodium oxalate.

Procedure

The urine was evaporated and ashed below 400°C in a muffle furnace and extracted as per the Stolte method (Stolte, 1911). Of the ash solution, 2 ml were diluted to 4 ml with water in a 15 ml graduated centrifuge tube (centrifuge tubes used should be previously cleaned with chromic sulphuric acid). Added one drop of phenol red indicator solution and introduced 10-fold diluted ammonium hydroxide solution drop by drop until the liquid was alkaline. Added 1N sulphuric acid till it was just acid again to redissolve the phosphates. Added one ml of 1N oxalic acid followed by 1 ml of a filtered saturated solution of sodium acetate. The latter was added drop by drop. Mixed and let the tube stand 45 minutes. Centrifuged for 10 minutes at 1300 revolutions per minute. Decanted the supernatant fluid carefully.

While the tube was still inverted, it was placed in a rack for five minutes to drain, the mouth of the tube resting on a pad of filter paper. The mouth of the tube was wiped dry with a soft cloth and the sides of the tube were washed down with 3 ml of 1:50 ammonia solution directed in a very fine stream from a wash bottle. The precipitate was stirred up with 3 ml of washing fluid and was again centrifuged. The supernatant solution was decanted and the tube was drained for five minutes as before. After the last washing fluid had been poured off, added 2 ml of 1N sulphuric acid, mixed the tube to suspend the precipitated, warmed it in a boiling waterbath for a few minutes and titrated the solution with 0.01N potassium permanganate until the first appearance of a pink colour which persisted for one minute. A blank determination was carried out with the reagents alone.

Calculation

0.2 (A-B) = milligrams of calcium in the sample, where A = ml of 0.01N potassium permanganate used in the titration of the urine, B = ml of 0.01N potassium permanganate used in the blank determination on reagents.

Estimation of Total phosphorus in urine (Fiske and Subba Row,1925)

Principle

Although urine phosphorus exists almost entirely as inorganic

phosphate and the determination as such is usually sufficient, a strictly total phosphorus determination requires the destruction of organic matter. This is brought about by heating with sulphuric acid and hydrogen peroxide.

Reagents

1. Sulphuric acid (5N).
2. Hydrogen peroxide (30%).
3. Ammonium molybdate solution (2.5%).
4. Aminonapthol sulphonic acid reagent.
5. Standard phosphate solution.

Procedure

Placed sufficient urine to contain between 0.2 and 0.8 mg of total phosphorus (usually 1-2 ml) in a large pyrex test tube. Added 10 ml of 5N sulphuric acid (or 5 ml of 10N acid) and added quartz chip to prevent bumping. Heated over an electric hot plate until the water had been driven off and a dark brown fluid remained. Added 30 per cent hydrogen peroxide by drops as necessary to complete oxidation of organic matter and leave a colourless solution. The hydrogen peroxide was allowed to drop directly into the tube contents and not through the sides of the tube. When oxidation was complete, cooled slightly, added 2-3 ml of water and boiled for 2-3 minutes to ensure hydrolysis of meta or pyrophosphate. Cooled and transferred quantitatively with rinsings

to a 100 ml volumetric flask. Made up to about 70 ml with water and added 10 ml of a 2.5 per cent solution of ammonium molybdate in water. Mixed and added 4 ml of the aminonaphthol sulphuric acid reagent. Diluted to 100 ml with water and mixed.

At the same time transferred to a similar flask 5 ml of standard phosphate solution containing 0.4 mg of P, 65 ml of water and 10 ml of 2.5 per cent solution of ammonium molybdate. Mixed by gentle shaking and added 4 ml of aminonaphthol sulphonic acid reagent. Diluted to the mark with water, mixed well by inversion, and allowed to stand for five minutes.

For photometric measurement using the Bausch & Lomb Spectronic 20 Spectrophotometer, prepared a blank solution by treating 70 ml of water in a 100 ml flask witn the same reagents used for the standard and unknown and diluted to the mark with water by inversion.

Calculation

$$\frac{\text{Reading of unknown}}{\text{Reading of standard}} \times \frac{0.4}{1} = \text{mg of total phosphorus in the volume of urine used.}$$

Estimation of Haemoglobin (Hawk et al. 1954)

Principle

The iron is detached from the haemoglobin molecule by treatment with concentrated sulphuric acid in the presence of potassium

persulphate, without heating. After removal of the proteins by tungstic acid, the iron in the filtrate is determined calorimetrically. From the total iron content, the haemoglobin content is readily obtained since haemoglobin contains 0.34 per cent of iron and only about 1 to 2 per cent or less of the total blood iron is non-haemoglobin iron.

Reagents

1. Concentrated sulphuric acid - iron free.
2. Saturated potassium persulphate solution:

   Mixed 7 to 8 g of potassium persulphate with 100 ml of water in a glass stoppered bottle. The undissolved excess settled to the bottom and compensated for loss by decomposition. Kept in the refrigerator.

3. Sodium tungstate solution (10%) : Dissolved 100 g of sodium tungstate in water and diluted to 1 litre.
4. Standard iron solution:

   Dissolved 0.702 g of crystalline ferrous ammonium sulphate (Mohr's salt) in 100 ml of water. Added 5 ml of concentrated sulphuric acid, warmed slightly and added concentrated potassium permanganate solution drop by drop until a drop produced a permanent colour. Transferred to a 1-litre volumetric flask with rinsings, diluted to the mark and mixed. This solution contains 0.1 mg of ferric iron per ml and is stable indefinitely.

5. Potassium thiocyanate solution (3N):

Dissolved 145 g of potassium thiocyanate in water and diluted to 500 ml. Filtered. Added 20 ml of pure acetone to improve the keeping quality. Deterioration will be evidenced by the rapid formation of a yellow colour in the blank test.

Procedure

With an Ostwald or micropipette accurately transferred 0.5 ml of well-mixed citrated whole blood to a 50 ml volumetric flask. Added 2 ml of iron-free concentrated sulphuric acid. Mixed by whirling for one to two minutes. Added 2 ml of saturated potassium persulphate solution. Mixed and diluted to about 25 ml with water. Added 2 ml of 10 per cent sodium tungstate solution. Mixed. Cooled to room temperature under the tap, diluted to volume with water, stoppered and mixed by inversion. Filtered and collected the filtrate in a dry flask. Prepared a standard in a second 50 ml volumetric flask by adding to it about 25 ml of water followed by 8 ml of concentrated sulphuric acid, 2 ml of saturated potassium per-sulphate solution and 2.5 ml of standard iron solution containing 0.1 mg of ferric iron per ml. Cooled to room temperature, diluted with water to the mark and mixed. For photometric measurement prepared a blank similar to the standard except that the standard iron solution was omitted.

Measured 10 ml of unknown filtrate, standard and blank into

separate test tubes. To each, added 0.5 ml of saturated potassium persulphate solution followed by 2 ml of 3N potassium thiocyanate solution. Mixed by inversion and read in the photometer within the next 30 minutes setting the photometer to zero density with the blank at 480 m/u.

Calculation

$$\frac{\text{Density of unknown}}{\text{Density of standard}} \times 0.25 \times \frac{100}{0.5} \times \frac{1}{3.4} = \text{grams haemoglobin per 100 ml blood.}$$

Determination of blood calcium (Clark & Collip, 1925)

Principle

Calcium is precipitated directly from the serum or plasma as oxalate. The latter is titrated with potassium permanganate.

Reagents

1. Ammonium oxalate (4%):

   40 g of ammonium oxalate were dissolved in a litre of distilled water.

2. Dilute ammonia:

   2 ml of concentrated ammonia in 98 ml of water.

3. Sulphuric acid (1N):

   28 ml of concentrated sulphuric acid were diluted with distilled water to one litre.

4. Potassium permanganate solution (0.01N):

Dissolved 0.4 g of pure potassium permanganate in 1 litre of redistilled water in a thoroughly clean flask. Inserted a funnel covered with a watch glass as a condenser and digested for several hours at near the boiling point. Cooled, let stand overnight and filtered with gentle suction through a 3-inch Buchner funnel lined with ignited asbestos. Transferred to a perfectly clean glass stoppered bottle and kept in a dark place. The 0.01 N permanganate was standardised against 0.01 N sodium oxalate.

Procedure

Introduced into a graduated 15 ml centrifuge tube, 2 ml of clear serum, 2 ml of distilled water and 1 ml of 4 per cent ammonium oxalate solution. Mixed thoroughly. Mixing was aided by holding the tube at the mouth and giving it a circular motion by tapping the lower end. Let stand for 30 minutes or longer. Again mixed the contents and centrifuged for about 5 minutes at 1500 revolutions per minute. Carefully poured off the supernatant liquid and while the tube was still inverted, let it drain in a rack for 5 minutes, resting the mouth of the tube on a pad of filter paper. Wiped the mouth of the tube dry with a soft cloth. Stirred up the precipitate and washed the sides of the tube with 3 ml of dilute ammonia directed in a very fine stream, from a wash bottle. Centrifuged the suspension and drained again as before.

Added 2 ml of approximately normal sulphuric acid by blowing it from a pipette directly upon the precipitate so as to break up the mat and facilitate solution. Placed the tube in a boiling water bath kept at 70 to 75°C. Titrated with 0.01 N potassium permanganate to a definite pink colour which persisted for at least one minute.

Calculation

1 ml of 0.01N potassium permanganate solution is equivalent to 0.2 mg of calcium.

$(x-b) \times 0.2 \times \frac{100}{2}$ = mg calcium per 100 ml serum, where x equals number of ml of permanganate required in the titration, and b is the blank, ie., the number of ml of permanganate required to titrate 2 ml of the sulphuric acid solution to the usual end point and 2 refers to the quantity of serum in ml taken for the determination to the usual end point.

Determination of inorganic phosphate in blood (Fiske and Subba Row, 1925)

Principle

The proteins of blood are precipitated with trichloroacetic acid. The protein-free filtrate is treated with an acid molybdate solution, which forms phosphomolybdic acid from any phosphate

present. The phosphomolybdic acid is reduced by the addition of 1, 2, 4-aminonaphtholsulphonic acid reagent, to produce a blue colour whose intensity is proportional to the amount of phosphate present.

Reagents

1. Trichloroacetic acid (10%):

   Dissolved 10 g of reagent grade trichloroacetic acid in water and diluted to 100 ml.

2. Molybdate II:

   Dissolved 25 g of reagent grade ammonium molybdate in about 900 ml of water. In a 1-litre volumetric flask, placed 300 ml of 10 N sulphuric acid. Added the molybdate solution and diluted with washings to 1 litre with water. Mixed well.

3. Aminonaphtholsulphonic acid reagent:

   Placed 195 ml of 15 per cent sodium bisulphite solution in a glass-stoppered cylinder. Added 0.5 g of 1,2,4-aminonaptholsulphonic acid. Added 5 ml of 20 per cent sodium sulphite. Stoppered and mixed until the powder was dissolved. If solution was not complete, added more sodium sulphite, 1 ml at a time, with shakings, but avoided an excess. Transferred the solution to a brown-glass bottle and stored in the cold.

4. Standard phosphate solution:

Dissolved exactly 0.351 g of pure dry mono-potassium phosphate in water and transferred quantitatively to a 1-litre volumetric flask. Added 10 ml of 10 N acid, diluted to the mark with water and mexed. This solution contains 0.4 mg of phosphorus in 5 ml.

Procedure

To 8 ml of 10 per cent trichloroacetic acid solution in a small flask, added slowly, with mixing, 2 ml of whole blood. Stoppered, mixed and filtered through a low-ash filter paper. Transferred 5 ml of filtrate to a cylinder or other container graduated at 10 ml and added 1 ml of the molybdate II reagent. Mixed well. Added 0.4 ml of aminonaphtholsulphonic acid reagent and again mixed. Diluted to the mark, mixed and allowed to stand for 5 minutes.

For photometric measurement, transferred a portion of the coloured solution to a suitable container and read in the photometer at 660 to 720 mμ. Set the photometer to zero density with a blank prepared by treating 5 ml of 10 per cent trichloroacetic acid with 1 ml of molybdate II reagent and 0.4 ml of aminonaphthol-sulphonic acid reagent, followed by water to a volume of 10 ml. Established the density of a standard phosphate solution as follows: Transferred 5 ml of the stock phosphate standard, containing 0.4 mg

of P to a 50 ml volumetric flask and made up to volume with 10 per cent trichloroacetic acid and mixed. Transferred 5 ml of this diluted standard containing 0.04 mg of P to a suitable container, added 1 ml of molybdate II and 0.4 ml of aminonaphthol-sulphonic acid reagent, diluted to 10 ml with water and mixed. Allowed to stand for 5 minutes and determined the density after setting the photometer to zero with a blank as described above.

Calculation

$$\frac{\text{Density of unknown}}{\text{Density of standard}} \times 0.04 \times 100 = \text{mg inorganic.}$$

P per 100 ml of whole blood, where 0.04 is the strength of the standard.

Estimation of urea in blood (Hawk et al. 1954)

Principle

The ammonia produced by the action of urease on the protein-free blood filtrate is distilled off and determined calorimetrically by reaction with Nessler's reagent.

Reagents

1. Acetate buffer solution:

Dissolved 15 g of crystallised sodium acetate in a 100 ml volumetric flask by the help of 50 to 75 ml of water. Added 1 ml of glacial acetic acid diluted to volume and mixed.

2. Urease solution:

Transferred 0.5 g of Jack bean meal to a clean 50 ml flask, added 20 ml of 30 per cent (by volume) alcohol. Shook for 10 minutes and filtered or centrifuged. This extract was always prepared on the day, it was to be used. Larger volume of extract or a stronger extract than is really necessary should not be used.

3. Urease paper:

Transferred to a clean 200 ml flask 30 g of Jack bean meal and 100 ml of dilute alcohol (30 ml of 95% alcohol diluted to 100 ml). Added 1 ml of the buffer mixture described above. Stoppered tightly and shook vigorously for at least five minutes and then shook less hard for about 10 minutes. Filtered and centrifuged half an hour in 15 ml tube, the mouth of which had been covered with tin foil. Transferred the extract to a porcelain dish and at once took it up on strips of rather heavy filter paper and hund them up to dry over two threads about 15 cm apart. While drying precautions were taken not to expose the papers to air currents as blasts of air might destroy the enzymes so long as water was present. As soon as the paper strips were thoroughly dry, they were cut into pieces of about 1 cm by 2.5 cm and preserved in wide mouthed bottles. These urease papers are reported to retain their activity for many months and even for years. The urease will get fixed in the paper and it is only by shaking the solution several times during the digestion that adequate contact and quantitative

hydrolysis of the urea can be secured.

4. Antifoaming oil mixture:

To one volume of crude fuel oil added about 10 volumes of toluene.

5. Saturated Borase solution:

Dissolved about 40 g of reagent grade sodium tetra borate (borase) in 1 litre of boiling water and allowed to cool to room temperature.

6. 0.1 N acid:

Standardised sulphuric acid was used.

7. Standard ammonium sulphate solution. Prepared the stock standard solutions as detailed below:

Dissolved 0.944 g of dry reagent grade ammonium sulphate in water, transferred with rinsings to a one litre volumetric flask, added a few drops of concentrated sulphuric acid, diluted to volume with water and mixed. This solution contained 1 mg of nitrogen in 5 ml which is stable indefinitely. To prepare the dilute standard used in the procedure, diluted 5 ml of stock standard to 100 ml with water. This solution contained 0.1 mg of nitrogen in 10 ml and was prepared fresh, daily.

8. Nessler's solution:

Placed 100 g mercuric iodide and 70 g potassium iodide in a litre volumetric flask and added

about 400 ml water. Rotated until the dissolution was complete. Dissolved 100 g NaOH in about 500 ml water, cooled thoroughly and added with constant shaking to the mixture in the flask made up with water to the litre mark when became perfectly clear. When the small amount of brownish-red precipitate which formed settled out, the supernatant fluid was poured off and used.

Procedure

Transferred 5 ml of tungstic acid blood filtrate to a pyrex test tube of 30 ml capacity. Added two drops of acetate buffer solution and either 1 ml of urease solution (prepared the same day) or a piece of urease paper. Inserted a cork and then either let stand at room temperature for 25 minutes or immersed for 10 minutes in 700 ml of water having an initial temperature of about 45°C. When urease paper was used the tube was shaken occasionally during the digestive period. Cooled the tube and added two drops of antifoaming oil mixture and 2 ml of saturated borax solution. Connected at once with the delivery tube and a test tube receiver graduated at 25 ml. The receiver contained 1 ml of 0.1 N acid and 1 ml of water, fastened the boiling tube in a clamp and started the distillation by applying the flame of a microburner, with a shield to prevent fluctuation of the flame due to air currents. As soon as the contents were nearly boiling, reduced the flame so that the first minute of boiling was very gentle. Then boiled

briskly for about three minutes and finally another minute with the delivery tube slightly raised from tne surface of liquid in the receiver. Prepared a blank tube containing 1 ml of 0.1 N acid diluted with water to about 20 ml added 2.5 ml of Nessler solution, diluted to 25 ml and mixed. The photometer was set to zero density with the blank and determined the densities of standard and unknown at 480-540 mμ.

Calculation

$$\frac{\text{Density unknown}}{\text{Density standard}} \times 0.1 \times \frac{100}{0.5} = \text{mg.}$$

Urea N per 100 ml blood.

Estimation of creatinine in blood (Hawk et al. 1954)

Principle

A portion of the blood filtrate is treated with alkaline picrate solution and the colour developed compared with that produced by a known amount of creatinine under the same conditions.

Reagents

1. Standard creatinine solution:

Prepared a stock standard by dissolving 1 g of pure dry creatinine in 0.1 N hydrochloric acid and diluted to 1 litre with the acid. This solution

contained 1 mg of creatinine per ml. Prepared the working standard by transferring 3 ml of stock standard containing 3 mg of creatinine, to a 500 ml volumetric flask and adding 50 ml of 0.1 N hydrochloric acid diluted with water to 500 ml and mixed the standard containing 0.03 mg creatinine in 5 ml stablizing the same for a week by the addition of a few drops of toluene.

2. Alkaline picrate reagent:

Prepared a saturated solution of purified picric acid- A 10 ml portion, titrated with 0.1 N alkali in the presence of phenophthalene as indicator, required 5.2 to 5.4 ml of alkali for neutralisation.

For preparing the fresh alkaline picrate reagent, transferred 25 ml of the saturated picric acid solution to a flask, added 5 ml of 10 per cent sodium hydroxide solution and used within a short time after preparing.

Procedure

Transferred 10 ml of 1:10 tungstic acid filtrate of whole blood to a small flask. In a second container, placed 5 ml of standard creatinine solution containing 0.03 mg of creatinine and added 15 ml of water. Added 5 ml of freshly prepared alkaline picrate reagent to the blood picrate and 10 ml to the diluted

creatinine standard. Mixed, and allowed to stand for 15 minutes for complete colour development and read within the next 15 minutes. Determined the densities in the photometer at 520 mμ after setting the photometer to zero density with water alone. Determined the density of a blank prepared by treating 10 ml of water with 5 ml of the alkaline picrate reagent and substracted this value from the observed densities of standard and unknown to obtain their true values.

Calculation

$$\frac{\text{Density of unknown}}{\text{Density of standard}} \times \text{mg creatinine in standard} \times \frac{100}{1} \times \frac{15}{30}$$

$$= \text{mg creatinine per 100 ml blood.}$$

Estimation of glucose in blood (Hawk et al. 1954)

Principle

Blood is deproteinised by a zinc hydroxide barium sulphate procedure which gives a filtrate containing practically no reducing substance other than glucose. The zinc-barium filtrate is heated with an alkaline copper reagent and then treated with a special arsenomolybdate colour reagent. The colour developed is compared with that obtained from a known amount of glucose.

Reagents

1. Barium hydroxide solution:

Dissolved 90 g of $Ba(OH)_2.8\ H_2O$ in distilled

water and diluted to 2000 ml in a graduated cylinder. Filtered when it was cloudy. Stored in well stoppered containers filled to capacity.

2. Zinc sulphate solution:

Dissolved 100 g of $Znso_4.7H_2O$ in distilled water, diluted to 2000 ml in a graduated cylinder and mixed.

3. Alkaline copper reagent:

Solution A: Dissolved 50 g of anhydrous sodium carbonate, 50 g of Rochelle salt, 40 g of sodium bicarbonate and 400 g of anhydrous sodium sulphate in about 1600 ml distilled water and diluted to 2 litres. Mixed, filtered and stored at room temperature. Care was taken to filter again when sediments were observed.

Solution B: Dissolved 150 g of $CuSo_4.5H_2O$ in distilled water and diluted to one litre. Added 0.5 ml of concentrated sulpnuric acid and mixed.

On the day the Alkaline copper reagent was to be used, placed 4 ml of solution B in a 100 ml graduated cylinder, diluted to 100 ml with solution A and mixed.

4. Arsenomolybdate colour reagent:

Dissolved 100 g of ammonium molybdate in 1800 ml of distilled water. Added 84 ml of concentrated sulphuric acid and stirred. Dissolved 12 g of

disodium orthoarsenate ($Na_2HAso_4.7H_2O$) in 100 ml of distilled water and added it to the acidified molybdate solution and stored. Placed the mixture in an incubator at 37°C for one day and stored in glass stoppered brown glass bottle to maintain stability for a long time.

5. Standard glucose solution:

Prepared a stock standard by dissolving exactly 1 g pure anhydrous glucose in about 15 ml of 0.2 per cent benzoic acid solution, transferred quantitatively to a 100 ml volumetric flask, diluted to the mark with the benzoic acid solution and mixed. This stable solution contained 10 mg of glucose/ml Standard I (0.0125 mg of glucose/0.5 ml) was prepared by diluting 0.5 ml of the stock standard to 200 ml with 0.2 per cent benzoic acid solution and mixed. For the preparation of Standard II solution (0.025 mg glucose per 0.5 ml) diluted 1.0 ml of stock standard to 200 ml as described for Standard I solution and for preparation of Standard III solution (0.050 mg glucose per 0.5 ml) diluted 2.0 ml of stock standard to 200 ml. These dilute solutions in 0.2 per cent benzoic acid solution kept well at room temperature for a long time.

Procedure

A. Deproteinisation

Placed 1 ml of blood in a 50 ml flask. Added 95 ml of barium hydroxide solution and mixed. Added 9.5 ml of zinc

sulphate solution and mixed. Shook vigorously and filtered through a dry filter paper and collected the filtrate in a dry flask.

B. Determination of glucose

Measured 0.5 ml of the barium-zinc filtrate into a test tube calibrated at 10 ml. Added 1 ml of alkaline copper reagent, mixed by tapping, covered the top of the tube with a marble and placed upright in a boiling water bath for 20 minutes. Cooled by placing the tube in water at room temperature for one minute. Added 1 ml of arsenomolybdate colour reagent, mixed by tapping, diluted to 10 ml with distilled water and mixed by inversion. Prepared a blank adopting the same procedure as described with 0.5 ml of water. The photometer was set to zero density with the blank and measured the optical densities of standard and unknown at 540 m/u.

The formula used for tne calculation is:

$$\frac{\text{Density of unknown}}{\text{Density of standard}} \times \text{mg glucose in the standard} \times \frac{100}{0.025}$$

$$= \text{mg glucose/100 ml blood.}$$

Estimation of cholesterol in serum (Hawk et al. 1954)

Principle

Serum is treated with alcoholic potassium hydroxide which

liberates the cholesterol from lipoprotein complexes and caused hydrolysis of the cholesterol esters yielding all cholesterol in the less combined state. The free cholesterol is extracted into petroleum ether and measured in this solvent by means of the Liebermann-Burchard reaction.

Reagents

1. Potassium hydroxide solution (33%):

   Dissolved 10 g reagent grade KOH in 20 ml of water.

2. Alcoholic potassium hydroxide solution:

   Prepared just before using. Added 6 ml 33 per cent potassium hydroxide solution to 94 ml absolute alcohol.

3. Standard cholesterol solution:

   Dissolved 100 mg dried cholesterol (recrystallised 4 times from absolute alcohol) in sufficient absolute alcohol to make 250 ml. This solution contained 0.4 mg cholesterol in 1 ml.

4. Modified Liebermann-Burchard Reagent:

   Added 1 volume of concentrated sulphuric acid to 20 volumes of chilled acetic anhydride (below 10°C) in a glass stoppered container. Shook well and kept cold for nine minutes. Then added 10 volumes

of glacial acetic acid and warmed the mixture to room temperature. Used within one hour of preparation.

Procedure

Extraction: To 0.5 ml of serum (or plasma) in a 25 ml glass stoppered centrifuge tube, added 5 ml of alcoholic potassium hydroxide solution, stoppered, shook well and incubated in a water bath at 37°C for 55 minutes. Cooled at room temperature. Added 10 ml of petroleum ether and mixed well. Added 5 ml of water and shook vigorously for one minute. Centrifuged at slow speed for five minutes or until the emulsion broke and two clear layers formed. A 4 ml aliquot of the petroleum ether was transferred to a dry vessel and placed in a 60°C water bath. The solvent was evaporated by blowing a gentle stream of air over the solution.

Standard preparation: A 5 ml sample of the standard cholesterol solution was mixed with 0.3 ml of 33 per cent potassium hydroxide solution in a 25 ml glass stoppered centrifuge tube and treated in exactly the same manner as the serum described above. After centrifugation 1, 2 and 3 ml aliquot, in duplicate, of the petroleum ether layer were measured into six dry vessels and evaporated to dryness as described above. These standards contained the equivalents of 200, 400 and 600 mg cholesterol per 100 ml.

Colour development: Arranged the vessels containing the dried samples so that an empty vessel (for the blank) was first, then three standards followed by the unknown and finally the second set of standards. Placed all vessels in a 25°C water bath and added 6 ml of modified Liebermann-Burchard reagent to each vessel at regular time intervals. The bottled were stoppered, shaken and kept in the water bath. Thirty minutes after the addition of the reagent and at regular intervals thereafter, the optical densities of tne samples were determined at 620 $m/^{u}$ setting the instrument to read zero density with the blank.

Calculation

$$\frac{\text{Density of standard}}{\text{Equivalent concentration of standard}} = \text{K cholesterol.}$$

These K values should agree within 4 per cent. The average of all the K values is used for calculating the cholesterol content of the unknown.

$$\frac{\text{Density of unknown}}{\text{Average K cholesterol}} \times 500 = \text{mg total cholesterol per 100 ml serum.}$$

Estimation of chloride in serum (Hawk et al. 1954)

Principle

The sample is titrated with standard mercuric citrate solution at the proper acidity in the presence of diphenyl

carbazone as indicator. Chloride present reacts with the added mercuric ions to form soluble but less dissociated mercuric chloride. When an excess of mercuric ion has been added, the indicator turns purple. The end position is sharp and relatively stable.

Reagents

1. Diphenyl carbazone solution:

   Dissolved 100 mg of S. diphenyl carbazone in 95 per cent alcohol and diluted to 100 ml. Stored in a dark bottle in the cold. Equiped the bottle with a rubber-bulb medicine dropper whose top was adjusted so as to deliver 65 to 70 drops of solution per ml. Prepared fresh solution each month.

2. Standard sodium chloride solution:

   Dried some reagent grade sodium chloride in an oven at 110° to 120°C over night, cooled and weighed out 584.5 mg. Dissolved in a little water and transferred with rinsings to a 1-litre volumetric flask. Diluted to the mark with water and rinsed. This solution, stable indefinitely and contained 10 milli-equivalents of chloride per litre or 58.45 mg of sodium chloride per 100 ml, was used to standardise each new lot of standard mercuric nitrate solution.

3. Standard mercuric nitrate solution:

   Placed a few hundred ml of water in a 1-litre

volumetric flask and added 20 ml of 2 N nitric acid. Added 3 g of reagent grade mercuric nitrate, dissolved by shaking, diluted to volume with water mixed and standardised as follows: Transferred 2 ml of standard sodium chloride solution to a small flask. Added 4 drops of diphenyl carbozone solution and titrated with the mercuric nitrate solution from a microburette. Tne amount of mercuric nitrate solution required equaled the value A used in the calculations above. If the strength of mercuric nitrate solution was adjusted so that A equaled 2.00, either by adding more mercuric nitrate or by dilution with water containing 2 ml of 2 N nitric acid per litre as the case may be. This standard mercuric nitrate solution is stable indefinitely and need not be protected from light so that large amounts may be prepared at one time.

Procedure

Transferred 2 ml of Folin Wufiltrate of serum (equivalent to 0.2 ml of original sample) to a small flask and added 0.06 ml (4 drops) of diphenyl carbazone indicator solution. Titrated against the standard mercuric nitrate solution using a micro-burette capable of being read to 0.01 ml and delivering small drops. At tne end point tne colour of the solution changed from light yellow to deep purple.

The serum mignt be titrated directly without previous

deproteinization. This procedure eliminated errors in the preparation of the filtrate. Transferred 0.2 ml of sample to a small flask, added 1.8 ml of water, 0.06 ml of indicator and titrated as above. The colour of the solution underwent several changes during the titration, becomming light yellow just before the end point was reached and changing to pale violet at the end point. Results by the direct titration were slightly higher than when the filtrate was used possibly because of slight loss of chloride during deproteinization.

Calculation

Results for either the protein free or direct titration were calculated as follows:

Ml mercuric nitrate solution x $\frac{100}{A}$ = mg chloride per litre, where A equals the number of mercuric nitrate solution required for 2 ml of standard sodium chloride solution. If A equals 2.00, the calculation simplified to:

Ml mercuric nitrate solution used x 50 mg of chloride per litre.

Assay of Vitamin B_{12} in blood plasma (Kavanagh, 1963)

Procedure

Glasswares

All glasswares were washed and scrupulously cleaned for

the removal of traces of organic matter because of the sensitivity of the B_{12} assay. It was also essential to free the glassware of traces of cleaning preparations, because they frequently inhibited the growth of the test organisms. All glasswares were soaked in a good quality detergent, washed in hot water and then rinsed with distilled water. Special care was taken to handle glasswares so that no dirt particle adhered.

Freshly prepared all glass distilled water was used throughout the assay.

Stock solution of Vitamin B_{12}

Stock solution (100.0/ug/ml) of Vitamin B_{12} (Glaxo Laboratories) was stored in the refrigerated temperature (0°-5°C). This solution was stable for about one month.

Assay medium preparation

Assay procedures were followed in the sequence given below: Assay medium was prepared in double strength.

1. Basal medium (double strength) pH:6.8 (adjusted with 1N NaOH).

Consisted of:

K_2HPO_4	..	9 g
KH_2PO_4	..	3 g

Na Citrate	..	0.5 g
$MgSO_4 5H_2O$	..	0.1 g
$(NH_4)_2SO_4$	..	1.0 g
Glucose	..	10 g
L. Asparagine	..	4 g
L. Arginine	..	0.1 g
L. Glutamic acid	..	0.1 g
Glycine	..	0.1 g
L. Histidine	..	0.1 g
L. Proline	..	0.1 g
D.L. Tryptophane	..	0.1 g
Sodium thioglycolate	..	0.1 g
Glass-distilled water	..	500 ml

2. Preparation of Vitamin B_{12} dilute solutions from the stock solution.

The concentrations used in the B_{12} assay were the following:

1 /^{u}/^{u}g/ml; 3 /^{u}/^{u}g/ml; 6 /^{u}/^{u}g/ml; 10 /^{u}/^{u}g/ml; 30 /^{u}/^{u}g/ml; 60 /^{u}/^{u}g/ml; 100 /^{u}/^{u}g/ml and 300 /^{u}/^{u}g/ml.

Duplicate estimations were made and the above concentrations were used for the standard curve.

3. Preparation of samples

Blood samples were refrigerated initially and centrifuged

to obtain plasma. Plasma samples were subjected to mild digestion with 3N Hcl for 18 hours at 55°C.

Samples were serially diluted and arranged with standard Vitamin B_{12} so that one level would fall within the linear range of the standard curve.

Assay culture

E. Coli (Mutant strain 113-3 : DAVIS).

RESULTS

RESULTS

Data obtained on the body weights of elephants determined in a weigh-bridge are presented in Table 1 along with their body measurements such as shoulder height, chest girth, body length ffom point of shoulder to point of buttock (P.S. to P.B.), neck girth and body length from point of shoulder to point of ilium (P.S. to P.I.). Correlations calculated between pairs of shoulder height, chest girth, body length (P.S. to P.B.), neck girth, body length (P.S. to P.I.) and body weight are given in Table 2. The first order partial correlations between body weight and a particular parameter keeping the other measurements constant in succession are shown in Table 3. The relations formulated for predicting body weight with the three parameters viz., chest girth, neck girth and body length (P.S. to P.B.) are detailed in Table 4. The determined and the expected body weights of elephants as per the various formulae (Table 4) are presented in Table 5. In Table 5 are included tne expected body weights as per the formulae followed by the Forest Departments of Tamil Nadu and Kerala and those reported from Ceylon. The prediction relations and the coefficients of variation of expected body weights are set out in Table 6. The deviations of tne expected body weight from the determined body weight in respect of each formula are indicated in Table 7 and diagrammatically represented in Fig. 1.

Data on body weight, age, metabolic body size and body

surface area of the adult and young experimental subjects are presented in Table 8. In Table 9 are given the average daily feed consumptions of the adult and young elephants during the feeding trials I and II. The average daily dry matter consumptions of the experimental subjects during trial I and trial II are given in Tables 10 and 11 respectively.

On chemical analysis, the palm leaf fed to the elephants contained on dry matter basis: Dry matter, 39.1%; Crude protein, 7.7%; Crude fibre, 31.0%; Nitrogen-free-extract, 48.3%; Ether extract, 3.4%; Total ash, 9.6%; Acid insoluble ash, 5.83%; Calcium, 0.4405%; Phosphorus, 0.155% and 0.3341 ppm cobalt.

In Tables 12 and 13 are shown the average weights of the dung and dung dry matter voided by the elephants in the two groups during trials I and II respectively. Tables 14 and 15 present respectively data on the weights of dung boluses as per order of appearance in defecations and frequency of defecation and defecation weights observed during trial I and Tables 16 and 17 the same recorded during trial II. The frequency and the volume of urine discharged by the elephants micturition-wise during trials I and II are detailed in Tables 18 and 19 respectively. Data on the urinary output of total solids observed during trials I and II are shown in Tables 20 and 21 respectively.

In Tables 22 and 23 are presented the chemical composition

of dung voided by the elephants during trials I and II respectively.

The digestion coefficients of dry matter, crude protein, ether extract, crude fibre and nitrogen-free-extract in palm leaf obtained during the trials I and II are given respectively in that order in Tables 24 and 29, 25 and 30, 26 and 31, 27 and 32 and 28 and 33. Table 34 presents the summarised data. Results obtained during trials I and II on the nutritive value of palm leaf in terms of digestible crude protein (DCP) and total digestible nutrients (TDN) are set out in Tables 35 and 36 respectively.

The DCP and TDN intakes of the adult and growing animals during trials I and II are presented in Table 37.

Data on total solids, nitrogen, calcium and phosphorus excreted in urine by the animals in trials I and II are detailed in Table 38.

The nitrogen balance data gathered during trials I and II are presented in Tables 39 and 40 respectively. In Tables 41 and 42 are shown data on calcium balance obtained in trials I and II respectively and in Tables 43 and 44 the same on phosphorus balance.

The gross energy (GE) value of palm leaf fed and the same of dung and urine voided during trials I and II are presented in

Table 45. Data on the digestible energy intakes of the adult and young animals during trials I and II are detailed in Tables 46 and 47 respectively. Values for digestible energy determined and the same for TDN as determined and as calculated for the two groups of animals in trials I and II are set out in Table 48. Data on digestible energy (DE) and TDN as determined and as calculated are shown in Table 49. Derived metabolisable energy (ME) values are detailed in Table 50. In Table 51 are given the values for gross energy and digested energy/unit weight/surface area and/ metabolic size. Values for metabolisable energy expressed as percentage of gross energy and digested energy are set out in Table 52. Requirements of DCP, TDN, DE and ME for maintenance and growth are detailed in Tables 53 and 54 respectively.

Haematological values obtained for the adult and young elephants under experimentation are presented in Table 55.

TABLES

Table 1. Body measurements and body weights* of elephants.

No.	Source	Name of the elephant	Sex	Age in years	Shoulder ht. in cms	Chest girth in cm	Body length (P.S. to P.B.) in cm	Neck girth in cm	Body length (P.S. to P.I.) in cm	Body weight in kg
.	Thiruvambadi	Kesavan	Male	30	290.5	401.5	200.0	250.0	171.5	3760
.	Devaswom "	Rajasekharan	"	30	270.5	395.5	200.0	251.5	150.0	3735
.	"	Vishnu	"	25	274.5	405.5	210.5	260.5	165.5	3920
.	"	Unnikrishnan	"	10	203.0	293.0	170.0	188.0	138.0	1720
.	"	Govindankutty	"	35	285.0	420.0	220.0	271.0	180.0	4945
.	M. Bhaskara	Chandrasekharan	"	45	298.0	420.0	210.0	292.0	185.0	4850
.	Menon (BMT)	Motiprasad	"	15	240.0	350.0	180.0	240.0	145.0	2900
.	"	Sundarprasad	"	15	243.0	338.0	185.0	220.0	145.0	2790
.	Bharat Circus	Paru	Female	40	225.0	345.0	210.0	210.0	150.0	2650
.	"	Begum	"	26	220.0	300.0	190.0	170.0	140.0	1950
.	"	Radha	"	20	211.0	290.0	185.0	165.0	130.0	1440
.	"	Chanchal	"	20	190.0	270.0	165.0	158.0	117.0	1535
.	"	Sundari	"	19	198.0	273.0	170.0	170.0	116.0	1500
.	"	Lakshmanan	Male	27	216.0	320.0	190.5	190.0	145.0	2030
.	"	Ganesh	"	30	270.0	387.0	205.0	240.0	135.0	3460
.	Paramekkavu Devaswom	Rajendran	"	28	277.0	385.0	205.0	255.0	170.0	3990
.	Kuttangulangara Devaswom	Gopalakrishnan	"	35	275.0	418.0	180.0	270.0	140.0	4630
.	Kizhakeveetil	Balakrisnnan	"	7	204.0	283.0	165.0	170.0	132.0	1665
.	House, Trichur	Gopi	"	40	287.0	412.0	255.0	285.0	195.0	4890
.	"	Damodaran	"	50	291.0	415.0	245.0	290.0	190.0	5135

*As determined in a weigh-bridge.

Table 2. Body measurements and body weights of elephants: Correlations.

Measurements	Shoulder height	Chest girth	Body length P.S.+ to P.B.++	Neck girth	Body length P.S. to P.I.@	Body weight
Shoulder height		0.98**	0.75**	0.96**	0.84**	0.96**
Chest girth			0.75**	0.97**	0.81**	0.97**
Body length P.S. to P.B.				0.75**	0.88**	0.78**
Neck girth					0.85**	0.98**
Body length P.S. to P.I.						0.86**

\+ P.S. = Point of shoulder.
++ P.B. = Point of buttocks.
@ P.I. = Point of ilium.

** Critical value of r = ± 0.44 at 5% level and ± 0.56 at 1% level.

Table 3. Body measurements and body weights: Partial correlations.

Partial correlation of body weight on	after eliminating				
	Shoulder height	Chest girth	Body length P.S. to P.B.	Neck girth	Body length P.S. to P.I.
Shoulder height		0.19	0.91**	0.34	0.86**
Chest girth	0.52*		0.93**	0.40	0.91**
Body length P.S. to P.B.	0.32	0.33		0.34	0.10
Neck girth	0.74**	0.66**	0.95**		0.93**
Body length P.S. to P.I.	0.35	0.52*	0.54*	0.26	

* Critical value of partial correlation coefficient = ± 0.46 at 5% level.

** " " = ± 0.58 at 1% level.

Table 4. Body measurements and body weignts: Formulae.

Regression of body weight on	Formulae*	Precision
1. Chest girth (cm)	Expected body weight (W) in kg = 23 girth (g) — 4984	95%
2. Body length (P.S. to P.B.) and chest girth in cm	Expected body weight (W) in kg = 6.9 lengh (l) + 20.7 girth (g) — 5556	95%
3. Chest girth and neck girth (cm)	Expected body weight (W) in kg = 8.2 girth (g) + 18.4 neck girth (ng)—3927	97%
4. Chest girth + neck girth (cm)	Expected body weight (W) in kg = 12.8 (g+ng)—4281	97%
5. l (body length P.S. to P.B.) g (chest girth) in cm	Expected body weight (W) in kg = 10^{-4} x 2.4313 $l^{1.2}$ $g^{2.6}$	97%
6. l (body length P.S. to P.B.) g (chest girtn) in cm	Expected body weight (W) in kg = 10^{-5} x 12.0539 lg^2	97%

* Formulae establisned by method of least squares.

Table 5. Determined and expected body weights as per formulae.

imal No.	Body weight in kg (Determined)	Formulae 1	2	3	4	5	6	7@	8*	9*
		W=23g-4984	W=6.91+20.7g-5556	W=8.2g+18.4ng-3927	W=12.8(g+ng)-4281	$W=10^{-4}\frac{2.43131^{\cdot 2}}{g^{2.6}}$	$W=10^{-5}\frac{12.0539}{lg^2}$ x	W=1.25 $\frac{LG^2}{300}$**	Cube root of W=(ht+22.39)/18.9	Cube root of W=(g+60.6)/28.9
1	3760	4251	4135	3965	4058	4127	3884	3718	4542	4090
2	3735	4113	4013	3944	4001	3968	3770	3608	3723	3929
3	3920	4343	4290	4191	4244	4280	4172	3992	3878	4196
4	1720	1755	1682	1935	1876	1763	1760	1683	1697	1834
5	4945	4676	4656	4503	4564	4729	4677	4475	4298	4599
6	4850	4676	4587	4890	4833	4687	4463	4272	4871	4599
7	2900	3066	2931	3359	3271	2829	2659	2543	2676	2869
8	2790	2790	2717	2893	2861	2597	2548	2437	2767	2623
9	2650	2951	3034	2766	2823	2810	3012	2883	2241	2761
0	1950	1916	1965	1661	1735	1914	2062	1972	2107	1944
1	1440	1686	1724	1487	1543	1745	1875	1794	1882	1784
2	1535	1226	1172	1194	1197	1417	1451	1387	1419	1497
3	1500	1295	1268	1440	1389	1466	1528	1461	1586	1537
4	2030	2376	2382	2193	2247	2264	2345	2243	2004	2284
5	3460	3917	3869	3662	3745	3770	3701	3541	3702	3715
6	3990	3871	3828	3922	3911	3723	3664	3504	3976	3667
7	4630	4630	4339	4469	4525	4489	3792	3628	3891	4542
8	1665	1525	1441	1522	1517	1601	1593	1524	1720	1682
9	4890	4492	4732	4695	4641	4634	5217	4992	4385	4370
0	5135	4561	4725	4812	4743	4684	5086	4867	4558	4459

) Formula followed in Tamil Nadu and Kerala; * Formulae reported by Kurt and Netta Singh (1968); L&G in inches, W in lbs converted to kg.

Table 6. Prediction relations and coefficient of variation of the expected body weights.

Formula No.	Prediction relation	Coefficient of variation	Percentage variation explained
1	$W = 23g - 4984$	39.10	95
2	$W = 6.91 + 20.7g - 5556$	39.55	95
3	$W = 8.2g + 18.4ng - 3927$	39.84	97
4	$W = 12.8\ (g + ng) - 4281$	39.67	97
5	$W = 10^{-4} \times 2.43131^{\cdot 2} g^{2.6}$	38.44	97
6	$W = 10^{-5} \times 12.05391 g^{2}$	38.06	95
7	$W = \frac{1.25\ LG^2}{300}$	38.07	94
8	Cube root of body weight $(W) = \frac{\text{height} + 22.39}{18.9}$	37.43	93
9	Cube root of body weight $(W) = \frac{\text{girth} + 60.6}{28.9}$	36.42	96

Coefficient of variation of original body weight = 40.47

Table 7. Deviation from determined body weight.

Formulae								
1	2	3	4	5	6	7	8	9
$W=23g-4984$	$W=6.91+20.7g-5556$	$W=8.2g+18.4ng-3927$	$W=12.8(g+ng)-4281$	$W=10^{-4}x\ 2,43131\cdot^{2}\ g^{2.6}$	$W=10^{-5}x\ 12.0539\ lg^{2}$	$W=\frac{1.25LG^{2}}{300}$*	Cube root of body wt= $\frac{ht+22.39}{18.9}$	Cube root of body wt= $\frac{g+60.6}{28.9}$
+ 2840	+ 2493	+ 2030	+ 2164	+ 960	+ 2271	+ 1077	+ 1785	+ 1932
- 2222	- 2503	- 2022	- 2035	- 2010	- 2507	- 4048	- 3357	- 2446

* L&G in incnes; W in lbs (converted to kg)

Table 8. Body weight, metabolic body size and body surface area of the experimental animals.

Name of animal	Sex	Age in years	Body weight in kg	Metabolic body size $W^{.73}$*	Body surface area in sq.m
Narayanan	Male	40	4178	439.7	25.92
Ravindran	"	38	3032	348.0	20.93
Sathyanarayanan	"	9	1194	176.3	11.25
Kesavankutty	"	10	1480	206.2	12.98

* Brody, 1945.

Table 9. Average daily feed consumption.

Name of the animal	Trial I (*ad lib.* feeding)				Trial II Restricted feeding (75% of *ad lib.* intake)			
	Palm leaf given in kg	Refuse in kg	Consumed in kg	% Refuse	Palm leaf given in kg	Refuse in kg	Consumed in kg	% Refuse
Narayanan	210.0	42.0	168.0	20.0	140	13.5	126.5	9.64
Ravindran	172.0	52.0	120.0	30.2	100	8.5	91.5	8.50
Average	191.0	47.0	144.0	25.1	120	11.0	109.0	9.07
SE	± 19.0	± 5.0	± 24.0	± 5.1	± 20	± 2.5	± 17.5	± 0.57
Sathyanarayanan	92.5	27.3	65.2	29.5	60	7.6	52.4	12.70
Kesavankutty	103.7	30.2	73.5	29.1	60	5.0	55.0	8.30
Average	98.1	28.8	69.4	29.3	60	6.3	53.7	10.50
SE	± 5.6	±1.45	± 4.15	±0.2	± 0	±1.3	± 1.3	± 2.20

Table 10. Average dry matter consumption: Trial I (ad lib. feeding)

Name of the animal	Intake of palm leaf in kg/day	Dry matter % in palm leaf	Dry matter consumed in kg/day	Dry matter consumption in kg/100 kg body weight	Dry matter consumption for metabolic body size in kg
Narayanan	168.0	39.1	65.69	1.57	0.149
Ravindran	120.0	39.1	46.92	1.55	0.135
Average	144.0	39.1	56.31	1.56	0.142
SE	±24.0	±0.0	±9.39	±0.01	± 0.007
Sathyanarayan	65.2	39.1	25.49	2.13	0.145
Kesavankutty	73.5	39.1	28.74	1.94	0.139
Average	69.4	39.1	27.12	2.04	0.142
SE	± 4.15	±0.0	±1.63	±0.10	± 0.003

Table 11. Average dry matter consumption: Trial II (Restricted feeding)

Name of the animal	Intake of palm leaf in kg/day	% Dry matter in palm leaf	Dry matter consumed in kg/day	Dry matter consumption in kg/100 kg body weight	Dry matter consumption for metabolic body size in kg
Narayanan	126.5	39.1	49.46	1.18	0.113
Ravindran	91.5	39.1	35.78	1.18	0.103
Average	109.0	39.1	42.62	1.18	0.108
SE	± 17.5	±0.0	± 6.84	± 0.00	± 0.005
Sathyanarayan	52.4	39.1	20.49	1.72	0.116
Kesavankutty	55.0	39.1	21.51	1.45	0.104
Average	53.7	39.1	21.00	1.59	0.110
SE	± 1.3	±0.0	± 0.00	± 0.14	± 0.006

Table 12. Average dry matter of dung voided: Trial I.

Name of the animal	Dung voided in kg/day	Dry matter % of dung	Dry matter voided in kg/day	Dry matter voided in kg/100 kg body weight	Dry matter voided/metabolic body size in kg
Narayanan	147.7	24.1	35.60	0.85	0.08
Ravindran	108.7	19.0	20.65	0.68	0.06
Average	128.2	21.6	28.13	0.77	0.07
SE	± 19.5	± 2.5	± 7.48	± 0.09	± 0.01
Sathyanarayanan	65.1	22.5	14.65	1.23	0.08
Kesavankutty	67.7	22.0	14.89	1.00	0.07
Average	66.4	22.3	14.77	1.12	0.08
SE	± 1.3	± 0.25	± 0.12	± 0.12	± 0.01

Table 13. Average dry matter of dung voided: Trial II.

Name of the animal	Dung voided in kg/day	Dry matter % of dung	Dry matter voided in kg/day	Dry matter voided in kg/100 kg body weight	Dry matter voided/metabolic body size in kg
Narayanan	111.5	21.5	23.97	0.57	0.055
Ravindran	77.8	21.5	16.73	0.55	0.048
Average	94.7	21.5	20.35	0.56	0.052
SE	± 16.85	± 0.0	± 3.62	± 0.01	± 0.004
Sathyanarayanan	59.3	23.0	13.64	1.14	0.077
Kesavankutty	56.0	22.7	12.71	0.86	0.062
Average	57.7	22.9	13.18	1.00	0.070
SE	± 1.65	± 0.16	± 0.47	± 0.14	± 0.008

Table 14. Data on weight of dung boluses: Trial I.

Name of the animal	Defecation No.	Order of appearance of boluses in defecations (weight in kg)													Total weight in kg	No. of boluses	Av.wt of bolus in kg
		1	2	3	4	5	6	7	8	9	10	11	12	13			
Narayanan	1	1.50	1.20	1.00	1.10	1.80	2.00	1.15	3.50						13.25	8	1.66
	2	1.80	3.60	2.50	1.60										9.50	4	2.38
	3	2.60	2.00	2.30	1.80	1.90	2.10								12.70	6	2.12
	4	2.00	3.40	2.40	1.90										9.70	4	2.43
	5	2.00	2.50	3.20											7.70	3	2.57
	6	1.70	2.00	1.50	1.10	1.20	1.20	1.00							9.70	7	1.39
	Total	11.60	14.70	12.90	7.50	4.90	5.30	2.15	3.50						62.55	32	12.55
	Av.	1.93	2.45	2.15	1.50	1.63	1.77	1.08	3.50						10.43	5.33	2.09

(contd.....)

Table 14 (Contd.....)

ne of ani-	Defe-cation No.	Order of appearance of boluses in defecations (weight in kg)													Total wt. in kg	No.of boluses	Average weight of boluses in kg
		1	2	3	4	5	6	7	8	9	10	11	12	13			
	1	1.80	2.75	1.70	0.80	1.80	1.00	1.80	1.50	0.80	1.10	1.65	1.05	1.75	19.50	13	1.50
	2	1.70	2.00	2.00	1.00	1.05									7.75	5	1.55
in-	3	1.50	2.05	2.00	1.70	1.50									8.75	5	1.75
n	4	1.55	2.00	2.10	1.60	1.00									8.25	5	1.65
	5	1.90	2.10	1.25											5.25	3	1.75
	6	2.00	2.80	1.50	1.45										7.75	4	1.94
	Total	10.45	13.70	10.55	6.55	5.35	1.00	1.80	1.50	0.80	1.10	1.65	1.05	1.75	57.25	35	10.14
	Av.	1.74	2.28	1.76	1.31	1.34	1.00	1.80	1.50	0.80	1.10	1.65	1.05	1.75	9.54	5.83	1.69
	1	0.90	0.40	0.50	1.40	0.40	0.80								4.40	6	0.73
	2	0.35	1.10	0.80	0.60	0.60									3.45	5	0.69
hya-	3	0.80	0.50	0.40	1.00	1.10	0.20								4.00	6	0.67
ayanan	4	1.00	0.80	0.45											2.25	3	0.75
	5	0.90	1.00	0.80	0.40	0.60	0.90	0.75							5.35	7	0.76
	Total	3.95	3.80	2.95	3.40	2.70	1.90	0.75							19.45	27	3.60
	Av.	0.79	0.76	0.59	0.85	0.68	0.63	0.75							3.89	5.40	0.72
	1	1.15	0.40	0.75	1.30										3.60	4	0.90
	2	0.85	0.60	0.65	0.55	0.65	0.70								4.00	6	0.67
avan-	3	1.10	0.80	0.70	1.00	0.80	1.00	0.70							6.10	7	0.87
ty	4	0.70	1.10	0.30											2.10	3	0.70
	Total	3.80	2.90	2.40	2.85	1.45	1.70	0.70							15.80	20	3.14
	Av.	0.95	0.73	0.60	0.95	0.73	0.85	0.70							3.95	5	0.79

(Table 14 Concld.)

Table 15. Frequency and weights of defecations recorded: Trial I.

Name of the animal	Day	Weight of the bolus in kg		Average weight of bolus in kg	Average weight per defecation in kg recorded for the day	No. of defecations per day			Total wt. of dung per day in kg*	Average weight of dung in kg per day
		Maximum observed	Minimum observed			Day	Night	Total		
Narayanan	First	3.50	1.00	2.049	11.817	3	10	13	137.35	
	Second	3.40	1.90	2.486	8.700	4	10	14	160.30	147.7
	Third	2.00	1.00	1.386	9.700	5	10	15	145.50	
Ravindran	First	2.75	0.80	1.539	13.850	3	7	10	87.20	
	Second	2.10	1.00	1.712	7.417	4	12	16	134.60	108.7
	Third	2.80	1.45	1.938	7.750	3	9	12	104.40	
Sathyanarayanan	First	1.40	0.20	0.697	3.950	3	9	12	51.80	
	Second	1.00	0.45	0.750	2.250	4	10	14	68.20	65.1
	Third	1.00	0.40	0.764	5.350	4	10	14	75.35	
Kesavankutty	First	1.15	0.40	0.760	3.800	3	10	13	54.50	
	Second	1.10	0.70	0.871	6.100	3	9	12	78.85	67.7
	Third	1.10	0.30	0.700	2.100	6	10	16	69.65	

* Total weight of all defecations.

Table 16. Data on weight of dung boluses: Trial II

Name of the animal	Defecation No.	Order of appearance of boluses in defecations (weight in kg)									Total weight in kg	No.of boluses	Average weight of bolus in kg
		1	2	3	4	5	6	7	8	9			
Narayanan	1	2.80	1.80	1.25	0.90	2.70					9.45	5	1.89
	2	1.85	1.20	2.15	2.15	3.55					10.90	5	2.18
	3	1.75	1.55	3.75	0.70	2.50					10.25	5	2.05
	4	2.15	3.05	4.80							10.00	3	3.33
	Total	8.55	7.60	11.95	3.75	8.75					40.60	18	9.45
	Average	2.14	1.90	2.99	1.25	2.92					10.15	4.50	2.36
Ravindran	1	0.45	2.80	0.50	0.50	1.35					5.60	5	1.12
	2	1.55	0.90	1.15	1.65						5.25	4	1.31
	3	2.15	2.05	2.50	1.10						7.80	4	1.95
	4	1.80	1.00	3.55	1.25						7.60	4	1.90
	Total	5.95	6.75	7.70	4.50	1.35					26.25	17	6.28
	Average	1.49	1.69	1.93	1.13	1.35					6.56	4.25	1.57
Sathyanarayanan	1	1.50	0.75	0.60	1.00						3.85	4	0.96
	2	1.35	1.00	0.85	0.75	0.80	0.95				5.70	6	0.95
	3	1.00	0.70	1.00							2.70	3	0.90
	4	0.55	0.55	0.85	0.85						2.80	4	0.70
	5	1.30	0.70	0.65	1.15						3.80	4	0.95
	6	0.65	0.95	1.20	1.30						4.10	4	1.03
	Total	6.35	4.65	5.15	5.05	0.80	0.95				22.95	25	5.49
	Average	1.06	0.78	0.86	1.01	0.80	0.95				3.83	4.17	0.92

(Contd.....)

Table 16 (Contd..)

Name of the animal	Defecation No.	Order of appearance of boluses in defecations (weight in kg) 1	2	3	4	5	6	7	8	9	Total weight in kg	No.of boluses	Av. wt. of bolus in kg
Kesavankutty	1	0.55	0.90	0.65	0.40	0.55	0.95				4.00	6	0.67
	2	1.90	1.25	1.00							4.15	3	1.38
	3	0.65	1.65	0.95	0.48	0.30	0.35	1.15	0.58	0.75	6.86	9	0.76
	4	1.00	1.65								2.65	2	1.33
	5	0.40	0.75	1.00	1.50						3.65	4	0.91
	Total	4.50	6.20	3.60	2.38	0.85	1.30	1.15	0.58	0.75	21.31	24	5.05
	Average	0.90	1.24	0.90	0.79	0.43	0.65	1.15	0.58	0.75	4.26	4.80	1.01

(Table 16 Concld.)

Table 17. Frequency and weights of defecations recorded: Trial II.

Name of the animal	Day	Weight of the bolus in kg		Average weight of bolus in kg	Average weight per defecation in kg recorded for the day	No. of defecations per day			Total weight of dung per day in kg*	Average weight of dung in kg per day
		Max. observed	Min. observed			Day	Night	Total		
Narayanan	First	4.80	0.70	2.256	10.150	4	10	14	116.60	111.5
	Second	-	-	-	-	5	7	12	89.45	
	Third	-	-	-	-	4	7	11	128.50	
Ravindran	First	3.55	0.45	1.544	6.563	5	5	10	69.60	77.8
	Second	-	-	-	-	6	7	13	80.35	
	Third	-	-	-	-	4	10	14	83.35	
Sathyanarayanan	First	1.50	0.55	0.918	3.825	7	7	14	60.60	59.3
	Second	-	-	-	-	6	7	13	55.45	
	Third	-	-	-	-	6	9	15	61.95	
Kesavankutty	First	1.90	0.30	0.888	4.260	5	7	12	51.10	56.0
	Second	-	-	-	-	4	7	11	50.35	
	Third	-	-	-	-	5	8	13	66.45	

* Total weight of all defecations.

Table 18. Frequency and volume of urine discharged micturition-wise: Trial I.

Name of the animal	Day	Volume of urine discharged per micturition in litres										Total volume of urine discharged/ day in litres
		1	2	3	4	5	6	7	8	9	10	
(1)	(2)	(3)										(4)
Narayanan	First	10.000	4.600	8.000	5.000	13.400	1.100					42.100
	Second	8.000	5.800	2.600	6.000	9.600	5.000	8.400	5.600			51.000
	Third	10.300	9.000	6.000	11.400	12.400	4.800	10.800				64.700
	Average	9.433	6.467	5.533	7.467	11.800	3.633	9.600	5.600			52.600
Ravindran	First	4.335	0.750	2.800	2.000	3.600	3.400	1.500				18.385
	Second	2.800	3.200	4.080	2.400	1.635	3.000	2.600	6.600	10.800	2.600	39.715
	Third	6.100	5.400	5.400	5.000	4.000	5.400	2.000	3.400			36.700
	Average	4.412	3.117	4.093	3.133	3.078	3.933	2.033	5.000	10.800	2.600	31.600
Sathyanarayanan	First	3.150	3.600	1.200	3.600	5.000	3.200					19.750
	Second	2.650	3.200	3.400	2.000	2.200	2.900	3.400	2.600	3.000	2.000	27.350
	Third	1.600	4.100	1.300	3.400	4.000	2.400	5.000	6.000	4.000		31.800
	Average	2.467	3.633	1.967	3.000	3.733	2.833	4.200	4.300	3.500	2.000	26.300
Kesavankutty	First	1.890	2.600	2.000	1.800	3.200						11.490
	Second	4.600	4.800	2.600	6.800	6.000	5.000	7.800				37.600
	Third	3.900	1.850	1.060	3.200	7.000	5.000	3.000				25.010
	Average	3.463	3.083	1.887	3.933	5.400	5.000	5.400				24.700

(Contd....)

(Table 18 - Contd....)

Volume of urine discharged per micturition in litres		Average volume per micturition in litres	No. of micturitions per day		Total no. of micturitions
			Day	Night	
Max.	Min.				
(5)		(6)	(7)		(8)
13.400	1.100	7.017	3	3	6
9.600	2.600	6.375	2	6	8
12.400	4.800	9.243	3	4	7
11.800	2.833	7.545	2.67	4.33	7.00
4.335	0.750	2.626	2	5	7
10.800	1.635	3.972	6	4	10
6.100	2.000	4.587	3	5	8
7.078	1.462	3.728	3.67	4.67	8.33
5.000	1.200	3.292	3	3	6
3.400	2.000	2.735	5	5	10
6.000	1.300	3.533	3	6	9
4.800	1.500	3.187	3.67	4.67	8.33
3.200	1.800	2.298	1	4	5
7.800	2.600	5.371	3	4	7
7.000	1.060	3.573	4	3	7
6.000	1.820	3.747	2.67	3.67	6.33

(Table 18 Concld.)

Table 19. Frequency and volume of urine discharged micturition-wise: Trial II.

Name of the animal	Day	Volume of urine discharged per micturition in litres										Total vol. of urine discharged/ day in litres
		1	2	3	4	5	6	7	8	9	10	
(1)	(2)	(3)										(4)
Narayanan	First	10.150	4.300	5.000	8.000	6.000	11.000					44.450
	Second	0.200	6.300	4.400	6.000	8.400	5.200	6.000				36.500
	Third	5.400	6.000	6.300	4.000	7.000	12.000	0.800	6.000			47.500
	Average	5.250	5.533	5.233	6.000	7.133	9.400	2.267	6.000			42.817
Ravindran	First	3.000	2.400	3.000	3.600	2.400	7.000	2.200	5.000	3.000	1.800	33.400
	Second	5.000	4.800	1.400	4.000	4.000	3.000					22.200
	Third	3.500	4.100	6.000	4.000	5.000	2.900					25.500
	Average	3.833	3.767	3.467	3.867	3.800	4.300	2.200	5.000	3.000	1.800	27.033
Sathyanarayanan	First	2.800	2.200	2.000	6.000	4.000	5.000	4.000	4.000			30.000
	Second	5.500	2.800	1.500	4.500	4.000	3.000	5.000				26.300
	Third	2.000	3.400	1.600	4.500	6.000	5.000	3.200	2.400			28.100
	Average	3.433	2.800	1.700	5.000	4.667	4.333	5.067	2.133			28.130
Kesavankutty	First	1.900	3.200	4.000	3.500	3.000	5.200	4.200	2.000			27.000
	Second	5.500	3.800	3.500	4.000	6.000	3.000	0.800				26.600
	Third	2.500	3.000	5.000	4.000	1.000						15.500
	Average	3.300	3.333	4.167	3.833	3.333	4.100	2.500	2.000			23.033

(Contd.....)

(Table 19 - Contd....)

Volume of urine discharged per micturition in litres		Average volume per micturition in litres	No. of micturitions per day		Total no. of micturitions
			Day	Night	
Max.	Min.				
(5)		(6)	(7)		(8)
11.000	4.300	7.408	2	4	6
8.400	0.200	5.214	4	3	7
12.000	0.800	5.938	4	4	8
10.467	1.767	6.187	3.33	3.67	7.00
7.000	1.800	3.340	5	5	10
5.000	1.400	3.700	3	3	6
6.000	2.900	4.250	2	4	6
6.000	2.033	3.763	3.33	4.00	7.33
6.000	2.000	3.750	2	6	8
5.500	1.500	3.757	3	4	7
6.000	1.600	3.513	3	5	8
5.833	1.700	3.673	2.67	5.00	7.67
5.200	1.900	3.375	4	4	8
6.000	0.800	3.800	3	4	7
5.000	1.000	3.100	2	3	5
5.400	1.233	3.425	3	3.67	6.67

(Table 19 Concld.)

Table 20. Urinary output of total solids: Trial I.

Name of the animal	Body weight in kg	Urine discharged in litres/day	Percentage of total solids in urine	Total solids voided in kg/day	Total solids voided as percentage of body weight	Total solids voided per metabolic body size in kg	Urine discharged/kg body weight in ml.
Narayanan	4178	52.6	7.4	3.892	0.093	0.0089	12.6
Ravindran	3032	31.6	7.6	2.402	0.079	0.0069	10.4
Average		42.1	7.5	3.147	0.086	0.0079	11.5
SE		±10.5	±0.1	±0.745	±0.007	±0.001	± 1.10
Sathyanarayana	1194	26.3	6.0	1.578	0.132	0.0090	22.0
Kesavankutty	1480	24.7	8.1	2.001	0.135	0.0097	16.7
Average		25.5	7.1	1.790	0.134	0.0094	19.4
SE		± 0.8	±1.05	±0.212	±0.002	±0.0004	± 2.65

Table 21. Urinary output of total solids: Trial II.

Name of the animal	Body weight in kg	Urine discharged in litres/day	Percentage of total solids in urine	Total solids voided in kg/day	Total solids voided as percentage of body weight	Total solids voided per metabolic body size in kg	Urine discharged/kg body weight in ml.
Narayanan	4178	42.82	7.2	3.083	0.074	0.0070	10.3
Ravindran	3032	27.03	6.9	1.865	0.062	0.0054	8.9
Average		34.93	7.1	2.474	0.068	0.0062	9.6
SE		± 7.90	±0.16	±0.609	±0.006	±0.0008	±0.7
Sathyanarayanan	1194	28.13	7.2	2.025	0.170	0.0115	23.6
Kesavankutty	1480	23.03	6.3	1.451	0.098	0.0070	15.6
Average		25.58	6.8	1.738	0.134	0.0093	19.6
SE		± 2.55	±0.45	±0.287	±0.036	±0.0022	± 4.0

Table 22. Chemical composition of dung: Trial I.
(Percentage on dry matter basis)

Constituents	Adult animals		Growing animals	
	Narayanan	Ravindran	Sathyanarayanan	Kesavankutty
Dry matter	24.1	19.0	22.5	22.0
Crude protein	2.7	5.6	5.9	5.0
Ether extract	2.8	5.0	4.3	3.5
Crude fibre	46.6	39.4	41.6	43.4
Nitrogen-free-extract	30.2	27.2	25.6	26.7
Total ash	17.7	22.8	22.6	21.4
Acid insoluble ash	14.5	15.0	18.3	17.2
Calcium	0.40	0.39	0.35	0.51
Phosphorus	0.31	0.49	0.28	0.41

Table 23. Chemical composition of dung: Trial II.
(Percentage on dry matter basis)

Constituents	Adult animals		Growing animals	
	Narayanan	Ravindran	Sathyanarayanan	Kesavankutty
Dry matter	21.5	21.5	23.0	22.7
Crude protein	3.0	6.8	6.5	4.5
Ether extract	2.1	2.7	2.6	2.5
Crude fibre	46.0	39.6	27.8	34.5
Nitrogen-free-extract	33.7	32.1	45.4	37.3
Total ash	15.2	18.8	17.7	21.2
Acid insoluble ash	11.8	17.1	16.3	16.9
Calcium	0.42	0.46	0.41	0.51
Phosphorus	0.50	0.47	0.27	0.42

Table 24. Digestion coefficients of nutrients in palm leaf: Trial I.
(On dry matter basis)

Name of the animal	Dry matter					
	Intake in kg	Outgo in kg	Digested in kg	Digestion coefficient (%)	Average D. co-efficient (%)	S.E.
Narayanan	65.69	35.60	30.09	45.8		
Ravindran	46.92	20.65	26.27	56.0	50.9	± 5.10
Sathyanarayanan	25.49	14.65	10.84	42.5		
Kesavankutty	28.74	14.89	13.85	48.2	45.4	± 2.90

Table 25. Digestion coefficients of nutrients in palm leaf: Trial I.
(On dry matter basis)

Name of the animal	Crude protein					
	Intake in kg	Outgo in kg	Digested in kg	Digestion coefficient (%)	Average D. coefficient (%)	S.E.
Narayanan	5.06	0.96	4.10	81.0	74.5	±6.55
Ravindran	3.61	1.16	2.45	67.9		
Sathyanarayanan	1.96	0.86	1.10	56.1	61.3	±5.20
Kesavankutty	2.21	0.74	1.47	66.5		

Table 26. Digestion coefficients of nutrients in palm leaf: Trial I.
(On dry matter basis)

Name of the animal	Ether extract					
	Intake in kg	Outgo in kg	Digested in kg	Digestion coefficient (%)	Average D. coefficient (%)	S.E.
Narayanan	2.23	1.00	1.23	55.2	45.4	±9.80
Ravindran	1.60	1.03	0.57	35.6		
Sathyanarayanan	0.87	0.63	0.24	27.6	37.3	±9.65
Kesavankutty	0.98	0.52	0.46	46.9		

Table 27. Digestion coefficients of nutrients in palm leaf: Trial I.
(On dry matter basis)

Name of the animal	Crude fibre					
	Intake in kg	Outgo in kg	Digested in kg	Digestion coefficient (%)	Average D. coefficient (%)	S.E.
Narayanan	20.36	16.59	3.77	18.5	31.3	±12.80
Ravindran	14.55	8.14	6.41	44.1		
Sathyanarayanan	7.90	6.09	1.81	22.9	25.2	± 2.30
Kesavankutty	8.91	6.46	2.45	27.5		

Table 28. Digestion coefficients of nutrients in palm leaf: Trial I.
(On dry matter basis)

Name of the animal	Nitrogen-free-extract					
	Intake in kg	Outgo in kg	Digested in kg	Digestion coefficient (%)	Average D. coefficient (%)	S.E.
Narayanan	31.73	10.75	21.00	66.2	70.7	±4.50
Ravindran	22.66	5.62	17.04	75.2		
Sathyanarayanan	12.31	3.75	8.56	69.5	70.4	±0.90
Kesavankutty	13.88	3.98	9.90	71.3		

Table 29. Digestion coefficients of nutrients in palm leaf: Trial II.
(On dry matter basis)

Name of the animal	Dry matter					
	Intake in kg	Outgo in kg	Digested in kg	Digestion coefficient (%)	Average D. coefficient (%)	S.E.
Narayanan	49.46	23.97	25.49	51.5	52.4	± 0.85
Ravindran	35.78	16.73	19.05	53.2		
Sathyanarayanan	20.49	13.64	6.85	33.4	37.2	± 3.75
Kesavankutty	21.51	12.71	8.80	40.9		

Table 30. Digestion coefficients of nutrients in palm leaf: Trial II.
(On dry matter basis)

Name of the animal	Crude protein					
	Intake in kg	Outgo in kg	Digested in kg	Digestion coefficient (%)	Average D. coefficient (%)	S.E.
Narayanan	3.81	0.72	3.09	81.1	69.9 ?	±11.20
Ravindran	2.76	1.14	1.62	58.7		
Sathyanarayanan	1.58	0.89	0.69	43.7	54.7 ?	±11.00
Kesavankutty	1.66	0.57	1.09	65.7		

Table 31. Digestion coefficients of nutrients in palm leaf: Trial II.
(On dry matter basis)

Name of the animal	Ether extract					
	Intake in kg	Outgo in kg	Digested in kg	Digestion coefficient (%)	Average D. coefficient (%)	S.E.
Narayanan	1.68	0.50	1.18	70.2	66.7	± 3.55
Ravindran	1.22	0.45	0.77	63.1		
Sathyanarayanan	0.70	0.35	0.35	50.0	53.1	± 3.10
Kesavankutty	0.73	0.32	0.41	56.2		

Table 32. Digestion coefficients of nutrients in palm leaf: Trial II.
(On dry matter basis)

Name of the animal	Crude fibre					
	Intake in kg	Outgo in kg	Digested in kg	Digestion coefficient (%)	Average D. coefficient (%)	S.E.
Narayanan	15.33	11.03	4.30	28.0	34.1	±6.10
Ravindran	11.09	6.63	4.46	40.2		
Sathyanarayanan	6.35	3.80	2.55	40.2	37.3	±2.95
Kesavankutty	6.67	4.38	2.29	34.3		

Table 33. Digestion coefficients of nutrients in palm leaf: Trial II.
(On dry matter basis)

Name of the animal	Nitrogen-free-extract					
	Intake in kg	Outgo in kg	Digested in kg	Digestion coefficient (%)	Average D. coefficient (%)	S.E.
Narayanan	23.89	8.08	15.81	66.2	67.6	± 1.35
Ravindran	17.28	5.37	11.91	68.9		
Sathyanarayanan	9.90	6.19	3.71	37.5	46.0	± 8.45
Kesavankutty	10.39	4.74	5.65	54.4		

Table 34. Summarised data on digestion coefficients of nutrients in palm leaf.

ame of the animal	Trial-I					Trial - II				
	Dry matter	Crude protein	Ether extract	Crude fibre	Nitrogen-free-extract	Dry matter	Crude protein	Ether extract	Crude fibre	Nitrogen-free-extract
arayanan	45.8	81.0	55.2	18.5	66.2	51.5	81.1	70.2	28.0	66.2
avindran	56.0	67.9	35.6	44.1	75.2	53.2	58.7	63.1	40.2	68.9
verage	50.9	74.5	45.4	31.3	70.7	52.4	69.9	66.7	34.1	67.6
E	± 5.10	± 6.55	± 9.80	±12.80	± 4.50	± 0.85	±11.20	± 3.55	± 6.10	± 1.35
athyanara-anan	42.5	56.1	27.6	22.9	69.5	33.4	43.7	50.0	40.2	37.5
esavankutty	48.2	66.5	46.9	27.5	71.3	40.9	65.7	56.2	34.3	54.4
verage	45.4	61.3	37.3	25.2	70.4	37.2	54.7	53.1	37.3	46.0
E	± 2.90	± 5.20	± 9.65	± 2.30	± 0.90	± 3.75	±11.00	± 3.10	± 2.95	± 8.45

Table 35. Data on the nutritive values of palm leaf: Trial I.

Name of the animal	For 100 kg dry matter of leaf			For 100 kg raw leaf		
	DCP (kg)	TDN (kg)	NR	DCP (kg)	TDN (kg)	NR
Narayanan	6.24	48.2	6.72	2.44	18.8	6.70
Ravindran	5.23	57.9	10.07	2.04	22.6	10.08
Average	5.74	53.1	8.40	2.24	20.7	8.39
SE	± 0.51	± 4.85	± 1.68	± 0.20	± 1.90	± 1.69
Sathyanarayanan	4.32	47.1	9.90	1.69	18.4	9.89
Kesavankutty	5.12	51.7	9.10	2.00	20.2	9.10
Average	4.72	49.4	9.50	1.85	19.3	9.50
SE	± 0.40	± 2.30	± 0.40	± 0.16	± 0.90	± 0.40

Table 36. Data on the nutritive values of palm leaf: Trial II.

Name of the animal	For 100 kg dry matter of leaf			For 100 kg raw leaf		
	DCP (kg)	TDN (kg)	NR	DCP (kg)	TDN (kg)	NR
Narayanan	6.24	52.3	7.38	2.44	20.8	7.52
Ravindran	4.52	55.1	11.19	1.77	21.5	11.15
Average	5.38	53.7	9.29	2.11	21.2	9.34
SE	± 0.86	± 1.40	± 1.91	± 0.34	± 0.56	±1.92
Sathyanarayanan	3.36	37.8	10.25	1.31	14.8	10.30
Kesavankutty	5.06	46.3	8.15	1.98	18.1	8.14
Average	4.21	42.1	9.20	1.65	16.5	9.22
SE	± 0.85	± 4.25	± 1.05	± 0.33	± 1.67	±1.05

Table 37. Daily intake of digestible crude protein and total digestible nutrients.

Name of the animal	Trial-I (Full feeding)				Trial-II (75% of full feeding i n t a k e)			
	DCP (kg)	TDN (kg)	g/W kg$^{.73}$		DCP (kg)	TDN (kg)	g/W kg$^{.73}$	
			DCP	TDN			DCP	TDN
Narayanan	4.10	31.7	9.32	72.1	3.09	26.3	7.03	59.8
Ravindran	2.45	27.2	7.04	78.2	1.62	19.7	4.66	56.6
Average	3.28	29.5	8.18	75.2	2.36	23.0	5.85	58.2
SE	± 0.79	± 2.25	±1.14	± 3.05	± 0.74	± 3.3	±1.19	± 1.60
Sathyanarayanan	1.10	12.0	6.24	68.1	0.69	7.8	3.91	44.2
Kesavankutty	1.47	14.9	7.13	72.3	1.09	10.0	5.29	48.5
Average	1.29	13.5	6.69	70.2	0.89	8.9	4.60	46.4
SE	± 0.19	± 1.45	±0.45	± 2.1	± 0.20	± 1.1	±0.69	± 2.15

Table 38. Total solids, nitrogen, calcium and phosphorus in urine excreted.

Name of the animal	Trial - I				Trial - II			
	Total solids (%)	Nitrogen in mg/100 ml	Calcium in g/100 g	Phosphorus in g/100 g	Total solids (%)	Nitrogen in mg/100 ml	Calcium in g/100 g	Phosphorus in g/100 g
Narayanan	7.4	518	1.885	0.056	7.2	550	1.480	0.083
Ravindran	7.6	448	2.187	0.062	6.9	483	1.371	0.062
Average	7.5	483	2.036	0.059	7.1	517	1.426	0.073
SE	± 0.1	± 35	± 0.151	± 0.003	± 0.16	± 33.5	±0.054	±0.010
Sathyanarayanan	6.0	350	1.894	0.167	7.2	466	1.395	0.036
Kesavankutty	8.1	497	1.234	0.074	6.3	534	1.359	0.053
Average	7.1	424	1.564	0.121	6.8	500	1.377	0.045
SE	± 1.05	± 73.2	± 0.33	± 0.047	± 0.45	± 34	±0.018	±0.008

Table 39. Nitrogen balance: Trial I.

Name of the animal	Intake in g/day	Outgo in g/day			Balance in g/day	Nitrogen balance in g/Sq.m body surface/day	Nitrogen balance in g/metabolic body size/day	Nitrogen balance/kg body weight in g/day	Per cent retention
		Dung	Urine	Total					
Narayanan	809	154	272	426	383	14.776	0.8710	0.092	47.3
Ravindran	578	185	142	327	251	11.992	0.7213	0.083	43.4
Average	694	170	207	377	317	13.384	0.7962	0.088	45.4
SE	±116.0	± 16.0	±65.0	±49.0	±66.0	± 1.392	±0.0749	±0.005	± 2.0
Sathyanarayanan	314	138	92	230	84	7.467	0.4765	0.070	26.8
Kesavankutty	354	119	123	242	112	8.629	0.5432	0.076	31.6
Average	334	129	108	236	98	8.048	0.5099	0.073	29.2
SE	± 20.0	±9.5	±15.8	±5.5	±14.0	± 0.581	±0.0334	±0.003	± 2.4

Table 40. Nitrogen balance: Trial II.

Name of the animal	Intake in g/day	Outgo in g/day			Balance in g/day	Nitrogen balance in g/Sq.m body surface/day	Nitrogen balance in g/metabolic body size/day	Nitrogen balance/kg body weight in g/day	Per cent retention
		Dung	Urine	Total					
Narayanan	609	115	236	351	258	9.954	0.5868	0.062	42.4
Ravindran	441	182	131	313	128	6.116	0.3678	0.042	29.0
Average	525	149	184	332	193	8.035	0.4773	0.052	35.7
SE	± 84	±33.5	±52.5	±19.0	±65.0	±1.919	±0.1095	±0.010	± 6.7
Sathyanarayanan	252	142	131	273	-21	-1.867	-0.1191	-0.018	- 8.3
Kesavankutty	265	92	123	215	50	3.852	0.2425	0.034	18.9
Average	259	117	127	244	14.5	0.993	0.0617	0.008	5.3
SE	±6.5	±25.0	±4.0	±29.0	±35.5	±2.860	±0.1808	±0.026	±13.6

Table 41. Calcium balance: Trial I.

Name of the animal	Intake in g/day	Outgo in g/day			Balance in g/day	Calcium balance in g/Sq.m body surface/day	Calcium balance in g/metabolic body size/day	Calcium balance/kg body weight in g/day	Per cent retention
		Dung	Urine	Total					
Narayanan	289.0	142.4	73.4	215.8	73.2	2.828	0.1665	0.018	25.3
Ravindran	206.4	80.5	52.5	133.0	73.4	3.507	0.2109	0.024	35.6
Average	247.7	111.5	63.0	174.4	73.3	3.166	0.1887	0.021	30.5
SE	± 41.3	± 31.0	±10.5	± 41.04	± 0.1	±0.342	±0.0222	±0.003	± 5.15
Sathyanarayanan	112.2	51.3	29.9	81.2	31.0	2.756	0.1758	0.026	27.6
Kesavankutty	126.5	75.9	24.7	100.6	25.9	1.995	0.1256	0.018	20.5
Average	119.4	63.6	27.3	90.9	28.5	2.376	0.1507	0.022	24.1
SE	± 7.15	± 12.3	± 2.6	± 9.7	± 2.6	±0.381	±0.0251	±0.004	± 3.55

Table 42. Calcium balance: Trial II.

Name of the animal	Intake in g/day	Outgo in g/day			Balance in g/day	Calcium balance in g/Sq.m body surface/day	Calcium balance in g/metabolic body size/day	Calcium balance/kg body weight in g/day	Per cent retention
		Dung	Urine	Total					
Narayanan	217.6	100.7	45.6	146.3	71.3	2.751	0.1622	0.017	32.8
Ravindran	157.4	77.0	25.6	102.6	54.8	2.618	0.1575	0.018	34.8
Average	187.5	88.9	35.6	124.5	63.1	2.685	0.1599	0.018	33.8
SE	± 30.1	±11.9	±10.0	±21.9	± 8.3	±0.067	±0.0023	±0.001	± 1.00
Sathyanarayanan	90.2	55.9	28.2	84.1	6.1	0.542	0.0346	0.005	6.8
Kesavankutty	94.6	64.8	19.7	84.5	10.1	0.778	0.0490	0.007	10.7
Average	92.4	60.4	24.0	84.3	8.1	0.660	0.0418	0.006	8.8
SE	± 2.2	± 4.5	± 4.3	± 0.2	± 2.0	±0.118	±0.0072	±0.001	± 1.95

Table 43. Phosphorus balance: Trial I.

Name of the animal	Intake in g/day	Outgo in g/day			Balance in g/day	Phosphorus balance in g/sq.m body surface/day	Phosphorus balance in g/metabolic body size/ day	Phosphorus balance/kg body weight in g/ day
		Dung	Urine	Total				
Narayanan	105.1	110.4	2.2	112.6	-7.5	-0.289	-0.0171	-0.002
Ravindran	75.1	101.2	1.5	102.7	-27.6	-1.319	-0.0793	-0.009
Average	90.1	105.8	1.9	107.7	-17.6	-0.804	-0.0482	-0.006
SE	± 15.1	± 4.6	±0.4	± 5.0	±10.1	±0.515	±0.0311	±0.004
Sathyanarayanan	40.8	41.0	2.6	43.6	- 2.8	-0.249	-0.0159	-0.002
Kesavankutty	46.0	61.0	1.5	62.5	-16.5	-1.271	-0.0800	-0.011
Average	43.4	51.0	2.1	53.1	- 9.7	-0.760	-0.0480	-0.007
SE	± 2.6	± 10.0	±0.6	± 9.5	± 6.9	±0.511	±0.0320	±0.005

Table 44. Phosphorus balance: Trial II.

Name of the animal	Intake in g/day	Outgo in g/day			Balance in g/day	Phosphorus balance in g/sq.m body surface/day	Phosphorus balance in g/metabolic body size/ day	Phosphorus balance/kg body weight in g/day
		Dung	Urine	Total				
Narayanan	79.1	119.9	2.6	122.5	-43.4	-1.674	-0.0987	-0.010
Ravindran	57.2	78.6	1.2	79.8	-22.6	-1.080	-0.0649	-0.008
Average	68.2	99.3	1.9	101.2	-33.0	-1.377	-0.0818	-0.009
SE	±11.0	±20.7	±0.7	± 21.4	±10.4	±0.297	±0.0169	±0.001
Sathyanarayanan	32.8	36.8	0.7	37.5	- 4.7	-0.418	-0.0267	-0.004
Kesavankutty	34.4	53.4	0.8	54.2	-19.8	-1.525	-0.0960	-0.013
Average	33.6	45.1	0.8	45.9	-12.3	-0.972	-0.0614	-0.009
SE	± 0.8	± 8.3	±0.1	± 8.4	± 7.5	±0.554	±0.0346	±0.005

Table 45. Gross energy values of palm leaf* and dung & urine voided by animals.

Name of the animal	Trial-I Gross energy Cal/g		Trial-II Gross energy Cal/g	
	Dung (Dry matter)	Urine (Total solids)	Dung (Dry matter)	Urine (Total solids)
Narayanan	3.6208	3.6178	3.8870	3.2189
Ravindran	3.5867	3.4901	3.5317	3.1169
Average	3.6038	3.5540	3.7094	3.1679
SE	±0.0171	±0.0639	±0.1777	±0.0510
Sathyanarayanan	3.4908	3.3277	3.6394	2.9431
Kesavankutty	3.8377	3.3297	3.7935	2.8867
Average	3.6643	3.3287	3.7165	2.9149
SE	±0.1735	±0.0010	±0.0771	±0.0282

* 4.3551 Cal/g dry matter.

Table 46. Digestible energy: Trial I.

Name of the animal	Intake in Cal/day	Outgo in Cal/day	Digested Cal/day	Digestion coefficient (%)	Digestible energy Cal/sq.m/day	Digestible energy Cal/metabolic body size/day	Digestible energy Cal/kg body wt./day
Narayanan	286086.5	128900.5	157186.0	54.9	6064.3	357.5	37.6
Ravindran	204341.3	74065.5	130275.8	63.8	6224.4	374.4	43.0
Average	245213.9	101483.0	143730.9	59.4	6144.4	366.0	40.3
SE	± 40872.6	± 27417.5	± 13455.1	± 4.5	± 80.1	± 8.5	± 2.7
Sathyanarayanan	111011.5	51140.2	59871.3	53.9	5321.9	339.6	50.1
Kesavankutty	125165.6	57143.4	68022.2	54.3	5240.6	329.9	46.0
Average	118088.6	54141.8	63946.8	54.1	5281.3	335.0	48.1
SE	± 7077.1	± 3001.6	± 4075.5	± 0.2	± 40.6	± 4.6	± 2.1

Table 47. Digestible energy: Trial II.

Name of the animal	Intake in Cal/day	Outgo in Cal/day	Digested Cal/day	Digestion coefficient (%)	Digestible energy Cal/sq.m/day	Digestible energy Cal/metabolic body size/day	Digestible energy Cal/kg body wt./day
Narayanan	215403.2	93171.4	122231.8	56.8	4715.7	278.0	29.3
Ravindran	155825.5	59085.3	96740.2	62.1	4622.1	278.0	31.9
Average	185614.4	76128.4	109486.0	59.5	4668.9	278.0	30.6
SE	± 29788.9	±17043.1	± 12745.8	± 2.7	± 46.8	± 0.0	± 1.3
Sathyanarayanan	89236.0	49641.4	39594.6	44.4	3519.5	224.6	33.2
Kesavankutty	93678.2	48215.4	45462.8	48.5	3502.5	220.5	30.7
Average	91457.1	48928.4	42528.7	46.5	3511.0	222.6	32.0
SE	± 2221.1	± 713.0	± 2934.1	± 2.1	± 8.5	± 2.1	±1.3

Table 48. Digestible energy as determined and TDN as determined and as calculated.

Name of the animal		Determined			Calculated	
		Digestible energy in Cal/day	TDN per day in kg	Digestible energy Cal/kg TDN	TDN*assuming 1814 Cal/lb (4000 Cal/kg)	TDN**assuming 2000 Cal/lb (4409 Cal/kg)
Narayanan	Trial-I	157186.0	31.7	4959	39.3	35.7
	Trial-II	122231.8	26.3	4648	30.6	27.7
Ravindran	Trial-I	130275.8	27.2	4790	32.6	29.5
	Trial-II	96740.2	19.7	4911	24.2	21.9
Sathyanara-yanan	Trial-I	59871.3	12.0	4989	15.0	13.6
	Trial-II	39594.6	7.8	5076	9.9	9.0
Kesavankutty	Trial-I	68022.2	14.9	4565	17.0	15.4
	Trial-II	45462.8	10.0	4546	11.4	10.3

* Brody, 1945.
** Maynard, 1969.

Table 49. Digestible energy and TDN as determined and as calculated.

ame of the animal	Determined digestible energy Cal/day	Digested					Calculated** DE*Cal/day	TDN determined	TDN as calculated assuming 4409 Cal/kg	TDN as calculated assuming 4000 Cal/kg
		Crude protein (g)	Crude fibre (g)	Nitrogen-free extract (g)	Total carbohydrate (g)	Fat (g)				
Trial-I	157186.0	4100	3770	21000	24770	1230	137523	31.7	31.2	34.4
arayanan										
Trial-II	122231.8	3090	4300	15810	20110	1180	112007	26.3	25.4	28.0
Trial-I	130275.8	2450	6410	17040	23450	570	116518	27.2	26.4	29.1
avindran										
Trial-II	96740.2	1620	4460	11910	16370	770	84327	19.7	19.1	21.1
Trial-I	59871.3	1100	1810	8560	10370	240	51507	12.0	11.7	12.9
athyanara-yanan										
Trial-II	39594.6	690	2550	3710	6260	350	33168	7.8	7.5	8.3
Trial-I	68022.2	1470	2450	9900	12350	460	63882	14.9	14.5	16.0
esavan-kutty										
Trial-II	45462.8	1090	2290	5650	7940	410	42964	10.0	9.7	10.7

* DE = Digestible energy.
* Gross energy: Carbohydrate = 4.15 Cal/g; Protein = 5.65 Cal/g; Fat = 9.4 Cal/g (Maynard, 1969).

Table 50. Metabolizable energy values.

Name of the animal	Intake Cal/day	Outgo				Metabolizable energy Cal/day
		Dung Cal/day	Urine Cal/day	Methane energy* Cal/day	Total Cal/day	
Narayanan Trial-I	286086.5	128900.5	14080.5	11916.0	154897.0	131189.5
Trial-II	215403.2	93171.4	9923.9	9266.4	112361.7	103041.5
Ravindran Trial-I	204341.3	74065.5	8383.2	9876.2	92324.9	112016.4
Trial-II	155825.5	59085.3	5813.0	7333.9	72232.2	83593.3
Sathyanarayanan Trial-I	111011.5	51140.2	5251.1	4538.8	60930.1	50081.4
Trial-II	89236.0	49641.4	5959.8	3001.7	58602.9	30633.1
Kesavankutty Trial-I	125165.6	57143.4	6662.7	5156.8	68962.9	56202.7
Trial-II	93678.2	48215.4	4188.6	3446.5	55850.5	37827.7

* Based on the assumption that for every 100 Cal DE there will be a production of 7.581 Cal as methane energy (Benedict, 1936).

Table 51. Gross energy and digestible energy values.

Name of the animal	Gross energy				Digestible energy				Digestible energy as % of gross energy intake
	Intake Cal/day	Intake/ kg body weight/ day	Intake/ $kg^{.73}$/ day	Intake/ sq.m/day	Intake Cal/day	Intake/ kg body weight/ day	Intake/ $kg^{.73}$/ day	Intake/ sq.m/ day	
Trial-I Narayanan	286086.5	68.5	650.6	11037	157186.0	37.6	357.5	6064.3	54.9
Trial-II	215403.2	51.6	489.9	8310	122231.8	29.3	278.0	4715.7	56.8
Trial-I Ravindran	204341.3	67.4	587.2	9763	130275.8	43.0	374.4	6224.4	63.8
Trial-II	155825.5	51.4	447.8	7445	96740.2	31.9	278.0	4622.1	62.1
Trial-I Sathyanara-yanan	111011.5	93.0	629.7	9868	59871.3	50.1	339.6	5321.9	53.9
Trial-II	89236.0	74.7	506.2	7932	39594.6	33.2	224.6	3519.5	44.4
Trial-I Kesavan-kutty	125165.6	84.6	607.0	9643	68022.2	46.0	329.9	5240.5	54.3
Trial-II	93678.2	63.3	454.3	7217	45462.8	30.7	220.5	3502.5	48.5

Table 52. Metabolizable energy values.

Name of the animal	Metabolizable energy						Methane energy as per cent of gross energy intake
	Intake Cal/day	Intake Cal/kg body wt./day	Intake Cal/sq.m/ day	Intake Cal/kg$^{.73}$/ day	As per cent of gross energy	As per cent as digestible energy*	
Trial-I	131189.5	31.4	5061	298.4	45.9	83.5	4.17
Narayanan Trial-II	103041.5	24.7	3975	234.3	47.8	84.3	4.30
Trial-I	112016.4	36.9	5352	321.9	54.8	86.0	4.83
Ravindran Trial-II	83593.3	27.6	3994	240.2	53.6	86.4	4.71
Trial-I	50081.4	41.9	4452	284.1	45.1	83.6	4.09
Sathyanara-yanan Trial-II	30633.1	25.7	2723	173.8	34.3	77.4	3.36
Trial-I	56202.7	38.0	4330	272.6	44.9	82.6	4.12
Kesavankutty Trial-II	37827.7	25.6	2914	183.5	40.4	83.2	3.68

* Metabolizable energy = 82% of digestible energy (Maynard, 1969).

Table 53. Requirements of Dry matter, DCP, TDN, DE and ME for maintenance of adult elephants.

	Name of the elephant	Requirements			
		Per day in kg	Per kg body weight in g	Per kg$^{.73}$ in g	Per sq.m in g
Dry matter	Narayanan	49.5	11.848	112.6	1910
	Ravindran	35.8	11.807	102.9	1710
	Average	42.7	11.828	107.8	1810
	SE	±6.9	± 0.021	± 4.9	± 100
DCP	Narayanan	3.09	0.740	7.03	119.2
	Ravindran	1.62	0.534	4.66	77.4
	Average	2.36	0.637	5.85	98.3
	SE	±0.74	±0.103	±1.19	± 20.9
TDN	Narayanan	26.3	6.295	59.8	1015
	Ravindran	19.7	6.497	56.6	941
	Average	23.0	6.396	58.2	978
	SE	± 3.3	±0.101	± 1.60	± 37.0
DE Cal/day	Narayanan	122232	29.3	278.0	4716
	Ravindran	96740	31.9	278.0	4622
	Average	109486	30.6	278.0	4669
	SE	± 12746	± 1.3	± 0.0	± 47
ME*Cal/day	Narayanan	103042	24.7	234	3975
	Ravindran	83593	27.6	240	3994
	Average	93318	26.2	237	3985
	SE	± 9724.5	± 1.5	± 3.0	± 10.0

* ME = Metabolizable Energy.

Table 54. Requirements of Dry matter, DCP, TDN, DE and ME for growth of young elephants.

	Name of the elephant	Requirements			
		Per day in kg	Per kg body weight in g	Per kg$^{.73}$ in g	Per sq.m in g
Dry matter	Sathyanarayanan	25.5	21.357	144.6	2267
	Kesavankutty	28.7	19.392	139.2	2211
	Average	27.1	20.375	141.9	2239
	SE	± 1.6	± 0.983	± 2.7	± 28
DCP	Sathyanarayanan	1.10	0.921	6.24	97.80
	Kesavankutty	1.47	0.993	7.13	113.25
	Average	1.29	0.957	6.69	105.53
	SE	± 0.19	± 0.360	± 0.45	± 7.73
TDN	Sathyanarayanan	12.0	10.05	68.1	1067
	Kesavankutty	14.9	10.07	72.3	1148
	Average	13.5	10.06	70.2	1108
	SE	± 1.45	± 0.01	± 2.10	± 40.5
DE Cal/day	Sathyanarayanan	59871.3	50.1	339.6	5321.9
	Kesavankutty	68022.2	46.0	329.9	5240.5
	Average	63946.8	48.1	335.0	5281.2
	SE	± 4075.5	± 2.05	± 4.6	± 40.7
ME Cal/day	Sathyanarayanan	50081	41.9	284	4452
	Kesavankutty	56203	38.0	273	4330
	Average	53142	40.0	279	4391
	SE	± 3061	± 1.95	± 5.5	± 61.0

Table 55. Haematological values.

Constituents	Adult elephants			Young elephants		
	Narayanan	Ravindran	Av. ± SE	Sathyanarayanan	Kesavankutty	Av. ± SE
RBC million/mm^3	3.21	3.06	3.14 ± 0.075	3.12	3.73	3.43 ± 0.305
WBC thousand/mm^3	11.55	12.75	12.15 ± 0.600	13.00	9.35	11.18 ± 1.830
Haemoglobin g/100 ml (WB)*	11.30	12.80	12.10 ± 0.750	12.20	14.20	13.20 ± 1.000
Total protein g/100 ml plasma	7.61	7.96	7.79 ± 0.175	8.27	8.61	8.44 ± 0.170
Packed cell volume (%)	30.00	35.00	32.50 ± 2.500	33.00	43.00	38.00 ± 5.000
ESR mm at 30 mnn.	29	49	39 ±10.000	39	49	44 ± 5.000
Calcium mg % (S)**	11.70	11.50	11.60 ± 0.100	11.10	11.40	11.30 ± 0.200
Inorganic phosphorus mg/100 ml(WB)	4.96	4.84	4.90 ± 0.060	5.34	5.58	5.46 ± 0.120
Glucose mg/100 ml (WB)	56.00	58.00	57.00 ± 1.000	78.00	68.00	73.00 ± 5.000
Urea mg/100 ml (WB)	25.00	28.00	26.50 ± 1.500	34.00	29.00	31.50 ± 2.500
Chloride mg/100 ml (S)	446.60	429.06	437.83 ± 8.770	409.00	418.40	413.70 ± 4.700
Creatinine mg/100 ml (WB)	1.80	2.10	1.95 ± 0.150	1.70	1.60	1.65 ± 0.050
Cholesterol mg/100 ml (S)	99	87	93 ± 6.000	108	116	112 ± 4.000
Total Vitamin B_{12}/μg/100 ml (P)@	19.85	16.25	18.05 ± 1.800	17.37	16.50	16.94 ± 0.440

* (WB) = Whole Blood.
** (S) = Serum.
@ (P) = Plasma.

DISCUSSION

DISCUSSION

Results obtained during the course of the present investigation were statistically analysed as per appropriate methods of statistical analysis (Snedecor, 1956). Results are compared with those of Benedict (loc. cit.) in 'Jap'. Benedict's work, although, as admitted by him, suffers from (1) imperfect collection of urine (2) poor quality of hay fed and (3) crude methods adopted for the weighing and aliquoting of hay, is still the only one investigation on record that is some what akin to the present study. The essential data obtained are discussed below under separate heads.

Prediction of body weight from body measurements

From the results presented in Table I, it can be observed that for the same age different body measurements and body weights are seen; so also for the same chest measurements or body length or neck girth, different body weights are seen. The need for using a combination of measurements for predicting body weights is evident.

According to statisticians, the value of a dependent variable will have to be predicted very often from the values of related variables. In order to achieve this, a functional relationship between the dependent variable ie., the variable whose value is to be predicted and the independent variables ie., the variables whose values are used for prediction needs to be

established. The first probe, in such cases will usually be directed to finding the correlation between the different variables involved, as a significant correlation of considerable magnitude is indicative of a linear relationship between the pair of variables. The correlations calculated between pairs of shoulder height, chest girth, body length (PS to PB), neck girth, body length (PS to PI) and body weight and presented in Table 2, were found to be significantly different from zero ($P < 0.01$). The body weight was found to have a positive correlation of 0.96 with shoulder height, 0.97 with chest girth, 0.78 with body length (PS to PB), 0.98 with neck girth and 0.86 with body length (PS to PI). In order to choose the relevant variables for predicting the body weight, it was found necessary to compute the partial correlation of body weight with other measurements, keeping the rest constant. From the first order partial correlation between body weight and a particular parameter, keeping the other measurements constant in succession as given in Table 3, it can be seen that the correlation of shoulder height with body weight was induced by chest girth and neck girth. The table also highlights the fact that correlation between body weight and each of the parameters considerated is quite highly influenced by neck girth, chest girth and body length (PS to PB). These three parameters were, therefore, used for formulating relations for predicting body weight. Even among the three, better attention was paid to girth and neck girth. The different linear functions of body

weight with these variables expressed as formulae and established by the method of least squares with computations based on 20 observations and keeping eight decimal places and presented in Table 4 show that linear function of body weight on girth worked out as

$$W = 23\ g - 4984$$

This explained 95 per cent of the variation in body weight. The linear relation of body weight in terms of body length (PS to PB) and chest girth which also explained 95 per cent of the variation in body weight was found to be: $W = 6.91 + 20.7\ g - 5556$.

A better precision was found in predictig body weight in terms of girth and neck girth measurements and the corresponding linear relationship turned out to be $W = 8.2\ g + 18.4\ ng - 3927$, the percentage of variation in body weight explained in this case being 97. The same precision (97%) was attained in predicting the body weight as a linear function of the sum of chest girth and neck girth, the formula being $W = 12.8\ (g + ng) - 4281$. The prediction equation of weight in terms of length and girth when expressed in exponential terms viz., $W = 10^{-4} \times 2.4313\ l^{\cdot 2} g^{2.6}$ explained 97 per cent of the variations in the logarithms of the body weight and when approximated as $W = 10^{-5} \times 12.0539\ lg^2$ showed no increase in precision over the rest.

In the above relations units of weight and measurements are

taken as W = body weight in kg ; g = girth in cm; l = length in cm; ng = neck girth in cm.

When compared with the prediction relations, viz., $W = \frac{1.25\ LG^2}{300}$ currently in use by the Forest Departments of Tamil Nadu and Kerala (Krishnamoorthy, 1978 pers. comm. and Nair, 1978 pers. comm.) wherein body weight (W) is expressed in pounds and both length ie., point of shoulder to point of buttocks (L) and chest girth (G) in inches, it was found that the expected body weights of the 20 elephants under study as calculated in kg on this basis as given in Table 5, had a correlation with the determined weights as 0.97, the percentage variation in body weight explained being $100 \times (.97)^2 = 94$.

A totally different approach in predicting the body weight has been made in Ceylon (Kurt and Nettasinghe, 1968) and this has resulted in the formulation of two formulae, given below:

i) $y = -22.39 + 18.9\ x$

ii) $z = -60.6 + 28.9\ x$

where y = shoulder height in cm,

z = chest girth in cm and

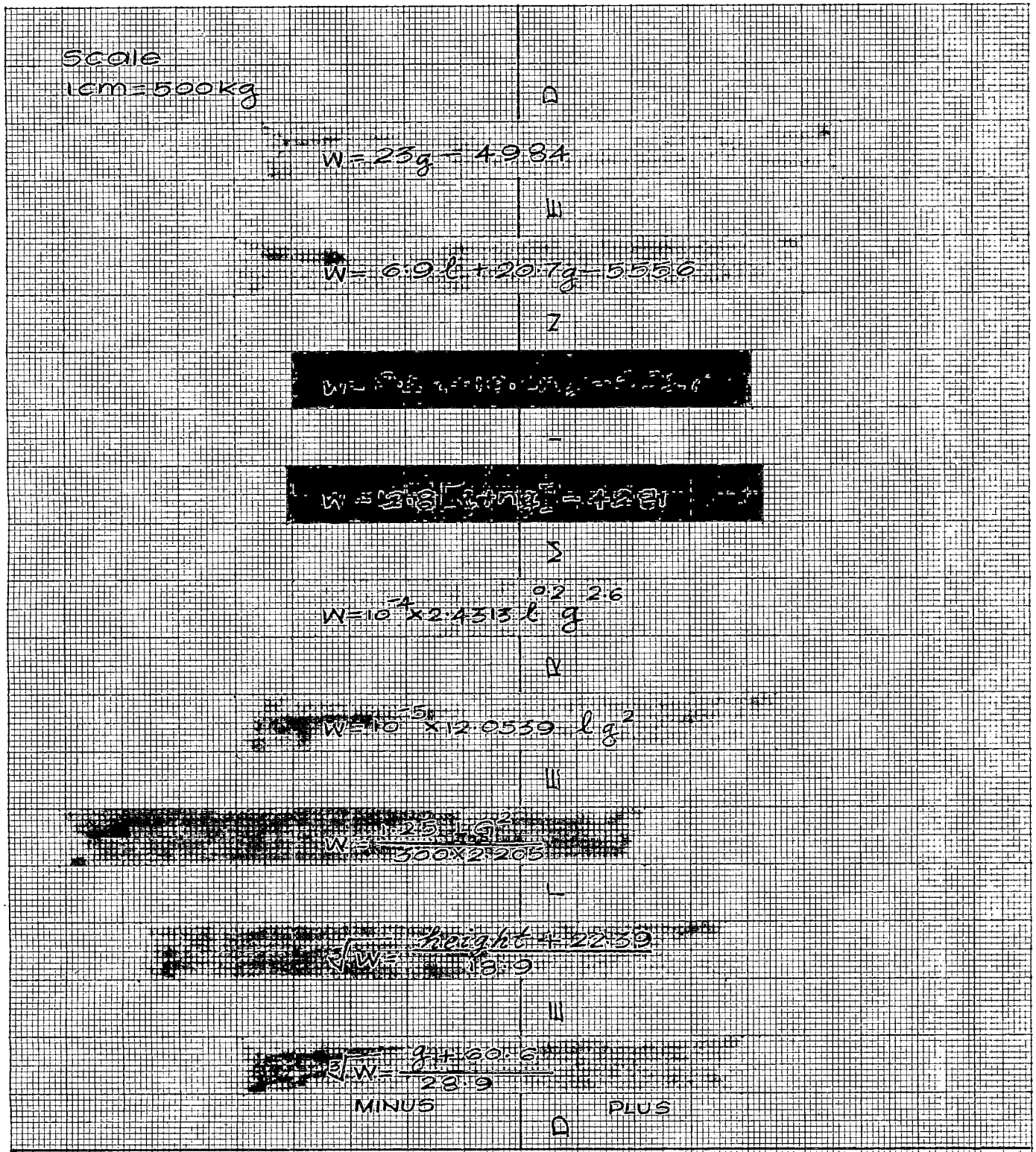
x = cube root of body weight in kg.

The expected body weights according to these formulae are also given in Table 5. The correlation between the expected and determined body weights by the first formula is 0.96, the percentage

variation in the expected body weight explained being 93. The corresponding correlation with respect to the second formula is 0.98. The percentage variation in expected body weight explained by the relation is 96.

The coefficient of variation of the original body weights of the 20 animals being 40.47, it is natural that a prediction formula that gives an expected weight that is equal to the determined weight will give to the expected weights, the same coefficient of variation as in the original data. From this point of view and from tne point of view of the percentage of variations explained, the formulae 3 and 4 given in Table 6 appear to be better for the purpose of prediction. The 9th formula (Kurt and Nettasinghe, 1968), though explains 96 per cent of the variation in the body weight, has only a coefficient of variation of 36.42 which implies that this formula has a smoothening effect on tne expected values. The fifth relation in Table 6 explains 97 per cent of the variation in the body weight and at the same time has a coefficient of variation of 38.44 and can therefore be considered to be better than formula 9 as the former smoothens the data less than the latter, the percentage of variation explained also not being in anyway less than that explained by the latter.

From the above discussion, it follows, that prediction of body weight in terms of chest girth and neck girth appears to be more precise than all other methods (Table 7 and Fig. 1). These



ESTIMATED

Fig1: NOTE THE ACCURACY OF AND CLOSENESS BETWEEN THE FORMULAE BASED ON CHEST GIRTH AND NECK GIRTH MEASUREMENTS

9 8 7 6 5 4 3 2 1 1 2 3 4 5 6 7 8 9

latter variables can either be taken as two independent variables or their sum may be treated as a single variable. In both cases the precision attained is surprisingly equal, it being 97 per cent. In cases where length and girth alone are available, the fifth formula given in Table 6 appears to be more appropriate.

A 'know what' of body weight is of great importance in the feeding of the elephant on scientific nutritional principles just as in the determination of drug dosages for treating domesticated animals and tranquilising wild elephants. Application of a formula based on body measurements will help surmount the difficulty encountered in determining the body weight of the elephant in a weigh-bridge (vide appendix). The availability of such a formula will also help guage the size of a far off elephant from its known body weight, if it is so warranted under certain impelling circumstances.

Balance trials

Feed intake

From the data presented in Table 9, it will be evident that in both the trials (Trials I and II) adult elephants consumed a little over double the quantity of palm leaf eaten by the young animals. Adult and young elephants fed palm leaf ad lib. (Trial I) wasted on an average 25.1 and 29.3 per cent respectively of the

same. Restricted feeding (Trial II) appears to reduce the percentage of refuse in the case of the adult and young animals by 64 per cent. Gopalan (loc. cit.) has observed that when fed at the camp, elephants generally spoil and waste about half the quantity of fodder supplied.

Dry matter consumption

From Tables 10 and 11, it will be seen that adult elephants ate double the quantity of dry matter consumed by the young animals in both the trials (Trials I and II). Per 100 kg body weight, it is seen that young animals consumed more dry matter than the adults in both the trials. Dry matter consumption expressed in terms of metabolic body size is found to be essentially the same for the two group of animals in each of the two trials. A dry matter consumption of 1.18 per cent of body weight is observed in the case of the adults in trial II as against 1.25 per cent worked out in 'Jap' which according to Benedict (loc. cit.) never received the feed, hay, in liberal amounts.

Defecation and dung dry matter

In all animals, irrespective of group or trial, defecation occurred more in the night than in the day. In both the trials (Trials I and II), young animals voided only a little over half the quantity of dung excreted by the adults (Tables 12 and 13). In trial I, young animals voided only a little over half the

quantity of dung dry matter excreted by the adult animals but in the second trial it was nearly two-third. It is seen that young animals void more dung dry matter per 100 kg body weight than the adults in both the trials, the difference between the groups being more conspicuous in the second than in the first. When calculated on metabolic body size basis, it was found that the dung dry matter voided by each group is less in the second trial as compared with the first. Frequency of defecation, weight of boluses, number of boluses per defecation and defecation weights appear to vary between groups, between trials and also between animals in the same group. The data presented in Tables 14 to 17 in these respects are in keeping with those observed by Benedict (loc. cit.) in 'Jap'.

Micturition and urinary total solids

It is seen from Tables 18 and 19 that in all animals, irrespective of group or trial, micturition occurred more in the night than in the day. As compared with the young, the adults discharged substantially greater quantity of urine per micturition as well as per day in both the trials. Simon (1959) has reported a daily discharge of 53.755 litres of urine in an elephant aged 32 years and a daily excretion of 25.94 litres in an animal 11 years of age.

In both the trials, adult elephants excreted more total solids per day in the urine as compared with the young, the percentage of total solids in the urine being essentially the same

in the two groups (Tables 20 and 21). Discharge of urine per kg body weight and of total solids per metabolic body size are greater in the case of young animals in both the trials as compared with the adults.

Digestion coefficients of nutrients in palm leaf

From the summarised data presented in Table 34, it will be seen that adult animals digested more of the dry matter as compared with the young animals in both the trials (Trials I and II), the difference in this respect being statistically significant only in trial II ($P < 0.05$). Restricted feed intake (Trial II) significantly reduces the digestibility of nitrogen-free-extract in the case of the young animals ($P < 0.05$). In both the trials, adult animals digested more of the crude protein as compared with the young animals.

Nutritive values of palm leaf

From Tables 35 and 36 it will be seen that there exists no difference between trials I and II in the DCP and TDN values of palm leaf obtained in the case of adult animals. In the case of young animals, restriction of feed intake appears to reduce the DCP and TDN values of palm leaf. Between the groups, it was found that the adult group returned higher values for DCP and TDN in both the trials. The differences in DCP and TDN between the trials

and between the groups, however, are not statistically significant ($P > 0.05$).

Nutrient intake

Data presented in Table 37 show that the adults as well as the young animals consumed more of DCP and TDN in trial I than in trial II, the intakes of the adult animals being more than those of the young in both the trials. The differences are the same when the values are expressed on the basis of metabolic body size. Adult animals consumed significantly higher TDN in trial II as compared with the young ($P < 0.05$), both groups showing significantly higher values in trial I than in trial II ($P < 0.01$).

In the case of 'Jap' (Benedict, loc. cit.) weighing 3672 kg and having a calculated metabolic body size of 400.3, the intakes of DCP and TDN, as worked out, are found to be 3.93 g and 49 g respectively per metabolic body size per day. The DCP and TDN intakes of the adult animals during trial II (restricted feeding) in the present study were: 5.85 g and 58.2 g respectively per metabolic body size per day. The DCP and TDN values obtained are found to be adequate to maintain adult animals in a substantially positive nitrogen balance (Table 40). The adult elephant 'Jap' (Benedict, loc. cit.) maintained only a slight positive nitrogen balance (15.56 g/day) with intakes of 3.93 g DCP and 49 g TDN per metabolic body size per day.

Nitrogen balance

It can be seen from Table 39 that both adult and young animals, when fed palm leaf ad lib. (Trial I), showed positive nitrogen balance, the average balance being 317 g per day for the adult group and 98 g per day for the young group. These when expressed per metabolic body size were: 0.7962 g and 0.5099 g respectively per day for the adult and young animals. The per cent retention of nitrogen was found to be on an average 45.4 and 29.2 respectively in the adult and young animals. The data presented in Table 40 in respect of nitrogen balance during trial II show that all animals maintained positive nitrogen balance except the young elephant Sathyanarayanan. The average nitrogen balance for the adult group was found to be 193 g per day and that for the young group, 14.5 g per day. The nitrogen balance data, when expressed per metabolic body size, were: 0.4773 g and 0.0617 g respectively for the adult and young animals. The per cent retention of nitrogen was found to be on an average 35.7 in the case of the adult and 5.3 in the case of the young.

The overall difference in nitrogen balance between the two groups is statistically significant ($P < 0.05$), the adult animals showing better balance than the young. As between the trials, both groups showed significantly higher nitrogen balance ($P < 0.05$) in trial I. The difference observed in per cent nitrogen retention

between the adult and young animals in trial II is statistically significant ($P < 0.05$), the adult animals showing better per cent nitrogen retention.

Nitrogen balance worked out in 'Jap' (Benedict, loc. cit.) is only 15.56 g per day which is 0.039 g per metabolic body size. Per cent nitrogen retention worked out comes to nearly 3 per cent. The low values in these respects are attributable to the limitations involved in the feeding trial carried out in 'Jap' (Benedict, loc. cit.).

Calcium balance

From the results on calcium balance presented in Tables 41 and 42, it can be observed that both the adult and young animals maintained positive calcium balance in both the trials, the average balance in g per day being 73.3 in the case of the adult and 28.5 in the case of the young during trial I and 63.1 and 8.1 respectively in trial II. These values when expressed in g per day per metabolic body size were found to be on an average: 0.189 for the adult and 0.151 for the young in the first trial and 0.160 and 0.042 respectively in the second trial.

The per cent retention of calcium was found to be on an average 30.5 in the adult and 24.1 in the young in the first trial and 33.8 and 8.8 respectively in the second trial. The difference

in calcium balance between the two groups in trial II is statistically significant ($P < 0.05$), the adult animals showing better balance. Between the trials, significant difference is observed in the case of the young, the animals showing better balance in trial I ($P < 0.05$).

Phosphorus balance

From the data set out in Tables 43 and 44 it is discernible that irrespective of groups or trials, all animals showed negative phosphorus balance. Obviously, requirements of phosphorus for maintenance as well as for growth of elephants are not met from the ad lib. feeding of palm leaves.

Digestible energy

It can be seen from the data on digestible energy presented in Tables 46 and 47 that the adult and young animals had, on an average, intakes of 143730.9 Cal/day and 63946.8 Cal/day respectively in the first trial and 109486 Cal/day and 42528.7 Cal/day respectively in the second trial. These values when expressed per metabolic body size were found to be on an average: 366 Cal/day for the adults and 335 Cal/day for the young during trial I and 278 Cal and 222.6 Cal/day respectively in the second trial.

Adult animals received significantly higher DE in both

trials as compared with the young ($P < 0.05$), both groups showing significantly higher values in trial I than in trial II ($P < 0.01$).

DE as determined and TDN as determined and as calculated

From DE values as determined and TDN values as determined and as calculated for farm animals in general (Brody, 1945 and Maynard, 1969) detailed in Table 48, it can be observed that the determined values of DE and TDN bear between them a relationship of 4875 Cal DE/kg TDN in the case of the adult and one of 4777 Cal DE/kg TDN in the case of the young during trial I. The relationships in trial II are found to be 4780 Cal DE/kg TDN in the case of the adult and 4811 Cal DE/kg TDN in the case of the young. The relationships between determined TDN and calculated TDN as they exist in the case of adult and young animals in trials I and II are shown below:

Trial	Animal group	Determined TDN (kg)	Calculated TDN (kg)			
			4409 Cal/kg (Maynard)	%increase over determined	4000 Cal/kg (Brody)	%increase over determined
I	Adult	29.5	32.6	10.5	36.0	22.0
	Young	13.5	14.5	7.4	16.0	18.5
II	Adult	23.0	24.8	7.8	27.4	19.1
	Young	8.9	9.7	9.0	10.7	20.2

It can be surmised from the above that application of Brody's figure viz., 4000 Cal/kg TDN in the calculation clearly overestimates the TDN by 20.6 per cent in the case of the adult (both trials combined) and 19.4 per cent in the case of the young (both trials combined). Application of Maynard's figure viz., 4409 Cal/kg TDN also overestimates the TDN by 9.2 per cent in the case of the adult and 8.2 per cent in the case of the young.

The increased noticed in the calculated TDN over the determined TDN can be explained by the fact that DE determinations take account of losses in digestion only where as in the case of TDN, as customarily calculated, the multiplication of protein by factor 1.36 is eliminated and fat is multiplied by 2.25 assuming carbohydrate as the base (Gross energy of Carbohydrate 4.15 Cal/g, Fat 9.4 Cal/g and Protein 5.65 Cal/g).

From Table 49, it can be seen that when the calculated DE values were divided by both Brody's value of 4000 and Maynard's value of 4409, only the TDN calculated as per Maynard's value closely approaches the determined TDN as indicated below:

Trial	Animal group	Calculated DE Cal/day	Calculated TDN (kg/day)		Determined TDN (kg/day)
			As per Brody	As per Maynard	
I	Adult	127021	31.8	28.8	29.5
	Young	57695	14.5	13.1	13.5
II	Adult	98167	24.6	22.3	23.0
	Young	38066	9.5	8.6	8.9

It is clear that in the calculation of TDN, Maynard's value finds better application than Brody's value. Maynard's value, however, cannot be directly applied to the determined value of DE, since it has been shown to be somewhat variable, though slightly, according to species and type of ration (Crampton et al. 1957; Swift, 1957).

Metabolizable energy

From the derived metabolizable energy values shown in Table 50, it will be seen that the values for the adult and young animals during trial I were on an average: 121603 Cal/day and 53142 Cal/day respectively and those in the second trial, 93317 Cal/day and 34230 Cal/day respectively. The metabolizable energy that the young animals get on an average is only 43.7 per cent of that of the adults in the first trial, the same in the second trial being 36.7 per cent.

Energy values

From the values of Gross energy and Digestible energy detailed in Table 51, it can be seen that the gross energy intakes of adult and young animals per day during trial I on an average were 245214 Cal and 118089 Cal respectively, the same in trial II being 185614 Cal and 91457.1 Cal respectively. Per metabolic body size, the values for adult and young animals were 619 Cal and 618 Cal

respectively in the first trial, the same in the second trial being 469 Cal and 480 Cal respectively.

The DE values given in Table 51 represent on an average 59.4 per cent of the gross energy intake in the case of the adult and 54.1 per cent of the same in the case of the young during trial I. The DE is 59.5 per cent of the gross energy intake of the adult and 46.5 per cent of the same of the young during trial II. It would appear that adults digest gross energy better than the young animals in both the trials, the difference between the two groups in this respect however being statistically significant only in trial II ($P < 0.05$). Benedict (loc. cit.) has observed that 40 per cent of the gross energy intake of 'Jap' was digestible.

From the data presented in Table 52, it can be seen that the metabolizable energy values per day per metabolic body size of adult and young animals during trial I were on an average 310.1 Cal and 278.4 Cal respectively, the same during trial II being 237.3 Cal and 178.7 Cal respectively. It would appear that adult animals get significantly higher ME in both trials ($P < 0.05$). Further, both groups of animals are seen to have received significantly more of ME in trial I than in trial II ($P < 0.01$). Metabolizable energy, when expressed as percentage of gross energy, is found to be on an average 50.4 in the case of

the adult and 45 in the case of the young during trial I, the values for the adult and young during trial II being 50.7 and 37.4 respectively. It is seen that in trial II adults receive significantly higher ME from gross energy as compared with the young ($P < 0.05$).

ME, when expressed as percentage of DE, is found to be on an average 84.8 in the case of the adult and 83.1 in the case of the young during trial I, the values for the adult and young during trial II being 85.4 and 80.3 respectively. Differences in ME values expressed as percentage of DE as between groups and as between trials are not statistically significant. The ME value in the case of 'Jap' (Benedict loc. cit.), as derived, is 170.2 Cal per metabolic body size per day. The ME values expressed as percentage of GE and of DE are 33 and 82.5 percent respectively in the case of 'Jap'.

Maynard (loc. cit.) has reported the per cent DE converted to ME as 82 for all feeds in the case of farm animals. Eighty two per cent has been accepted as the conversion factor by the N.R.C. in the case of cattle. From the present study (Table 52), it is found that the practice of using this conversion factor is applicable to the elephant as well.

According to Joshi (1976), Schiemann et al. (1971), the successors of Kellner and Fingerling at Rostock (East Germany)

have proposed a new and rather simple system of feed evaluation based on extensive research with cattle, sheep, pigs, rabbits and rats extended over a period of several of years. The system consists of a number of equations based on the conventional Weende feed analysis and digestibility coefficients which make it possible to calculate gross energy (GE), digestible energy (DE), metabolizable energy (ME) as well as net energy for fattening (NEF) for individual feeds and rations. The equations for cattle are:

$$\text{GE (kcal/kg)} = 5.72Z_1 + 9.50Z_2 + 4.79Z_3 + 4.17Z_4$$

$$\text{DE (")} = 5.79X_1 + 8.15X_2 + 4.42X_3 + 4.06X_4$$

$$\text{ME (")} = 4.32X_1 + 7.73X_2 + 3.59X_3 + 3.63X_4$$

$$\text{NEF(")} = 1.71X_1 + 7.52X_2 + 2.01X_3 + 2.01X_4$$

In the above equations Z_1, Z_2, Z_3 and Z_4 represent g crude protein, ether extract, crude fibre and nitrogen-free-extract, each per kg respectively and X_1, X_2, X_3 and X_4 represent respectively g digestible crude protein, digestible ether extract, digestible crude fibre and digestible nitrogen-free-extract, each per kg.

The energy values of palm leaf fed to the elephants calculated as per these equations for cattle are given below together with the values obtained during the present study.

	Values obtained as per the 'Rostock' equations	Values obtained during the present study	% variation
GE (kcal/kg)	4262	4355	2.2
DE (")	2290	2589	13.0
ME (")	1973	2208	11.9

From an inspection of the above values, it can be seen that application of the 'Rostock' equations underestimates the GE, DE and ME values of palm leaves fed to the elephants by 2.2, 13.0 and 11.9 per cent respectively. This inference drawn from meagre data is subject to further experimental tests with elephants.

Values obtained for Dry matter intake, DCP and TDN in Kodanad and Guruvayur trials

From a critical comparison of the data obtained from the digestion trials carried out at Kodanad and from the balance experiments conducted at Guruvayur, it is seen that higher values for dry matter intake, DCP and TDN were obtained for both adult and young animals in Kodanad trial as compared with those gathered from Guruvayur trial. The differences noticed in these respects are attributable partly to the small physical size of the palm leaves fed to the animals in Kodanad trials. It has been reported that chopping the fodder enhances feed consumption and digestibility of nutrients (Morrison, 1959; Benedict, loc. cit.). The differences in regard to the adult elephants are attributable

partly also to variations in the age of the animals employed in the two trials. It may be pointed out that Devarajan and Mahesh, each aged 21 years and used in the Kodanad trials, had attained only almost the adult age (vide appendix). It is probable that the nutrient requirements for growth had been superimposed on the maintenance needs of these animals. In the case of young animals, physiological state is another implicating factor involved in the discrepency observed. The young animals employed in the Kodanad trials had been captured only in the recent past and were in the process of being tamed at the time of the feeding experiments. It is quite probable that these, not wholly tamed elephants, showed a metabolic process different from that of fully domesticated animals. Essentially, such an inference will be in keeping with the observation made by Benedict (loc. cit.) according to whom, wild animals may have a somewhat different metabolism from that of the domesticated animals.

Dry matter, DCP, TDN, DE and ME requirements for maintenance and growth

From a critical comparison of the data presented in Tables 39 and 40, it is seen that palm leaf fed at a level of 75 per cent of the ad lib. intake, although satisfies the maintenance requirement of the adult elephant fails to support growth in the young, since one of the two young animals in the group showed a negative balance for nitrogen. Therefore, for arriving at the nutrient

requirements for maintenance (Table 53) and growth (Table 54) the data considered are those obtained respectively on restricted feeding in the case of the adult and ad lib. feeding in the case of the young. From the data presented in Tables 53 and 54 it can be deduced that the Dry matter, DCP, TDN, DE and ME requirements for growth are 31.6, 14.4, 20.6, 20.5 and 17.7 per cent respectively over those for maintenance per metabolic body size.

Slade et al. (1971) have reported the DCP requirements of horses as 58 g/100 kg body weight per day. A DCP requirement of 63.7 g/100 kg body weight per day has been found for the adult elephant in the present study. Stillions and Nelson (1972) have shown that the average DE intake in gelding horses is 33.8 kcal DE/kg/day. The corresponding figure in the adult elephant is found to be 30.6 kcal/kg/day in the present study. From these observations, it can be seen that the DE requirements in kcal/kg body weight per day and DCP requirements in g/100 kg body weight per day of the elephant are essentially identical with those of the horse.

Requirements of Calcium, Phosphorus and Cobalt for maintenance and growth

Values derived from the calcium intakes given in Tables 41 and 42 indicate that 0.474 and 0.625 g of Calcium per day per metabolic body size satisfy the requirements for maintenance and

growth respectively of the elephant. Values derived from the phosphorus intakes presented in Tables 43 and 44 show that for maintenance and growth, 0.172 and 0.227 g of Phosphorus per day per metabolic body size are inadequate, since the adult and growing animals manifested only a negative balance for this element. It would appear that the requirement for phosphorus is greater in the case of the elephant as compared with cattle whose requirements have been reported to be as 0.12 per cent of air dry ration (Maynard, loc. cit.). Obviously, elephants will need a phosphorus supplement when fed exclusively on palm leaf.

Palm leaf fed to the elephants contains 0.334 ppm cobalt. Cobalt constitutes 4.354 per cent of Vitamin B_{12} the concentration of which in blood plasma on an average is found to be 18.05/μg/100 ml (Table 55). Assuming that the entire cobalt supplied through palm leaves is utilized exclusively for the synthesis of Vitamin B_{12} and the blood constitutes approximately 10 per cent of the body weight of the elephant, as in the case of other species of animals (Maynard, loc. cit.), it is found, that the amount of cobalt consumed by the adult and young animals will not only meet their B_{12} requirements but will also leave enough for other purposes.

Brody (1945) has reported that the maintenance needs of all species of warm blooded animals, from mouse to elephant, in terms

of DCP, TDN and DE vary with the metabolic body size ($W_{kg}^{0.73}$) rather than with actual body weight ($W_{kg}^{1.0}$). He has further observed that the maintenance need of DE and of TDN is double the basal energy metabolism and that of DCP four times the protein equivalent of endogenous urinary nitrogen, the NR being 1:8.7.

In the present study, the determined values for DCP, TDN and DE per metabolic body size per day were 5.85 g, 58.2 g and 278 kcal respectively, the NR being 1:9. Based on the relationship of basal calories to endogenous urinary nitrogen (Brody, loc. cit.), values of 1.7 and 1.9 mg nitrogen/Cal basal energy were obtained respectively when the determined and calculated DE were used in the computations. When calculated values for DE were used in the computations the relationship observed viz., 1.9 mg nitrogen/Cal basal energy is found to be close to that of 2 mg nitrogen/Cal basal energy reported for other species by Smuts (Smuts, 1935). According to Maynard (loc. cit.), this relationship of 2 mg nitrogen/Cal basal energy is somewhat variable according to species and age. From the values obtained by Benedict in 'Jap' (Benedict, loc. cit.), Brody (loc. cit.) has deduced the heat production/$kg^{0.73}$ as 122 Cal for the elephant. In the present study 139 and 124 Cal were obtained respectively for adult elephants when determined DE and calculated DE were used, the value deduced from calculated DE being very close to 122 Cal reported by Brody (loc. cit.). On the basis of the

results presented in Tables 53 and 54, Feeding Standards in terms of Dry matter, DCP, TDN, DE and ME have been formulated for the elephant for maintenance and growth. Feeding standards are devised in the form of formulae. In order to give numerical indices to Dry matter, DCP, TDN, DE and ME, the values in the tables were rounded to the nearest intiger before applying in the formulae. The formulae recommended are given below:

	Formulae	
	For Maintenance	For Growth
Dry matter/100 kg body weight in kg	1.2	2.0
Dry matter in g	$108/kg^{.73}$	$142/kg^{.73}$
DCP g/day	$6/kg^{.73}$	$7/kg^{.73}$
TDN g/day	$58/kg^{.73}$	$70/kg^{.73}$
DE Cal/day	$278/kg^{.73}$	$335/kg^{.73}$
ME Cal/day	$237/kg^{.73}$	$279/kg^{.73}$

Haematological values

Haematological data presented in Table 55 indicate that except for Vitamin B_{12} the blood values are essentially identical with those reported in the literature for the elephant as physiological norms (Simon, 1961; Nirmalan et al. 1967; Nirmalan and Nair, 1969, 1971). The concentrations of Vitamin B_{12} in the blood plasma of adult and young elephants are found to be on an average 18.05 and 16.94 /μg/100 ml respectively. As far as could

be gathered from literature, the level of Vitamin B_{12} in the blood of elephant has not been reported before. Adjudged from the concentrations of blood constituents, the experimental subjects have been apparently in sound nutritional state during the course of the study.

SUMMARY

SUMMARY

Stimulated by the results of a digestion trial conducted previously in growing and adolescent elephants, an investigation involving, nitrogen, calcium, phosphorus and energy balance studies was carried out in two young and two adult elephants fed palm leaf ad lib. at first (Trial I) and subsequently at 75 per cent of the ad lib. intake (Trial II) with a view to evolve feeding standards for the elephant for maintenance and growth. Prior to this investigation, the reliability of applying a formula based on body measurements to predict body weights of the elephants as accurately as possible for purposes of their scientific feeding and judicious treatment was examined in 20 animals of varying age, sex and weight. The nutritional status of the elephants under balance trials was assessed in terms of concentrations of some of the well-known blood constituents. From the overall results obtained, the salient inferences drawn were the following:

1. For predicting the body weights of the elephants, formulae devised on the basis of chest girth and neck girth measurements are found to be more accurate than those involving body length, height and chest girth.

2. Adult animals, whether fed palm leaf ad lib. or at restricted level, consume more feed and more dry matter and void more dung dry matter and total urinary solids, as compared with the young elephants under identical conditions.

3. Adult animals digest dry matter, crude protein and nitrogen-free-extract better than the young at both levels of intake, the differences between them in the digestibility of dry matter on restricted level of intake being significant ($P < 0.05$). Restriction of feed intake significantly reduces the digestibility of nitrogen-free-extract ($P < 0.05$) in young animals.

4. Adult animals consume daily more DCP and TDN as compared with the young animals at both levels of intake. Restricted feeding reduces the DCP and TDN intakes of both the adult and young animals, the TDN intakes per metabolic body size of both groups being significantly less than the same observed during ad lib. feeding ($P < 0.01$). The adult animals consume significantly more TDN as compared with the young on restricted feeding ($P < 0.05$).

5. The overall differences in nitrogen balance between the two groups and between the two trials are significant ($P < 0.05$). Adult animals register higher values for positive nitrogen balance as compared with the young on both levels of feeding. Restricted feeding reduces the nitrogen balances in both the groups.

6. Adult animals show significantly higher calcium balance as compared with the young on restricted level of feeding ($P < 0.05$). Between the two levels of intake, significant difference is observed in the case of the young ($P < 0.05$), the animals showing better calcium balance on ad lib. feeding.

7. All animals, irrespective of group or level of intake, show negative balance for phosphorus.

8. Adult animals consume and digest gross energy better than the young in both the trials, the increase in the availability of digested energy per metabolic body size in the case of the adult animals in each trial being significant ($P < 0.05$). Restriction of feed intake significantly reduces the digested energy values in the case of both the groups ($P < 0.01$).

9. Dry matter, DCP, TDN, DE and ME requirements for the maintenance of the adult elephant are: 108g, 6g, 58g, 278 kcal and 237 kcal respectively per unit metabolic body size ($kg^{.73}$) per day.

10. Dry matter, DCP, TDN, DE and ME requirements for the growth of the young elephant are: 142g, 7g, 335 kcal and 279 kcal respectively per unit metabolic body size ($kg^{.73}$) per day.

11. The requirements of calcium for the maintenance and growth of the elephant are: 0.5g and 0.6g respectively per unit metabolic body size ($kg^{.73}$) per day.

12. Palm leaf even when fed ad lib. does not supply enough phosphorus eitner for maintenance or for growth.

13. Palm leaf even when fed at a restricted level provides adequate cobalt for Vitamin B_{12} synthesis and for other physiological purposes.

14. Feeding standards for the maintenance and growth of the elephant are formulated in terms of Dry matter, DCP, TDN, DE and ME values.

15. The concentrations of Vitamin B_{12} in blood plasma of the adult and young elephants are found to be on an average 18.05 and 16.94 /^{u}g/100 ml respectively.

16. Adult and young elephants fed palm leaf maintain sound nutritional status, adjudged from haematological values.

The significance of the above inferences is discussed briefly.

Summary of summary

1. Two formulae based on neck girth and chest girth measurements have been devised to predict the body weights of the elephants to 97 per cent accuracy.

2. It has been shown that whenever palm leaf forms the sole source of feed for the elephant, there is a need for a phosphorus supplement.

3. Feeding standards in terms of Dry matter, DCP, TDN, DE and ME for the maintenance and growth of the elephant have been evolved and recommended in

the form of formulae.

4. The level of Vitamin B_{12} in the blood of the elephant has been reported for the first time.

REFERENCES

REFERENCES

Albritton, E.C. (1954). Standard Values in Nutrition and Metabolism. W.B. Saunders Company, Philadelphia and London.

A.O.A.C. (1970). Official Methods of Analysis. 11th Ed. Association of Official Agricultural Chemists, Washington, D.C.

Anon, (1945). The Elephant in the Tamil Land. Annamalai University, Annamalainagar, Tamil Nadu.

Anon, (1958). 'Gaja Sastra' of Palakapya Muni, Saraswati Mahal Series No. 76. The Tanjore Maharaja Serfoji's Saraswati Mahal Library, Tanjore, Tamil Nadu.

Benedict, F.G. (1936). The Physiology of the Elephant. Carnegie Institution, Washington.

Brody, S. (1945). Bioenergetics and Growth. Reinhold Publishing Corporation, New York.

Clark, E.P. and Collip, J.B. (1925). "A study of Tisdall method for the determination of blood calcium with a suggested modification". J. Biol. Chem. 63: 461.

Crampton, E.W., Lloyd, L.E. and Mackay, V.G. (1957). "The calorie value of TDN". J. Anim. Sci. 16: 541.

Deraniyagala, P.E.P. (1955). Some extinct elephants, their relatives and the two living species. Colombo National Museum of Ceylon.

Evans, G.H. (1910). Elephants and their Diseases. Superintendent, Government Printing, Rangoon, Burma.

Fernando, S.D.A., Jayasinghe, J.B. and Panabokke, R.G. (1963). "A study of the temporal gland of an Asiatic Elephant". Ceylon vet. J. 11: 108.

Fiske, C.H. and Subba Row, Y. (1925). "The colorimetric determination of Phosphorus". J. Biol. Chem. 66: 375.

Gopalan, S. (1962). Elephants - their capture, care and management. The Manager, Publications, Delhi-8.

Hawk, P.B., Oser, B.L. and Summerson, W.H. (1954). Practical Physiological Chemistry. 13th Ed. New York. McGraw-Hill.

Joshi, D.C. (1976). "Energy evaluation of Forages". Indian vet. J. 53: 873.

Kavanagh, F. (1963). Analytical Microbiology. Academic Press, Inc. New York.

Kleiber, M. (1961). The fire of Life. John Wiley and Sons, New York.

Krishnamoorthy, V. (1978). Forest Veterinary Officer, Government of Tamil Nadu, Coimbatore. (Pers. comm.)

Kurt, F. and Nettasinghe, A.P.W. (1968). "Estimation of body weight of the Ceylon Elephant (Elephas maximus)". Ceylon Vet. J. 16: 24.

Laurie, A. (1978). The ecology and behaviour of the greater one-horned rhinoceros. Ph.D. thesis, University of Cambridge.

Maynard, L.A. and Loosli, J.K. (1969). Animal Nutrition. 6th Ed. McGraw-Hill Book Company, Inc. New York.

Mckay, G.M. (1973). Behaviour and ecology of the Asiatic Elephant in Southeastern Ceylon. Smithsonian Contributions to Zoology: 125.

Morrison, F.B. (1959). Feeds and Feeding. 22nd Ed. The Morrison Publishing Company, Clinton, Iowa.

Nair, P.G. (1978). Assistant Forest Veterinary Officer, Government of Kerala, Calicut. (Pers. comm.)

Nettasinghe, A.P.W. (1973). The inter-relationship of livestock and elephants at Thamankaduwa Farm, with special reference to feeding and environment. M.V.Sc. thesis, University of Sri Lanka, Peradeniya.

Nirmalan, G., Nair, S.G. and Simon, K.J. (1967). "Haematology of the Indian Elephant (Elephas maximus)". Can. J. Physiol. Pharmacol. 45: 985.

Nirmalan, G. and Nair, S.G. (1969). "Certain biochemical studies on the blood of Indian Elephants (Elephas maximus)". Res. vet. Sci. 10: 176.

Nirmalan, G. and Nair, S.G. (1971). "Plasma proteins and certain non-protein nitrogenous constituents in the blood of Indian elephants (Elephas maximus)". Br. vet. J. 127: 207.

Olivier, R.C.D. (1978). On the ecology of the Asian Elephant (Elephas maximus Linn.) with particular reference to Malaya and Sri Lanka. Ph.D. Dissertation, University of Cambridge.

Peacock, E.H. (1935). Where big game takes the waters. A hidden watcher at a Burmese 'salt-lick'. J. Bombay Nat. Hist. Soc. 37: 780.

Pillai, N.M. (1978). Conservator (Wild life), Forest Department, Government of Kerala, Trivandrum. (Pers. comm.)

Sandell, E.B. (1950). Colorimetric determination of Traces of Metals. 2nd Ed. Interscience Publishers, Inc. New York.

Shebbeare, E.O. (1958). Soondar Mooni. Victor Gollancz, London.

Sikes, S.K. (1971). The Natural History of the African Elephant. Weidenfeld and Nicolson, London.

Simon, K.J. (1958). "A preliminary study of the urine of elephants of Kerala". Indian vet. J. 35: 345.

Simon, K.J. (1959). "Further studies on the urine of elephants". Indian vet. J. 36: 209.

Simon, K.J. (1961). "Haematological studies on elephants". Indian vet. J. 38: 241.

Simon, K.J. (1962). "Reproduction in Indian elephants under captivity". Kerala Vet. 1: 46.

Sisson, S. and Grossman, J.D. (1953). The Anatomy of Domestic Animals. W.B. Saunders Company, Philadelphia and London.

Slade, L.M., Bishop, R., Morris, J.G. and Robinson, D.M. (1971). "Digestion and absorption of ^{15}N-labelled microbial protein in the large intestine of the horse". Br. vet. J. 127: xi.

Smuts, D.B. (1935). "The relation between the basal metabolism and the endogenous nitrogen metabolism, with particular reference to the estimation of the maintenance requirements of protein". J. Nutrition, 9: 403.

Snedecor, G.W. (1956). Statistical Methods Applied to Experiments in Agriculture and Biology. 5th Ed. The Iowa State University Press, Ames, Iowa, U.S.A.

Stillions, M.C. and Nelson, W.E. (1972). "Digestible energy during maintenance of the light horse". J. Anim. Sci. 34: 981.

Swift, R.W. (1957). "The Caloric Value of TDN". J. Anim. Sci. 16: 753.

Tisdall, F.F. and Kramer, B. (1921). "Methods for the direct quantitative determination of sodium, potassium, calcium and magnesium in urine and stools". J. Biol. Chem. 48: 1.

Vancuylenberg, B.W.B. (1974). The feeding behaviour of the Asiatic elephant in Southeastern Ceylon. M.Sc. thesis, University of Sri Lanka, Peradeniya.

Weigum, L.E. (1972). The problems in the preservation of the Seladang in the Malaysian National Park. M.Sc. thesis, Michigen State University.

Weir, J.S. (1969). "Chemical properties and occurrence on Kalahari sand of salt licks created by elephants". J. Zool. 158: 293.

---oOo---

APPENDIX

APPENDIX

STUDIES ON THE NUTRITIONAL REQUIREMENTS OF THE ELEPHANT (ELEPHAS MAXIMUS)

I. EVALUATION OF THE NUTRITIVE VALUE OF PALM LEAVES (CARYOTA URENS)*

V. Bhaskaran Nair and C.R. Ananthasubramaniam
Department of Nutrition
College of Veterinary and Animal Sciences
Kerala Agricultural University
Mannuthy

...

Literature available on elephant husbandry is confined mainly to the military use of the elephants, their ailments, anatomy, capture and reproduction in captivity (Evans, 1910 and Simon, 1962a, b), determination of their urinary, milk and blood constituents (Simon, 1958, 1959a, b, 1961; Nirmalan et al. 1967 and Nirmalan & S.G. Nair, 1968, 1969, 1971) and to the diagnosis and treatment of certain parasitic infestations (Rajamohanan, 1970; Sundaram et al. 1971, 1972 and Chandrasekharan et al. 1972a, b). As regards their feeding habits, basal energy expenditure and nutrient requirements in relation to body size, very little is known, besides the scattered and limited data reported by Benedict (1936), Brody (1945) and Albritton (1954).

Elephants play a significant role in enriching the forest wealth of Kerala. They are maintained in large numbers by the

---

*Work embodied in the Dissertation submitted by one of the authors (V.B.N.) in partial fulfilment of the requirements for the Senior Officers' Training Course.

State Forest Department, Temple Trusts and by several private parties and individuals and are put to good use for forestwork such as dragging, piling and heaping of timber meant for domestic purposes and for export to foreign countries, besides being employed frequently for adding colour and pomp to ceremonial festivities. Expensive cereals and such other high energy yielding food stuffs constitute part of the ration of these elephants. From the reports available with the Forest Department of the State and with the other sources, it is learnt that the feeding cost of elephants amounts to well over two-thirds of the overall expenditure incurred in their maintenance. Since wild elephants thrive and perform such vital functions as growth, reproduction and lactation by consuming exclusively leaves and barks of trees and shrub fodder, there are good reasons to speculate whether it is not possible to meet the requirements of domesticated elephants by feeding roughage alone. It was thought that an enquiry in this regard may yield the much needed basic information on the nutritive requirements of elephants in terms of Digestible crude protein (DCP) and Total digestible nutrients (TDN) and may also possibly help reduce the maintenance cost of the animals and allow diversion of substantial amounts of cereals for human consumption. Prompted by these pressing considerations a systematic study was carried out to evaluate the nutritive value of palm leaves (Caryota urens), the staple roughage commonly fed to the domesticated elephants in Kerala. The results obtained from the study are reported in the present paper.

Materials and Methods

Materials

Palm leaves inclusive of their stems (mid-ribs and secondary ribs) collected from trees in and around Kodanad in the Malayattoor Forest in the District of Ernakulam, Kerala, formed the material for the study.

Animals

Four elephants named as Devarajan, Mahesh, Shaji and Sunny belonging to the Kerala Forest Department and stationed at Kodanad were used as the experimental subjects for the digestion trial.

Methods

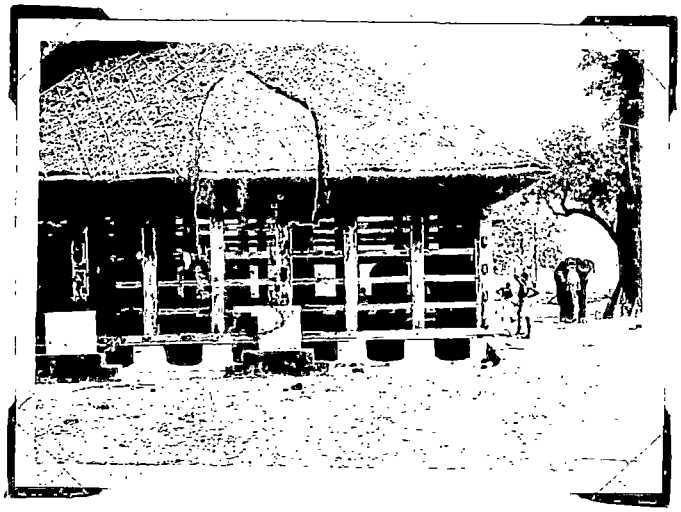
For the determination of the chemical composition of palm leaves and faecal matter, methods discribed in A.O.A.C. (1960) were followed. Records of daily intake of palm leaves and daily out-put of faeces were maintained. All animals except Sunny were weighed before and after the digestion trial with the aid of a weigh-bridge available at the Travancore Rayons Ltd., Perumbavoor, situated nearly 18 KM away from Kodanad. The weight of the elephant Sunny could not be determined as it had been captured only just a little over 2 months prior to the digestion trial and was in the process of being tamed. In order to surmount the difficulty encountered in the determination of the weights of the elephants with the aid of

a weigh-bridge, the validity of applying to this species the formula of $\frac{L \times G^2}{300}$ of Johnson (1939) for cattle was examined in a few animals.

Procedure

From a random collection of 200 palm leaves, 10 leaves were gathered randomly to estimate the leaf-stem ratio. Six leaves from this lot were chopped to a size of 2.5 cm, mixed and quartered to obtain a 5 kg sample which was oven-dried, subsequently pulverised in a K-orr mill, mixed and quartered again to yield a 600 g, sample for the determination of the proximate principles.

The animals were divided equally into two age groups of 21 years and 11 years, the elephants Devarajan and Mahesh with body weights of 2020 kg and 1880 kg respectively representing the former groups and Shaji weighing 1160 kg and Sunny the latter group. All the animals were dewormed with phenothiazine one month before the commencement of the digestion trial. For conducting the digestion trial, the animals were housed in individual cages made of solid timber. The cages were provided with sliding wooden bar shutters and with raised and perforated platforms to fecilitate easy cleaning and for drainage of urine free from faecal matter (Fig. 1). Water for drinking was provided in tanks in the forefront of what is called the Kraal (Fig. 2). The digestion trial lasted for a period of 11 days inclusive of an acclimatisation period of 6 days and a collection period of 5 days. Animals were fed ad lib. palm leaves chopped to 30 cm size. The faecal boluses were quantitatively



gathered manually during defecation. The faecal boluses voided by each animal were weighed individually and a sample of 15 per cent or more by weight taken defecation-wise as per the order of appearance of the boluses was preserved every day during the collection period of 5 days. At the end of the collection period, the samples in respect of each animal were pooled, oven-dried and made use of for chemical analysis. Digestion coefficients were worked out as per the conventional procedure.

Results and Discussion

The leaf-stem ratio was found to be 1:1. This ratio is not of any significance in as much as the elephants consumed as such, the palm leaves supplied to them ad lib. As observed by Evans (loc. cit.), the animals under the present study ate the given fodder incessently all the 24 hours in a day except for 2 to 3 hours during night when they slept.

The data on the body weights of the animals as determined by means of a weigh-bridge and on the corresponding weights calculated in accordance with the Johnson's formula (Johnson, loc. cit.) for cattle are not sufficient enough to establish a relationship between them and to draw accordingly a definite inference therefrom as to the reliability of application of the formula for predicting the actual weights of the elephants. However, the limited data gathered seem to justify the set objective and tend to suggest

the essential need for collecting adequate information in this respect implying thereby that the application of the formuls may prove helpful by providing a clue for making a ready and fairly accurate forecast of the body weights of the elephants.

Results of the chemical analysis of palm leaves are set out in Table-I.

TABLE-I
Chemical composition of palm leaves

Constituents	Percentage
Dry matter	38.8
Crude protein	2.0
Crude fibre	9.3
Nitrogen-free-extract	22.9
Ether extract	1.1
Total ash	3.5
Acid insoluble ash	1.91
Calcium	0.35
Phosphorus	0.23

From the data presented in Table-I, it will be seen that palm leaves are fairly rich in nitrogen-free-extract which constitutes nearly 60 per cent of the dry matter of the leaves. In respect of protein and nitrogen-free-extract, palm leaves seem to resemble coconut tree leaves (Chandra Menon et al. 1968), a roughage as and when available, fed to elephants in the State.

Data on digestion coefficients of nutrients and on total

digestible nutrients obtained in the case of animals aged 21 years and in the case of animals of 11 years of age are detailed in Tables II and III respectively.

TABLE-II

Digestion coefficients of nutrients and Total Digestible Nutrients in palm leaves

(21 year old group)

Nutrients	Digestion coefficients		Mean
	Devarajan	Mahesh	
Dry matter	64.54	67.12	65.83
Crude protein	66.71	79.25	72.98
Ether extract	53.57	59.39	56.48
Crude fibre	30.20	39.59	34.89
Nitrogen-free-extract	82.22	79.58	80.90
Digestible crude protein in kg/100 kg	1.33	1.58	1.45
Total Digestible Nutrients in kg/100 kg	24.29	24.95	24.62
Nutritive ratio	1:17.3	1:14.8	1:16.1

TABLE-III

Digestion coefficients of nutrients and Total Digestible Nutrients in palm leaves

(11 year old group)

Nutrients	Digestion coefficients		Mean
	Shaji	Sunny	
Dry matter	77.02	82.50	79.76
Crude protein	89.10	89.76	89.43
Ether extract	76.45	78.50	77.47
Crude fibre	52.23	63.40	57.81
Nitrogen-free-extract	87.52	90.59	89.05
Digestible crude protein in kg/100 kg	1.78	1.80	1.79
Total digestible nutrients in kg/100 kg	28.57	30.38	29.47
Nutritive ratio	1:15.1	1:15.9	1:15.5

It can be seen from the data assembled in Tables II and III that nutrients in palm leaves are well digested by animals in both the groups, the two growing animals of 11 years of age digesting the nutrients better than the two animals of 21 years of age. Animals within each group show very little difference between them in the digestibility of most of the nutrients. The high digestibility of nutrients in palm leaves is attributable to the small physical size of the leaves fed. This inference is in keeping with

that of Benedict (loc. cit.) who observed that cutting the fodder enhances the digestibility of nutrients. While Devarajan and Mahesh consumed respectively 181.2 kg and 199.7 kg of palm leaves per day, Shaji and Sunny ate daily 153.1 kg and 149.2 kg respectively. As reported by Evans (loc. cit.), palm leaves (Caryota urens) were readily eaten by elephants. The dry matter consumption per 100 kg body weight was found to be 3.5 kg for Devarajan and 4.1 kg for Mahesh as against 5.1 kg for Shaji. It would appear that the dry matter consumption of the elephants per 100 kg body weight is higher than the same of cattle as per Morrison's feeding standard (Morrison, 1959). The nutritive values of palm leaves in terms of DCP and TDN were found to be on an average 1.45 kg and 24.62 kg respectively per 100 kg of leaves for the 21 year age group and 1.79 kg and 29.47 kg respectively for the 11 year age group (Table II and III). The nutritive ratio of palm leaves was found to be 1:16.1 in the case of the 21 year old animals and 1:15.5 in the case of 11 year old animals. It was further observed that while the animals Devarajan and Mahesh showed an increase of 30 and 50 kg respectively in body weight, the animal Shaji registered an increase of 10 kg only during the experimental period of 11 days. The increase in body weight noticed in the case of Devarajan and Mahesh which had attained almost the adult age may be probably due to the fattening effect of palm leaves as observed by Evans (loc. cit.). Although the weight of Sunny had not been determined,

the feed intake, the general appearance and the energetic efficiency displayed by this elephant were suggestive of the animal having gained a slight increase in body weight just as its counterpart, Shaji. From a critical overall assessment of the results obtained during the course of the present study on feed intake and on Digestible crude protein and Total digestible nutrients in palm leaves (Tables II and III), it can be deducted that a DCP and a TDN of around 2.8 kg and 47 kg respectively should satisfy the maintenance requirements of elephants approaching the adult age and weight but will be inadequate for promoting growth in young animals. This tentative inference clearly warrants nitrogen balance trials designed to derive explicit information on the nutrient requirements of elephants for supporting and promoting specific physiological processes.

SUMMARY

The nutritive value of palm leaves (Caryota urens) for elephants was determined in four animals divided equally into two groups of 21 years of age and 11 years of age respectively. Chemical analysis revealed that palm leaves are fairly rich in nitrogen-free-extract and in respect of this nutrient and protein they resemble coconut tree leaves, a roughage, as and when available, fed to elephants in Kerala. From the results of a digestion trial carried out with palm leaves, the following inferences were drawn tentatively:

1. The nutrients in general in palm leaves are well digested by the elephants, the growing young animals of 11 years of age digesting the nutrients better than animals of 21 years of age.

2. The dry matter consumption of elephants per 100 kg body weight is higher than the same of cattle.

3. A DCP and a TDN of around 2.8 kg and 47 kg respectively should satisfy the maintenance requirements of elephants but will be quite inadequate for promoting growth in the young.

4. A nitrogen balance trial is indicated.

ACKNOWLEDGEMENT

The authors are indebted to Dr. P.G. Nair, Dean, College of Veterinary and Animal Sciences, Kerala Agricultural University, Mannuthy, for permission to publish the results of this study, Dr. K. Chandra Menon, Professor of Animal Husbandry (Retired) for guidance and supervision, Sri. M.P. George, the then Chief Conservator of Forests, Kerala, for affording necessary facilities at Kodanad and to Sri. T.K. Deevakaran, the then Divisional Forest Officer, Malayattur and his staff for the help rendered in the conduct of the digestion trial.

REFERENCES

Albritton, E.C. (1954). Standard values in Nutrition and Metabolism. W.B. Saunders Company, Philadelphia and London.

A.O.A.C. (1960). Official Methods of Analysis. 9th ed. Association of Official Agricultural Chemists, Washington, 4DC.

Benedict, F.G. (1936). The physiology of the Elephant. Carnegie Institution of Washington. Pub. 474.

Brody, S. (1945). Bioenergetics and growth. Reinhold Publishing Corporation, 330 West Forty-Second Street, New York (USA).

Chandra Menon, K., C.R. Ananthasubramaniam and K. Eswarankutty (1968). Paper presented at the ICAR Workshop on 'Agricultural By-products and Industrial waste materials for evolving economic rations for Livestock' held at the Kerala Veterinary College and Research Institute, Mannuthy, Trichur.

Chandrasekharan, K., Sundaram, R.K. and Peter, C.T. (1972a). Indian Vet. J. 49 (9) : 857.

Chandrasekharan, K., Prabhakaran, T. and Sundaram, R.K. (1972b). Kerala J. vet. Sci. 3 (2) : 190.

Evans, G.H. (1910). Elephants and their diseases. Superintendent, Government Printing, Rangoon, Burma.

Johnson, D.W. (1939). Extension Folder 70, Minn. Agr. Ext. Div. U.S.A.

Morrison, F.B. (1959). Feeds and feeding. The Morrison Publishing Company, Clinton, Iowa, U.S.A.

Nirmalan, G., S.G. Nair and K.J. Simon (1967). Can. J. Physiol. Pharmacol. 45 : 985.

Nirmalan, G. and S.G. Nair (1968). Ceylon vet. J. 16 : 16.

Nirmalan, G. and S.G. Nair (1969). Res. vet. Sci. 10 : 176.

Nirmalan, G. and S.G. Nair (1971). Br. vet. J. 127 : 207.

Rajamohanan, K. (1970). Kerala J. vet. Sci. 1 (1) : 73.

Simon, K.J. (1962a). Kerala vet. 1 : 110.

Simon, K.J. (1962b). Kerala vet. 1 : 46.

Simon, K.J. (1958). Indian vet. J. 35 : 345.

Simon, K.J. (1959a). Indian vet. J. 36 : 209.

Simon, K.J. (1959b). Indian vet. J. 36 : 500.

Simon, K.J. (1961). Indian vet. J. 38 : 241.

Sundaram, R.K., Chandrasekharan, K. and Madhavan Pillai, K. (1971). Kerala J. vet. Sci. 2 (1) : 55.

Sundaram, R.K., Padmanabha Iyer, R., Peter, C.T. and Alwar, V.S. (1972). Indian vet. J. 49 (1) : 1.