AN ABSTRACT OF THE THESIS OF

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Abstract approved :

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An evaluation was made on the nutritive value of tropical forages and by-product feeds for rabbit production. Digestibility of nutrient fractions, feed preferences, growth, combination of forages, supplementation of micro and macro nutrients and/or effects of drying temperature on the quality of four groups of forages, namely woody legumes (WL), non-woody legumes (NWL), agricultural by-products (AGBP) and grasses, and by-product feeds such as rice bran and wheat bran were studied. Animals used were crossbred (Flemish Giant x New Zealand White) or pure New Zealand White rabbits. The roles of fiber on the bioavailability of nutrients and their relationships to the inherent characteristics of tropical plants were also studied.

Composition, palatability and digestibility of nutrients of the forages were dependent on the species of plants, but were generally highest in the WL and poorest in grasses. Feeding leucaena and sesbania (WL group) produced the highest bodyweight gain (BWG) and efficiency of feed utilization (FCR) among the forage species. The combination of leucaena with papaya leaves or elephant grass improved BWG by 43 and 58 % and FCR by 7 and 17 %, respectively.

The rate of depression of forage quality was dependent on the drying temperature and the forage species. Calliandra and leucaena,

which have the highest tannin contents, underwent the most severe reduction in their nutrient digestibility.

Inclusion of rice bran up to 60 % in the diet produced comparable growth performance with the control diet. Supplementation of micro and macro nutrients to the rice bran in the forage-feeding system improved growth significantly.

The rate of depression of nutrient digestibility by the indigestible ADF content differed between nutrients or between forage species. Poorest nutrient digestion of grasses is associated with their high content of indigestible fiber, which is related to the properties of plants with the C-4 photosynthetic pathways.

The reproductive and growth performance of rabbits fed a 16 % crude protein (CP) alfalfa-wheat bran diet were comparable to those receiving 21 % CP containing soybean meal.

In conclusion, this study indicates that a simple diet of forages and grain-milling by-products, with no cereal grain and protein supplements, can be converted into high quality meat through rabbit production. The findings in this study can be applied to Indonesian conditions, and probably other tropical areas, for the selection of feedstuffs which will maximize the efficiency of small scale rabbit production under village conditions.

EVALUATION OF TROPICAL FORAGES AND BY-PRODUCT FEEDS FOR RABBIT PRODUCTION

by

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I shall pass through
this world but once.
Any good therefore
that I can do or any
kindness that I can
show to any human being
let me do it now.
Let me not defer or
neglect it for I shall
not pass this way again

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PREFACE

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I certify that thesis has not already been submitted for any degree and is not being currently submitted for any other degree.

I certify that any help received in preparing this thesis and all sources used have been acknowledged to the best of my understanding in this thesis.

May, 1987 Yono C. Raharjo

CONTRIBUTION OF AUTHORS

Dr. N.M. Patton is Director of the OSU-Rabbit Research Center. He was involved in the planning of the experiments, discussions of the results and also diagnosis of the diseases.

K. Supriyati, M.Sc., is a member of the Indonesian Feed Information Center. Her interest is in collection of data including composition and quality of feedstuffs for animals. She was involved directly with the preparation and chemical analysis of the materials used in the experiments, particularly those forages in Chapter II and III. She was also involved in the discussion of proposals and results of the experiments.

Dr. B. Tangendjaja is one of the leading scientists in the optimization of rice bran utilization for animals. He contributed some ideas for conducting a research on the use of rice bran in rabbits. He was actively involved in the discussion of the research proposals and results interpretation of the experiments conducted in Chapter VI.

Ir. S. Yuhaeni and M.E. Siregar, M.S., are members of the Department of Agrostology. They grew, harvested and prepared the forages for the studies conducted in Chapter VII. They were also actively involved in the preliminary experiments and discussions of the results.

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CHAPTER I

INTRODUCTION

Protein deficiency in humans is common in developing countries, particularly in rural areas. Indonesia, a nation consisting of 13,000 islands in South East Asia and a population of 170 million people, is no exception. A substantial protein-energy deficiency, particularly among the vulnerable groups (children, pregnant and lactating women), was observed in Indonesia (LIPI, 1968). Abunain (1979) estimated that about 9 million Indonesian preschool children suffered from protein-energy malnutrition. This can retard both mental and physical development (Karyadi, 1983). Malnutrition may be due in part to the imbalanced energy:protein ratio since the staple food source is usually rice, in which the crude protein (CP) content is low (7 - 8 %). It is therefore necessary to make up the protein shortfall by supplementation. The potential for meeting this protein deficit from ruminant meat in the near future is not optimistic, because of their low reproductive rate. Poultry and litter producing animals, such as swine and rabbits, have a high reproductive capacity and rapid growth rate. Swine and poultry require high quality feeds, which are in short supply in Indonesia. Additionally, swine production has limited feasibility because of the majority of the population is Moslem.

Rabbits have a high biological potential for meat production. Theoretically, one doe can produce 10 litters per year. With an average of 8 rabbits per litter and carcass weight of 1 kg per rabbit at market age, one doe can yield 80 kg of dressed rabbit carcass per year. Cheeke and Patton (1979) computed that rabbit can produce five time more meat than cattle from the same amount of an alfalfa-based diet.

Specific merits of rabbit production and its place in developing countries have been reviewed (Owen, 1981; Lebas, 1983; Cheeke, 1986; Cheeke et al, 1987). A particularly attractive aspect, in relation to village rabbit production, is that rabbits do not have to compete with humans for feed sources, nor directly with the traditional species used in the intensive animal industry. Rabbits are able to grow, reproduce and lactate on high forage diets that can be harvested locally. Supplementation with by-products, such as rice bran, which can be obtained locally, means that the system is self sufficient and low cost. Because of their small size, rabbits require very little space and thus, rabbit is a suitable choice for a small scale backyard farming system. Cages can be made almost entirely from split bamboo (Plate 1) and other local materials at little or no cost. A split bamboo floor is apparently better than a wire cage floor in terms of providing support and preventing sore hocks (Cheeke, 1983a). Rabbit manure and fur are potentially a cash resource and this can be used to purchase rice bran or other needs. Surplus rabbits can be sold to other potential producers or food processors and it is likely that this will be a source of income in the future. Furthermore, rabbits can be looked upon as a 'biological refrigerator'. The carcass yield of about 1 kg per fryer is sufficient meat to provide a family of at least 6 in a single meal. Storage of meat under the difficult warm, humid conditions of the tropics, or in the areas where refrigerators are still a luxury, is therefore not a major consideration.

In 1981, the Indonesian Government, through the Directorate General for the Livestock Services, initiated a project to build rabbit breeding centers in 17 out of 27 provinces in the country. The rabbits were then distributed to 709 counties spread all over the country (DGLS, 1981).

The project is aimed at improving the nutritional status of village people, who have little money and poor quality diets. The target of the project is to increase animal protein consumption to at least 8 kg per head per year.

A program called 'the mini meat factory', introduced by Suriaatmadja and developed by YAPIKA (Foundation for family nutritional improvement), was adopted for improvement of village nutrition (Suriaatmadja, pers. comm.). The concept of the program includes the distribution of 3 does and 1 buck to each assigned family in the village. By following a set breeding schedule, a doe is bred each month. They can be expected to produce litters at the proper intervals so that a family can eat at least one fryer rabbit per week all year-round (Rollos and Tuwo, 1982). Through improvement of management, such as a more frequent breeding schedule, this program can be expected to produce more meat and/or income for the raisers. In brief, as Cheeke (1983a) stated.....' the situation in Indonesia provides a unique opportunity for development of rabbit production. There is a high human population density, a shortage of protein at the village level, and an abundance of forages and by-products which could be converted by rabbit to human food. There is great enthusiasm for rabbit production, beginning at the top with the President....Therefore, rabbit production may have more potential in Indonesia than almost anywhere else in the world....'.

Undoubtedly, tropical rabbit production depends primarily on the feeding of high forage diets. Various forages are abundantly available all year-round particularly in the wet, high rainfall areas. This ensures a continuous supply of feed to the animals. From the chemical composition point of view, their leaves, particularly of the legume species, offer a considerable potential as a major source of energy, crude protein, minerals and vitamins for herbivorous animals (Crowder and Chedda, 1982; Telek, 1983). Rabbits utilize those nutrients, particularly proteins and B vitamins, efficiently because of the nature of their digestive process. Forages contain a high level of fiber. Fiber is essential in rabbit diets for normal functioning of the gut (Lang, 1981b; Cheeke, 1983b; Ehrlein, 1983) and the prevention of cecal-colonic hypomotility (Laplace, 1978), enteritis (Colin et al, 1976; Cheeke and Patton, 1980; Borrielo and Carman, 1983), trichobezoirs and hair pulling (Cheeke et al, 1987). The low digestibility of fiber in rabbits (Slade and Hintz, 1969), is compensated for by a high feed intake, and a selective separation of fiber in the colon and its rapid excretion (Cheeke, 1983). Thus the requirement of energy, protein and other nutrients can be largely derived from a high intake of forages. An improvement in fiber utilization could be significant in increasing the efficiency of rabbit production.

Although tropical forages have a considerable potential as feedstuffs for rabbit production, some limiting factors exist. Great variations occur in the nutrient content among species, among cultivars within species, and among stage of growth within cultivars (Crowder and Chedda, 1982). Secondary substances, such as oxalates in grasses (Bogdan, 1977); tannins in agricultural by-products and legumes (Gohl, 1981; Pierpoint, 1983; Aw and Swanson, 1985) and other toxic compounds such as cyanide, mimosine and hemagluttinins (Cheeke and Shull, 1985) are often found and cause growth depression and mortality. Consequently, great variations in feeding value, including the voluntary intake by the animals, exist among individual forages. Furthermore, the information on the feeding value of these forages, including nutrient content, digestibility, palatability and growth response in rabbits, are scanty. Therefore in this study, experiments were conducted to provide as much information on the feeding value of tropical forages as possible.

In this series of experiments, forages were classified into 3 groups : woody and non-woody legumes, agricultural by-products, and grasses. In each experiment, an attempt was made to include these representatives of 3 groups into the experimental treatments. Digestibilities were determined because this method is not only important as the screening method for the quality of individual forages, but also can be carried out in a large number of forages in a relatively short time. Digestibility trials were conducted with adult and growing rabbits. Since digestibility values do not reflect the overall quality in terms of growth performance, and the presence of toxic compounds in some cases is not detected in the digestibility trials, growth trials are needed. For example, leucaena contains the toxic amino acid mimosine, which is highly absorbed in the intestine (Szyszka et al, 1984). Thus, while digestibility values are not affected, or even increased in the presence of mimosine, the growth of animals may be depressed.

The importance of voluntary intake in animal production is well recognized (Johnson et al, 1971; Church and Pond, 1978; Cordova et al, 1978). In the case of grasses, there is a high correlation between dry matter intake and digestibility of dry matter and energy (Minson, 1971, 1972). However, large variations of intakes occur between forage species, owing to the chemical and physical properties of each forage that affect palatability (Harris et al, 1983), regardless of the digestibility. Tannins, in many legumes (Cheeke and Shull, 1985) and oxalates, in many tropical grasses (Crowder and Chedda, 1982) are among those factors depressing voluntary intake. Hard, hairy and prickly leaves are not palatable to the rabbits. Imperata cilindrica and Kilinga monocephala, which are sharp and hairy are hardly consumed by rabbits (Sitorus et al, 1982). In addition, a high fiber content, which is responsible for lower digestibility of dry matter and energy, was reported to increase retention time of ingesta and decrease rate of passage of digesta in sheep (Thornton and Minson, 1973). This probably would not happen in rabbits because of the structure of their gastro intestinal system. Rabbits are able to consume a large quantity of a fibrous diet without any adverse physiological effects (Lang, 1981a, Cheeke, 1983b, Lebas, 1983). Therefore, measurement of voluntary intake of each forage is equally important as the measurement of nutritive value.

Rabbit feeding systems at the village level involve feeding combinations of different forages in variable proportions (Plate 2). The combination may be beneficial to some extent, i.e. the concentration of possible toxicants present is diluted and a deficiency of nutrients from one forage may be balanced from the other forage. Nonetheless, this practice can not detect the potential or detrimental effect of a particular or individual forages and can not be expected to result in efficient forage utilization nor consistent production. Combinations of forages, at certain ratios, may be beneficial if the nutritive value of the individual forages is known.

In commercial scale rabbit production, it is most common that feed is given in the pelleted form. Forages must be dried prior to pelleting. Drying and/or pelleting could be an impotant means to transfer good quality forages from one area to another where those particular forages are lacking. Heat processing of forages may cause some changes on the nutritive value. Not only can it increase the quality, but also it can be potentially detrimental. Drying may depress the digestibility of dry matter and metabolisable energy (Crowder and Chedda, 1982), and may increase voluntary intakes (Church and Pond, 1978) and reduce the availability of amino acids (Pusztai, 1985). Cheeke and Carlsson (1978) showed an increased nitrogen content in the acid and neutral detergent fiber fractions of alfalfa, amaranthus and chenopodium when they were air dried. Heat treated alfalfa depressed growth of rabbits (Lebas, 1975). Inclusion of 40 % (Parigi-Bini et al, 1984) or 60 % (Tangendjaja et al, 1985) leucaena in pelleted rabbit diets decreased protein digestibility from 78 to 52 or from 73 to 40 %, respectively.

A better understanding of effect of processing can improve forage utilization.

Equally important as forages, for rabbit production, are by products from food processing. Included in this group are rice bran, copra meal, groundnut meal, corn bran, wheat bran, soybean curd waste, etc. Some of them, particularly rice bran, have been used as a concentrate (supplement) to forage rabbit feeding.

Rice bran is a major by-product from rice milling. It constitutes about 10 % of paddy rice and is available in relatively large quantities in the major rice-growing areas in the world. In Indonesia, for example, rice is a major human food. About 22 million tons of paddy rice are produced annually (Tempo, 1986), meaning that almost 2.2 million tons of rice bran are available every year. It contains approximately 12 % crude protein, 12 % crude fiber and 12 % ether extract(Maust et al, 1972). Thus it can be used as a moderately good source of protein, energy and fiber, which are necessary for rabbit growth. Rice bran is cheap and can be found almost anywhere in Indonesia. Rice bran has been widely and successfully used at high levels in poultry diets (Kratzer et al, 1974; Piliang et al, 1982). Nevertheless, rice bran has also been reported to contain some anti-nutritive factors, including low nutrient digestibility and low availability of phosphorus (Kratzer and Payne, 1977; Barber and de Barber, 1980; Corley et al, 1980). In addition, when contaminated with rice hulls, rice bran contains a higher indigestible fiber and silica content and consequently the nutrient digestibility value is lower (Maust et al, 1972). Through some manipulations, as have been succesfully practiced in poultry, including supplementation with macro and micro minerals and amino acids, a more efficient utilization of rice bran in rabbit diets can be expected.

Beside the evaluation of tropical forages, this study also included the evaluation of a by-product-forage diet based on wheat bran and alfalfa meal. An alfalfa-wheat bran based diet, with no cereal grain, may reduce feed cost from conventional cereal-grain diet. Sanchez et al (1985) reported that such a diet, containing 16 % crude protein, gave performance of young rabbits equal to that of diets with 21 % soybean meal, containing 21 % crude protein. No data, however, were reported on rabbits during gestation and lactation. In addition, supplementation of urea, which is controversial (King, 1971; Cheeke, 1978; Semertzakis, 1978), may be expected to improve performance in adult rabbits in which the cecum is more developed (Houpt, 1971; Lang, 1981a).

In summary, the objectives of this study were to evaluate (1) the utilization by rabbits of some tropical forages and by- product feeds, in terms of composition, intake, digestibility and growth performance. (2) the effect of combination of forages on rabbit growth; (3) the effect of heat treatment on the quality of tropical forage legumes; and (4) the utilization of alfalfa-wheat mill run based diets containing 16 % crude protein, with or without urea or methionine supplementation, on the reproduction and growth of rabbits.

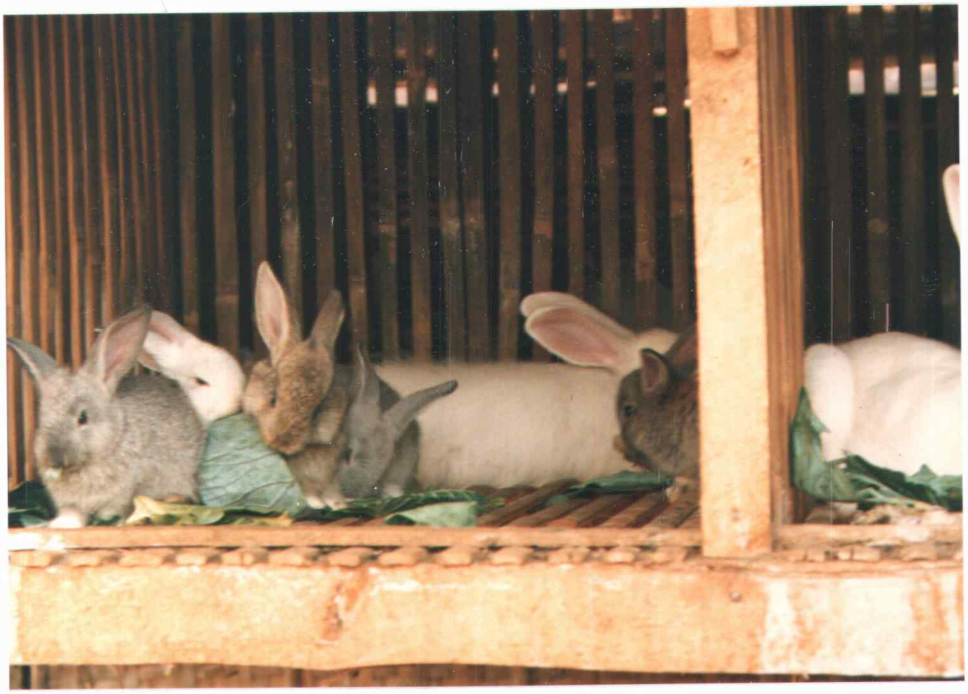

Plate 1. Split bamboo cages usually used for rabbit raising in the village area.

Plate 2. Typical forages used for feeding rabbits in the village area.

REFERENCES

Abunain, D. 1979. Nutritional Intakes in Indonesia. Proc. Third Biennial Meeting of AESSEA, Kuala Lumpur, Nov. 23-30th.

Aw, T.L. and B.G. Swanson. 1985. Influence of tannin on Phaseolus vulgaris protein digestibility and quality. J. Food Sci. 50:67-71.

Barber, S. and C.B. deBarber. 1980. Rice bran : Chemistry and Technology. In 'Rice : Production and Utilization' Luh, B.S. editor). pp. 790-862. AVI Publ. Co. Inc., Westport, Connecticut.

Bogdan, A.V. 1977. Tropical Pastures and Fodder Plants (Grasses and Legumes). Longman, London and New York.

Borrielo, S.P. and R.J. Carman. 1983. Association of Iota-like toxin and Clostridium spiriforme with spontaneous and antibiotics-associated diarrhea and colitis in rabbits. J. Clinical Microbiol. 17:414-418.

Cheeke, P.R. 1978. Use of urea and other non-protein nitrogen by the rabbit. J. Appl. Rabbit Res. 2(1):6-7.

Cheeke, P.R. 1983a. Rabbit production in Indonesia. J. Appl. Rabbit Res. 6:80-86.

Cheeke, P.R. 1983b. The significane of fiber in rabbit nutrition. J. Appl. Rabbit Res. 6:103-106.

Cheeke, 1986. Potentials of rabbit production in tropical and subtropical agricultural system. J. Anim. Sci. 63:1581-1586.

Cheeke, P.R. and R. Carlsson. 1978. Evaluation of several crops as sources of leaf meal: Composition, effect of drying procedure and rate growth response. Nutr. Rep. Inter. 18:465-473.

Cheeke, P.R. and N.M. Patton. 1979. Utilization of alfalfa by rabbits. In: The Domestic Rabbit: Potentials, Problems and Current Research. Proc. Symp. 71st Ann. Meet. ASAS. U.A., Tucson, Arizona, pp. 25-28. Published by OSU Rabbit Research Center.

Cheeke, P.R. and N.M. Patton 1980. Carbohydrate overload of the hind gut - A probable cause of enteritis. J. Appl. Rabbit Res. 3(3):20-23.

Cheeke, P.R. and L.R. Shull. 1985. Tannins and polyphenolic compounds. In 'Natural Toxicants in Feeds and Poisonous Plants'. pp. 322-357. AVI Publ. Co., Inc., Westport, Connecticut.

Cheeke, P.R., M.A. Grobner and N.M. Patton. 1986. Fiber digestion and utilization. J. Appl. Rabbit Res. 9:25-30.

Cheeke, P.R., N.M Patton, S.D. Lukefahr and J. M. McNitt. 1987. Rabbit Production. Sixth edition. The Interstate Printers and Publishers. Danville, Illinois.

Colin, M., C. Maire, J. Vaissaire and L. Renault. 1976. Experimental study on replacement of crude fiber by mineral ballasts (sand and mica) in rabbit diets. Rec. Med. Vet. 152:457-465.

Cordova, F.J., J.D. Wallace and R.D. Pieper. 1978. Forage intake by grazing species : A review. J. Range Mgmt. 31:430-438.

Corley, J.R., D.H. Baker and R.A. Easter. 1980. Biological availability of phosphorus in rice bran and wheat bran as affected by pelleting. J. Anim. Sci. 50:286-292.

Crowder, L.V. and H.R. Chedda. 1982. Tropical Grassland Husbandry. Longman, London and New York.

DGLS. 1981. A Minor Livestock Development Plan for Low Income People. Directorate General for Livestock Services. Dept. of Agric. Jakarta. Indonesia.

Ehrlein, H.J., M. Reich and M. Schwinger. 1983. Colonic motility and transit of digesta during hard and soft feces formation in rabbits. J. Physiol. 338:75-86.

Gohl, B. 1981. Tropical Feeds : Feed Information, Summaries and Nutritive Value. FAO Animal Production and Health Series. No. 12, pp. 302-307. FAO of the UN., Rome, Italy.

Harris, D.J., P.R. Cheeke and N.M. Patton. 1983. Feed preference studies with rabbits fed fourteen different fresh greens. J. Appl. Rabbit Res. 6:121-122.

Harris, D.J., P.R. Cheeke and N.M Patton. 1984. Evaluation of Black Locust leaves for growing rabbits. J. Appl. Rabbit Res. 7:7-9.

Houpt, T.R. 1967. Urea metabolism in the rabbit. Fed. Proc. 20: 349.

Johnson, W.L., W.A. Hardison, A.L. Ordaveza and L.S. Castillo. 1968. Factors affecting voluntary intake by cattle and water buffalo. J. Agric. Sci. 71:67-71.

Jones, W.T. and J.L. Mangan. 1977. Complexes of the condensed tannins of sainfoin (Onobricis viciifolia Scop.) with fraction 1 leaf protein and with submaxillary mucoproteins and their reversal by polyethylene glycol and pH. J. Sci. Food Agric. 28:126-136.

Karyadi, D. 1983. Role of Nutrition in National Development. Speech delivered during Professorial Promotion. Bogor Agric. Univ. July 23rd.

King, J.O.L. 1971. Urea as a protein supplement for growing rabbits. Brit. Vet. J. 127:523-528.

Kratzer, F.H. and C.G. Payne. 1977. Effect of autoclaving, hot water treating, parboiling and addition of ethoxyquin on the value of rice bran as a dietary ingredients for chickens. Bri. Poult. Sci. 18:475-482.

Kratzer, F.H., L. Earl and C. Chiaravanont. 1974. Factors influencing feeding value of rice bran for chickens. Poult. Sci. 53: 1795-1800.

Lang, J. 1981a. The nutrition of the commercial rabbit. 1. Physiology, digestibility and nutrient requirements. Nutr. Abstr. Rev. 51:197-224.

Lang, J. 1981b. The nutrition of the commercial rabbit. 2. Feeding and general aspects of nutrition. Nutr. Abstr. Rev. 51(5): 287-299.

Lebas, F. 1983. Small scale rabbit production. Feeding and management system. World Anim. Rev. 46:11-17.

Lebas, F., J. Dolz and A. Espaignet. 1975. Effect of drying conditions of dehydrated lucerne on growth performances of rabbits receiving diets containing lucerne. Annal. Zootech. 24:144.

LIPI. 1968. Workshop on Food. Indonesian Institute of Sciences. Jakarta, May 27th - June 1st.

Maust, L.E., W.G. Pond and M.L. Scott. 1972. Energy value of cassava-rice bran diet with or without zinc for growing swine. J. Anim. Sci. 35:953-957.

Minson, D.J. 1971. The digestibility of voluntary intake of six varieties of Panicum. Aust. J. Exptl. Agric. Anim. Husb. 11: 18-25.

Minson, D.J. 1972. The digestibility and voluntary intake by sheep of six tropical grasses. Aust. J. Exptl. Agric. Anim. Husb. 12:21-27.

Owen, J.E. 1981. Rabbit meat for the developing countries. Wrld. Anim. Rev. 39:2-11.

Parigi-Bini, R., M. Cinetto and N. Carotta. 1984. Digestibility and nutritive value of Leucaena leucocephala in rabbit diets. III World Rabbit Congress. 1: 399-407. Rome, Italy.

Pierpoint, W.S. 1983. Reaction of phenolic compound with proteins and their relevance to the production of leaf protein. In: Leaf Protein Concentrates (L. Telek and H.D. Graham, eds), pp. 235-267. AVI Publ.Co. Inc., Westport, Connecticut.

Piliang, W.G., H.R. Bird and M.L. Sunde. 1982. Rice bran as a major energy source for laying hens. Poult. Sci. 61:357-363.

Pusztai, A. 1985. Constraints on the nutritional utilization of plant proteins. Nutr. Abstr. Rev. 55(7):363-369.

Rollos, H. and D. Tuwo. 1982. Feed yourself by rabbit raising. Tool Foundation. Amsterdam.

Sanchez, W.K., P.R. Cheeke and N.M. Patton. 1985. Effect of dietary crude protein level on the reproductive performance and growth of New Zealand White rabbits. J. Anim. Sci. 60: 1029-1039.

Semertzakis, N. 1978. Utilization of non-protein nitrogen by adult female rabbits for maintenance during pregnancy. Nutr. Abstr. Rev. (B) 48:198(1548).

Singh, B. and S.S. Negi. 1986. Effect on wool production of supplementing Black Locust (Robinia pseudoacacia) and biul (Grewia optiva) leaves ad libitum to a concentrate diet of Angora rabbits. J. Appl. Rabbit Res. 9:159-163.

Sitorus, P., S. Sastrodiharjo, Y.C. Raharjo, I.G. Putu, Santoso, B. Sudaryanto and A. Nurhadi. 1982. Report of the survey on the rabbit raising in Java. Central Research Institute for Animal Science, Box 123, Bogor, Indonesia.

Slade, L.M.and H.F. Hintz. 1969. Comparisons of digestion in horses, ponies, rabbits and guinea pigs. J. Anim. Sci. 28:842-843.

Szyszka, M., U. ter-Meulen, B. Cheva-Isarakul, S. Posri and N. Potikanond. 1984. Results of research on leucaena as an animal feed in West Germany. Leucaena Res. Rep. 5:5-11.

Tangendjaja, B., Y.C. Raharjo and J.B. Lowry . 1985. Evaluation of Leucaena leaf meal and its toxicity to rabbits. Research report. Research Institute for Animal Production. Box 123, Bogor, Indonesia.

Telek, L. and F.W. Martin. 1983. Tropical plant for leaf protein concentrates. In: Leaf Protein Concentrates (L. Telek and H.D. Graham, eds.), pp.81-116. AVI Publ. Co., Ins., Wesport, Connecticut.

Tempo. 1985. We and Rice. Tempo magazine. (Indonesia) 38:12-18.

Thornton, R.F. and D.J. Minson. 1973. The relationship between apparent retention time in the rumen, voluntary intake and apparent digestibility of legume and grass diets in sheep. Aust. J.

CHAPTER II

EVALUATION OF TROPICAL FORAGES AND BY-PRODUCT FEEDS FOR RABBIT PRODUCTION

1. NUTRIENT DIGESTIBILITY AND EFFECT OF HEAT TREATMENT[1,2]

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CHAPTER II

EVALUATION OF TROPICAL FORAGES AND BY-PRODUCT FEEDS FOR RABBIT PRODUCTION

1. NUTRIENT DIGESTIBILITY AND EFFECT OF HEAT TREATMENT*

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SUMMARY

A number of tropical forages, including five woody legumes, seven non-woody legumes, seven grasses and one agricultural by-product were evaluated for their nutrient composition and digestibility in rabbits. Twenty four crossbred (Flemish Giant x New Zealand White) rabbits of 8 month old were used. Four individual rabbits were used for each test forage, which was hand-chopped and offered fresh for 9 days. Forage intake and feces excretion were recorded during the last 5 days. When grasses were tested, 30 g/day concentrate diet was given to each rabbit. For some forages, the effect of drying and pelleting was also studied. Analyses were made on dry matter (DM), gross energy (GE), crude protein (CP), acid and neutral detergent fiber (ADF and NDF), ash, calcium (Ca) and phosphorus (P).

Large variations in the composition, feed intake and nutrient digestibility occurred depending on forage species. Woody legumes had the highest nutrient composition, digestibility and palatability. Their digestibility values for DM, GE and CP ranged from 69.5 to 79.3, 65.8 to 77.5 and from 64.2 to 83.9, respectively. Grasses had very low

nutritional value, which may be related to their high fiber content. Significant and negative correlations were observed between ADF or NDF with the DM intake and with the digestibility of GE or CP. The corresponding nutrient digestibility values for grasses ranged from 12.3 to 46.3, 9.4 to 45.2 and from 5.6 to 64.6 % respectively. Non-woody legumes and agricultural by-product were intermediate between woody legumes and grasses. Their nutrient digestibility values averaged 50 %. Regardless of the species of forage, CP was generally the most digestible nutrient category. For most forages, the digestibility values of Ca and P were negative. Drying and pelleting decreased the nutrient digestibility values, particularly of the woody legumes, probably because of heat-stimulated browning reactions and protein-tannin complex formation.

INTRODUCTION

With the increasing scarcity of animal proteins and the high cost of commercial animal feed, particularly in developing countries, forages may play an important role as a high quality human food after being converted into meat (Owen, 1976; Cheeke, 1983; Farrell and Raharjo, 1984). Forages are cheap and abundantly available all year in high rainfall tropical countries, such as Indonesia. The chemical composition of their leaves offers considerable potential as the major source of nutrients for herbivorous animals (Skerman, 1977; Telek, 1983). The potential of forages is particularly significant for rabbits, an emerging livestock species (Cheeke and Patton, 1979) that is capable of digesting leaf proteins effectively (Slade and Hintz, 1969; Cheeke and Myer, 1975). Hypothetically, Cheeke and Patton (1979) computed that rabbits can produce five times more meat than cattle from the same amount of an alfalfa-based diet. High fiber material which is usually a constraint in poultry diets is beneficial to rabbits for preventing enteritis (Cheeke and Patton, 1980). The role of fiber in rabbit nutrition is discussed elsewhere (Lang, 1981; Cheeke, 1983b). Furthermore, Lebas (1983) noted that although rabbits are not able to obtain as much energy from the fiber as ruminants, they can consume a large quantity of feed sufficient to meet their energy requirement.

However, the nutrient content of forages varies greatly among species, among cultivars within species (Skerman, 1977) and even among stages of growth in the same cultivars (Crowder and Chedda, 1982). In addition, phenolics and other toxic compounds are often present and exert deleterious effects on the animals (Fernandez et al., 1982; Pierpoint, 1983; Cheeke and Shull, 1985). Consequently, great variations in nutritive values exist among individual forages. Moreover, information on the nutrient content and digestibility of tropical forages in rabbits is scanty.

This experiment was designed to study the nutrient content and nutrient digestibility in rabbits fed several tropical forages. The effects of drying and pelleting, which may alter the nutritive value (Lebas, 1975; Woodham, 1983) were also studied.

MATERIALS AND METHODS

The feeding trial was carried out over a 5 mo period (September, 1984 - January, 1985) at the Balai Penelitian Ternak (Research Institute for Animal Production), Bogor, Indonesia.

Animals and Housing. Twenty-four New Zealand White x Flemish Giant rabbits of 7 to 9 months of age were used. Unless otherwise specified, four individual rabbits were used for each test forage. Rabbits were housed individually in all-wire cages (66 x 66 x 30 cm) equipped with a plastic screen underneath for fecal colection. A U-shaped metal feeder (50 x 14 x 12 cm) and a 500 ml, U-shaped metal waterer were attached to the front and back of each cage. Cages were suspended by T-metal supporters about 120 cm above the concrete floor. Cages were placed in a concrete building similar to that described by Moore (1985), except that this building had two open sided walls, to allow more air movement.

Diets and Management. Five woody legumes, five non-woody legumes (shrubs), seven grasses and one agricultural by-product (cassava tops), together with some heat-treated preparations of these forages, were tested for their nutrient digestibility. Most grasses were 6 weeks old, while legumes were cut at the flowering stage. Forages were hand-chopped to about 1 - 1.5 cm prior to the feeding trial. The forages were tested after being wilted overnight and/or after being steam pelleted. With leucaena, fresh and sundried forms were also tested. Individual forages were prepared for feeding by putting them into a preweighed ziplock plastic bag for each rabbit and storing in a cool room of 4^{o} C during the trial. Test forages were given twice daily for 9 days, and forage intake and fecal collection were recorded during the last 5 days. Feces were collected daily, pooled in a ziplock bag and stored in the freezer. When the trial was completed, the feces were oven dried at 60° C for 36-48 h, and ground for the chemical analyses. Forage residues and spillages were collected daily and pooled in a ziplock bag and stored in the freezer. Dry matter analyses were performed on the samples of forages before and after the feeding trial.

All forages, except grasses, were fed alone and the digestibility determined directly. Since feeding grasses alone caused a severe loss of body weight, a concentrate diet (Table II. 1) was fed at 30 g/rabbit/day and the digestibility was determined by difference. The same concentrate diet was fed *ad libitum* for 7-10 days in between the test periods to allow the rabbits to recover their weight loss.

Chemical and Statistical Analysis. Analysis for dry matter (DM), crude protein, ash, calcium (Ca) and phosphorus (P) was performed using methods of A.O.A.C. (1980). Organic matter (OM) was calculated by subtracting the ash from DM content. Neutral detergent fiber (NDF), which was first treated with amylase (McQueen and Nicholson, 1979), and acid detergent fiber (ADF) were analyzed following the procedure of Goering and Van Soest (1970). Gross energy (GE) was determined using an adiabatic bomb calorimeter. Unless otherwise mentioned, all values are expressed on a percentage of dry matter basis. A one way analysis of variance was used to analyze the digestibility values among species for each nutrient. Differences between means were compared by least significant difference and the regression analyses were performed according to Steel and Torrie (1980).

Table II. 1. Composition of concentrate diet used for maintenance and supplementation of grasses during the study of nutrient digestibility of tropical forages by rabbits.

Dietary Composition		Chemical Composition (Dry Matter Basis)	
Ingredient	%		
Corn	31.0	Crude protein (%)	23.1
Soybean meal	25.0	Gross energy (MJ/kg)	16.4
Fish meal	5.0	Acid detergent fiber (%)	21.0
Rice bran	15.0	Neutral detergent fiber (%)	38.9
Elephant grass*	20.0	Ash (%)	10.7
Molasses	3.0	Calcium (%)	0.8
Limestone	0.5	Phosphorus (%)	0.8
Vitamin/mineral premix A**	0.25		
Salt	0.3		

* Dried and ground.
** Manufactured by Pfizer for chick starter.

RESULTS AND DISCUSSION

The chemical composition of the test forages is presented in Table II. 2. A supplementary table (Table II. 8) containing nutrient content of different forages similar to the forages used in this experiment is provided, recognizing that the nutrient composition of forages is greatly influenced by part of the tree, age of cutting, level of fertilization, geographical location, etc. (Skerman, 1977; Crowder and Chedda, 1982).

Chemical composition of forages varied among species, but values were in the ranges reported in Table II. 8. While legumes have higher contents of DM, OM, GE, CP and Ca, grasses have higher ADF, NDF and ash. Nutrient contents of woody legumes were comparable among species, except Albizia falcata and Sesbania sesban that had lower CP content (16.1 and 17.8% respectively). Other woody legumes contained GE and CP ranging from 17.8 to 19.9 MJ/kg and 19.59 to 22.81 %, respectively. The range of CP, fiber and Ca, but not P, content of all woody legumes was higher than the corresponding values required for lactation and growth (NRC, 1977; Raharjo et al., 1986). On the other hand, except for centrosema that contained 21.38% CP, other non-woody legumes had CP contents ranging from 13.13 to 16.25%, which were lower than the level needed for production. Grasses, with elephant grass (Pennisetum purpureum) being superior among them, contained CP and GE ranging from 5.81 to 11.95% and 11.0 to 16 MJ/kg respectively. Cassava tops (Manihot esculenta) contained CP, GE and CF comparable to the woody legumes. Based on the nutrient contents, these results

Table II. 2. Chemical composition of forages used in the nutrient digestibility experiment (% dry matter basis).

Forage	Treat-ment	DM	OM	GE		CP	ADF	NDF	Ash	Ca	P
				MJ/kg	kcal/kg						
Woody legumes:											
Albizia falcata	W*	35.91	94.90	18.1	4326	16.31	26.43	38.02	5.10	0.65	0.17
Calliandra calothyrsus	W	37.85	93.43	19.9	4756	21.80	29.06	44.67	6.57	1.71	0.18
	P	91.41	94.90	19.8	4732	19.59	27.19	54.30	5.10	0.78	0.18
Leucaena leucocephala	F	29.85	93.20	17.8	4254	22.81	21.45	33.10	6.80	1.34	0.21
	W	35.63	93.30	17.6	4206	21.88	21.80	35.00	6.70	1.47	0.20
	SD	84.65	93.93	19.6	4684	24.50	20.18	38.00	6.07	1.38	0.28
	P	91.27	92.33	19.8	4732	25.56	22.75	35.80	7.67	2.08	0.24
Sesbania formosa	W	26.72	94.70	18.7	4469	19.94	20.78	34.13	5.30	0.73	0.37
Sesbania sesban	W	34.85	93.94	17.8	4254	17.81	29.11	35.40	6.06	0.75	0.37
Non-woody legumes (shrubs):											
Cassia rotundifolia A**	P	92.33	93.70	16.7	3991	15.00	47.00	59.30	6.30	0.76	0.25
B	P	92.50	94.20	16.1	3848	16.25	48.90	60.60	5.80	0.68	0.26
Centrosema pubescens	W	31.60	93.60	15.0	3885	21.38	35.27	51.41	6.40	0.74	0.23
Desmodium heterophyllum	W	30.93	86.00	15.7	3752	13.44	37.10	48.51	14.00	0.73	0.22
Neonotonia wightii cv. Tinaroo	P	89.80	91.50	14.4	3442	13.13	43.30	55.80	8.50	1.52	0.23
Pueraria phaseoloides	P	90.90	91.20	16.2	3872	15.63	39.90	50.70	8.80	0.74	0.36
Stylosanthes guianensis	W	25.44	92.80	13.0	3107	14.81	33.08	41.55	7.20	1.24	0.22
Grasses:											
Brachiaria brisantha	W	18.99	86.90	11.8	2820	6.69	36.81	59.31	13.10	0.47	0.16
Chloris gayana	W	19.95	88.60	15.5	3705	7.63	44.60	70.20	11.40	0.30	0.18
Panicum maximum cv. Green Panic	W	23.85	86.50	14.8	3537	5.81	48.70	69.40	13.50	0.33	0.19
cv. Guinea	W	21.03	84.50	15.0	3585	6.63	47.10	66.20	15.50	0.70	0.21
Paspalum plicatulum	W	21.34	85.40	14.7	4230	6.50	44.70	65.10	14.60	0.50	0.15
Pennisetum purpureum	W	17.59	87.50	16.0	3824	11.95	38.20	61.40	12.50	0.29	0.36
Setaria splendida	W	14.60	86.80	11.0	2629	6.94	39.70	55.54	13.20	0.46	0.20
Agricultural by-product:											
Cassava tops (Manihot esculenta)	W	27.34	91.70	20.1	4804	16.81	28.20	38.93	8.30	1.76	0.28
	P	91.64	90.70	18.9	4517	17.06	28.35	46.00	9.30	2.02	0.40

OM, organic matter
GE, gross energy
CP, crude protein
ADF, acid detergent fiber
NDF, neutral detergent fiber
Ca, calcium
P, phosphorus

* W, wilted
P, pelleted
F, fresh
SD, sun dried

** A, cultivar CPI 49713
B, cultivar Q 10057

Woody legumes: $y = 16.17 + 0.92\ x$ (y = NDF, x = ADF)
$r = 0.454$

Non-woody legumes: $y = 11.03 + 1.02\ x$
$r = 0.938$

Grasses: $y = 23.05 + 0.95\ x$
$r = 0.814$

Overall: $y = 8.57 + 1.19\ x$
$r = 0.905$

suggested that a lower intake of legumes than of grasses would be needed to achieve the same rate of gain.

Irrespective of the type of fiber, significant negative relationships were observed between fiber and GE or CP (Table II. 3). Increasing levels of ADF or NDF decreased the CP and GE contents. Thus grasses have a lower content of readily available soluble proteins and carbohydrates than legumes. A close relationship ($r = 0.91$) between ADF and NDF content was also observed.

Sundrying and steam pelleting did not change the composition of the forages, except for a considerable increase of NDF in calliandra and cassava tops. Cheeke and Carlsson (1978) reported a similar observation when alfalfa, amaranthus and chenopodium were air dried. Possible interactions of polyphenols and proteins (Cheeke et al., 1980; Pusztai, 1985) may explain the increase of these fiber fractions. Cheeke and Carlsson (1978) also showed an increase of nitrogen (N) content of the NDF and ADF fractions, indicative of heat tie-up of protein.

Feed consumption and body weight loss during the trial are shown in Table II. 4. Feed consumption was greatly influenced by the plant species. Comparing 14 different species, Harris et al. (1983) also reported a considerable variation in the palatability of greens. In general, results of this experiment suggested that woody legumes were more palatable than the non-woody legumes, while grasses were the least palatable. Champe and Maurice (1983) also reported a low palatability of diets containing coastal Bermuda grass. The low palatability of grasses may be attributed to several factors. High levels of oxalates in pennisetum, setaria and paspalum were reported to reduce

Table II. 3. Regression of ADF or NDF content (x) with NDF, CP and GE content (y) of some tropical legumes (n = 17).

		Intercept	Slope	Coefficient of Correlation
x	y	A	B	r
ADF	NDF	-0.805	1.474	0.96
ADF	GE	22.14	-0.182	-0.68
ADF	CP	32.56	-0.555	-0.84
NDF	GE	21.47	-0.112	-0.64
NDF	CP	30.77	-0.346	-0.81

Table II. 4. Feed consumption (± SD) and body weight loss of rabbits fed different tropical forages during 5 d digestibility trial.

Forage		n	Feed Consumption ± SD: As Is Basis	Feed Consumption ± SD: Dry Matter Basis	Body Weight Loss, g
Woody legumes:					
Albizia falcata	W*	4	303 ± 28.4	109 ± 10.2	221
Calliandra calothyrsus	W	4	786 ± 12.5	297 ± 5.0	87
	P	8	659 ± 44.6	603 ± 40.7	65
Leucaena leucocephala	F	4	1527 ± 39.3	456 ± 11.7	141
	W	4	1481 ± 115.9	528 ± 82.6	81
	SD	4	484 ± 91.6	389 ± 63.8	192
	P	4	788 ± 124.9	719 ± 114.0	208
Sesbania formosa	W	5	488 ± 30.0	130 ± 8.0	83
Sesbania sesban	W	5	459 ± 16.6	160 ± 5.8	94
Non-Woody legumes (shrubs):					
Cassia rotundifolia A	P	4	649 ± 34.3	599 ± 31.7	59
B	P	4	537 ± 24.9	497 ± 23.1	88
Centrosema pubescens	W	4	452 ± 23.0	143 ± 7.3	187
Desmodium heterophylum	W	4	461 ± 23.3	143 ± 7.2	179
Neonotonia wightii cv. Tinaroo	P	4	478 ± 47.8	430 ± 43.0	61
Pueraria phaseoloides	P	4	661 ± 35.9	601 ± 32.7	187
Stylosanthes guianensis	W	4	525 ± 40.0	134 ± 10.1	73
Grasses:					
Brachiaria brisantha	W	4	261 ± 54.1	50 ± 10.3	213
Chloris gayana	W	4	322 ± 60.2	64 ± 12.0	134
Panicum maximum					
cv. Green panic	W	4	419 ± 97.9	100 ± 23.4	219
cv. Guinea	W	4	258 ± 48.7	54 ± 9.8	175
Paspalum plicatulum	W	4	573 ± 55.7	22 ± 11.9	241
Pennisetum purpureum	W	4	794 ± 74.0	140 ± 13.2	142
Setaria splendida	W	4	428 ± 68.4	63 ± 10.0	207
Agricultural by-product:					
Manihot esculenta	W	5	1056 ± 44.2	289 ± 12.1	106
	P	5	599 ± 80.1	549 ± 73.4	180

* W = wilted F = fresh
P = pelleted SD = sun dried

voluntary feed intake (Crowder and Chedda, 1982). On the other hand, Smith (1962) found that DM intake of hyperhenia forage was decreased at 10 g/kg $BW^{0.75}$/day for every 1% decrease of CP content. Furthermore, from survey data, Sitorus *et al.* (1982) reported that sharp, hard and hairy leaves were unpalatable to rabbits. Cheeke (1979) and Harris *et al.* (1983) found the similar result that fresh comfrey (*Symphytum officinale*) which is hairy and prickly was also unpalatable to rabbits. Low intake of forage legumes may be due to the presence of tannins and other phenolic compounds (Crowder and Chedda, 1982; Cheeke and Shull, 1985). Leucaena, however, was found to be the most palatable among these forages. This was consistent with previous results (Raharjo and Cheeke, 1985). Reports on the good palatability of leucaena leaves by different species of animals are found elsewhere (e.g. Skerman, 1977; Harris *et al.*, 1931b; Jones and Megarrity, 1983). On the other hand, when leucaena was given in a pelleted form for a 3 month feeding period, decreased feed intake was reported (Tangendjaja *et al.*, 1985). Furthermore they suspected that the decrease may be due to the presence of DHP (3-hydroxy-4-pyridone), a mimosine metabolite, which is goitrogenic to mice and rats (Hegarty *et al.*, 1979). Consumption of leucaena in this study was 91 g/rabbit/day, which should be adequate for maintenance (Harris *et al.*, 1981b) but the rabbits lost weight. Severe weight loss was observed when grasses were tested. Similar results were reported by Voris *et al.* (1940) when feeding bluegrass alone to rabbits. The study conducted here suggested that feeding grasses alone is detrimental to rabbit growth.

Pelleting greatly increased the DM intake and slightly alleviated body weight loss for some legumes. Conversely, for leucaena and cassava tops, pelleting had an adverse effect. Cheeke *et al.*, (1980) also reported a very poor performance of rats fed diet containing leaf protein concentrates prepared from leucaena and cassava tops, because of their tannin content. There was no clear relationship between the DM intake and weight loss nor with the fiber content of the forages.

Nutrient digestibility values are presented in Tables II. 5 and 6. High variability was observed among nutrients and/or within nutrients among species. Irrespective of the nutrients, woody legumes, except calliandra, had significantly higher digestibility values compared with the two other groups of forages. This higher digestibility value of legumes was probably due to their lower fiber content. Table II. 7 shows that digestibility of DM, GE and CP was significantly and negatively influenced by fiber level in the feedstuffs. In addition, the digestibility values of ADF and NDF in most of the woody legumes, except those in the pelleted form, were also significantly better than those of grasses. Working with 9 legumes and 1 grass (*Panicum maximum*), which were included at 40% in the diet Harris *et al*. (1981c) reported very low ADF and NDF digestibility values for the grass. It is likely that legumes have a higher content of degradable fractions of their leaves, such as mesophyll cells and phloem, than grasses. In the study of fragmentation of forages during mastication and digestion, using light and electron microscopy techniques, Cheeke *et al*. (1985) showed that legume forages were more completely degraded than orchard grass in rabbits. In addition, Akin (1979) and Minson and McLeod (1983) showed a lower nutritive value of warm season, tropical grasses than the cool season, temperate grasses. The warm season grasses have higher contents of less easily degraded

Table II. 5. Mean (± SD) of the % digestibility of dry matter, organic matter, gross energy, crude protein, acid detergent fiber, and neutral detergent fiber of some tropical forages in rabbits.

Forage	Treat-ment	Dry Matter	Organic Matter	Gross Energy	Crude Protein	Acid Detergent Fiber	Neutral Detergent Fiber
Woody legumes:							
Albizia falcata	W	74.73 ± 1.59^{gh}	75.18 ± 3.05^{gh}	70.31 ± 1.69^{i}	73.40 ± 3.20^{ij}	57.96 ± 2.91^{k}	63.09 ± 4.02^{h}
Calliandra calothyrsus	W	49.46 ± 1.44^{ef}	50.29 ± 2.82^{e}	51.43 ± 2.77^{jgh}	49.79 ± 8.15^{de}	12.46 ± 9.53^{de}	25.64 ± 7.93^{cd}
Leucaena leucocephala	P	36.87 ± 1.24^{cd}	37.29 ± 2.93^{b}	41.34 ± 2.37^{cde}	24.81 ± 5.03^{bc}	-22.96 ±10.87^{a}	25.30 ± 4.52^{cd}
	F	72.99 ± 1.61^{gh}	72.95 ± 3.27^{gh}	66.93 ± 3.86^{i}	72.90 ± 6.49^{ij}	42.58 ± 3.71^{j}	55.82 ± 7.66^{gh}
	W	74.17 ± 1.24^{gh}	73.23 ± 1.15^{gh}	69.54 ± 3.31^{i}	75.93 ± 2.52^{jk}	37.7 ± 2.32^{ij}	54.50 ± 4.90^{gh}
	SD	68.04 ± 1.25^{g}	68.14 ± 2.52^{g}	65.95 ± 1.71^{i}	69.48 ± 3.07^{hi}	25.82 ± 5.04^{fgh}	52.15 ± 1.75^{gh}
	P	51.66 ± 1.10^{f}	51.90 ± 2.34^{e}	48.32 ± 3.54^{efgh}	48.02 ± 3.87^{de}	-0.57 ± 4.22^{b}	25.43 ± 3.89^{cd}
Sesbania formosa	W	69.48 ± 1.85^{g}	68.20 ± 4.66^{g}	65.75 ± 3.62^{i}	64.15 ± 2.61^{ghi}	30.91 ± 4.75^{ghi}	46.45 ± 8.34^{fg}
Sesbania sesban	W	79.32 ± 1.05^{h}	80.46 ± 1.96^{h}	77.52 ± 3.21^{j}	83.91 ± 1.63^{k}	62.33 ± 1.96^{l}	62.56 ± 3.47^{h}
Non-Woody legumes (Shrubs):							
Cassia rotundifolia A	P	41.64 ± 2.77^{cde}	42.03 ± 5.76^{bcd}	40.13 ± 4.73^{cd}	57.52 ± 3.46^{fg}	22.74 ± 9.62^{efg}	26.80 ± 7.72^{cd}
B	P	41.73 ± 1.20^{cde}	41.93 ± 2.74^{bcd}	36.80 ± 4.14^{c}	51.97 ± 0.72^{ef}	28.04 ± 2.54^{fghi}	28.22 ± 3.39^{cd}
Centrosema pubescens	W	42.99 ± 1.54^{cde}	54.18 ± 4.54^{f}	54.18 ± 4.54^{gh}	72.87 ± 1.42^{ij}	29.27 ± 3.27^{fghi}	32.46 ± 3.57^{de}
Desmodium heterophylum	W	28.14 ± 2.18^{b}	48.72 ± 2.08^{def}	48.72 ± 2.08^{def}	52.10 ± 3.48^{ef}	13.36 ± 7.01^{cd}	13.55 ± 8.18^{ab}
Neonotonia wightii cv. Tinaroo	P	49.35 ± 1.36^{ef}	49.69 ± 2.60^{ef}	39.80 ± 4.89^{ch}	56.59 ± 2.33^{fg}	36.73 ± 1.80^{ij}	30.73 ± 0.62^{def}
Pueraria phaseoloides	P	46.35 ± 1.58^{ef}	46.10 ± 2.92^{cde}	44.31 ± 2.85^{def}	62.56 ± 0.93^{gh}	21.11 ± 3.17^{ef}	27.39 ± 4.05^{c}
Stylosanthes guianensis	W	43.35 ± 4.16^{d}	55.13 ± 7.38^{f}	55.13 ± 7.38^{h}	53.87 ± 6.00^{ef}	23.28 ±11.29^{efg}	18.54 ± 14.72^{bc}
Grasses:							
Brachiaria brisantha	W	16.65 ± 2.61^{a}	16.23 ± 5.56^{a}	24.48 ± 9.07^{b}	17.80 ± 7.12^{a}	4.18 ± 5.33^{de}	11.34 ± 5.89^{a}
Chloris gayana	W	38.90 ± 3.26^{c}	39.60 ± 6.54^{bc}	36.26 ± 5.61^{c}	32.41 ±20.14^{c}	33.22 ± 5.63^{hi}	41.94 ± 4.97^{ef}
Panicum maximum cv. Green panic	W	15.66 ± 1.44^{a}	15.28 ± 3.50^{a}	12.63 ± 3.49^{a}	5.62 ± 5.34^{a}	10.31 ± 2.50^{cd}	12.48 ± 4.16^{ab}
cv. Guinea	W	12.30 ± 1.32^{a}	8.96 ± 2.79^{a}	10.72 ± 4.18^{a}	12.97 ± 4.68^{a}	7.79 ± 3.28^{cd}	7.26 ± 5.31^{a}
Paspalum plicatulum	W	35.02 ± 2.09^{c}	34.62 ± 3.86^{ab}	33.73 ± 3.73^{ch}	21.20 ± 6.71^{b}	25.67 ± 5.24^{fgh}	29.58 ± 6.35^{d}
Pennisetum purpureum	W	46.26 ± 1.59^{ef}	46.31 ± 2.90^{cde}	45.23 ± 4.04^{def}	64.65 ± 2.10^{ghi}	34.64 ± 1.87^{hi}	42.77 ± 0.80^{ef}
Setaria splendida	W	14.95 ± 4.81^{a}	15.78 ± 9.35^{a}	9.44 ± 2.64^{a}	6.16 ± 6.08^{a}	16.06 ±10.11^{de}	8.99 ±13.17^{a}
Agricultural by-product:							
Cassava tops	W	49.85 ± 0.72^{f}	50.59 ± 1.65^{ef}	47.04 ± 3.20^{defg}	41.96 ± 1.86^{d}	25.57 ± 2.53^{fgh}	32.95 ± 3.40^{def}
(Manihot esculenta)	P	45.12 ± 1.00^{ef}	45.20 ± 1.78^{cde}	47.21 ± 2.89^{defg}	41.75 ± 4.58^{d}	6.56 ± 4.31^{cd}	35.91 ± 2.04^{def}

* Values with different superscripts in the same column are different ($P < 0.05$).

W = wilted F = fresh
P = pelleted SD = sun dried

Table II. 6. Mean (±SD) of the % digestibility of ash, calcium (Ca) and phosphorus (P) of some tropical forages in rabbits.

Forage	Treat-ment	Ash	Ca	P
Woody legumes:				
Albizia falcata	W	$69.16 \pm 6.80^{ij*}$	40.02 ± 7.08^{fgh}	-15.50 ± 36.51
	W	34.94 ± 4.96^{cde}	36.17 ± 2.78^{fg}	-9.27 ± 6.38
Calliandra calothyrsus	P	29.07 ± 18.20^{abcde}	24.15 ± 12.22^{ef}	-76.72 ± 85.74
Leucaena leucocephala	F	73.48 ± 3.12^{j}	74.05 ± 3.98^{i}	-9.47 ± 9.77
	W	74.59 ± 1.54^{j}	73.22 ± 1.75^{i}	-9.15 ± 11.07
	SD	66.76 ± 2.69^{hij}	65.77 ± 2.88^{hi}	-6.67 ± 20.18
	P	48.78 ± 2.39^{efghi}	57.47 ± 4.59^{ghi}	-15.03 ± 14.04
Sesbania formosa	W	54.43 ± 8.01^{fghij}	29.12 ± 11.58^{f}	20.19 ± 13.88
Sesbania sesban	W	61.60 ± 4.42^{ghij}	47.21 ± 8.28^{fgh}	20.63 ± 21.52
Non-Woody legumes (Shrubs):				
Cassia rotundifolia A	P	35.87 ± 8.16^{cdef}	33.16 ± 5.88^{fg}	2.95 ± 11.92
B	P	38.60 ± 9.58^{def}	27.95 ± 7.70^{f}	18.87 ± 9.73
Centrosema pubescens	W	31.22 ± 10.01^{bcde}	4.37 ± 11.00^{de}	-108.57 ± 31.92
Desmodium heterophylum	W	11.46 ± 7.93^{ab}	-0.30 ± 8.90^{d}	-231.15 ± 31.86
Neonotonia wightii cv. Tinaroo	P	45.74 ± 4.89^{efgh}	47.35 ± 6.02^{fgh}	-20.80 ± 14.60
Pueraria phaseoloides	P	48.98 ± 5.90^{fghi}	-5.20 ± 8.71^{d}	14.03 ± 4.07
Stylosanthes guianensis	W	21.50 ± 12.19^{abcd}	47.47 ± 10.78^{fgh}	-137.29 ± 17.41
Grasses:				
Brachiaria brisantha	W	17.28 ± 6.00^{abc}	-110.24 ± 51.07^{b}	-549.78 ± 160.43
Chloris gayana	W	33.75 ± 8.31^{cde}	-121.14 ± 37.14^{b}	-191.38 ± 49.51
Panicum maximum cv. Green panic	W	17.93 ± 8.81^{abc}	-93.27 ± 24.01^{c}	-166.63 ± 29.81
cv. Guinea	W	30.48 ± 9.62^{abcde}	-10.30 ± 9.89^{d}	-183.16 ± 40.51
Paspalum plicatulum	W	37.48 ± 6.32^{cdef}	-8.91 ± 21.17^{d}	-172.66 ± 59.48
Pennisetum purpureum	W	45.96 ± 5.65^{efgh}	-120.90 ± 17.41^{b}	-54.07 ± 25.86
Setaria splendida	W	9.53 ± 11.73^{a}	-185.97 ± 24.20^{a}	-476.40 ± 50.60
Agricultural by-product:				
Cassava tops (Manihot esculenta)	W	42.02 ± 2.28^{defg}	34.64 ± 2.72^{fg}	6.94 ± 4.09
	P	44.22 ± 2.65^{efg}	45.79 ± 4.36^{fgh}	-37.01 ± 8.92

* Values with different superscripts in the same column are different ($P < 0.05$).

W = wilted F = fresh
P = pelleted SD = sun dried

Table II. 7. Regression of ADF or NDF with intake of dry matter (DMI) and with the digestibility of dry matter (DDM), gross energy (DGE) and crude protein (DCP) of some tropical forages by rabbits.

		Intercept	Slope	Coefficient of Correlation
x	y	A	B	r
ADF	DMI	554.1	-11.23	-0.71*
NDF	DMI	578.2	-6.99	-0.65*
ADF	DDM	106.3	-1.84	-0.79*
NDF	DDM	100.0	-1.30	-0.74*
ADF	DGE	104.1	-1.73	-0.78*
NDF	DGE	98.7	-1.09	-0.75*
ADF	DCP	111.2	-1.90	-0.70*
NDF	DCP	104.2	-1.17	-0.66*

* $P<.05$

components, such as vascular tissue, parenchyma bundle sheaths and epidermis (Akin, 1979). Pond et al. (1984) suggested that anatomical variations of forages plays a role in degradation of the nutrients.

The high fiber content of grasses may also contribute to their low nutrient digestibility. High fiber increases the rate of passage, which reduces the digestion time, and may also encrust other nutrients, particularly when lignin is high, rendering them undigestible (Cheeke and Myer, 1975; Crowder and Chedda, 1982). Low CP digestibility might also be due to this encrustation. Increased excretion of endogenous protein in the feces when high fiber diets are fed could also be a factor in reducing apparent digestibility of CP. A further possibility is that condensed tannins may precipitate proteins in the digestive tract (Hagerman and Butler, 1978; Oh et al, 1980).

Drying and pelleting greatly reduced ($P < .05$) the digestibility of all nutrients and was greatest in leucaena. Inclusion of leucaena at 40% (Parigi-Bini et al, 1984) or at 60% (Tangendjaja et al, 1985) in pelleted rabbit diets was reported to reduce the digestibility of CP from 78 to 52% or from 73 to 40%, respectively. Robinson et al., (1985) also reported a higher CP digestibility for fresh grass than dried alfalfa meal. Interactions of phenolic compounds, carbohydrates (Ledward, 1979; Aw and Swanson, 1985) and/or lipids (Buchanan, 1969) with protein may be the factors responsible. Elevated N content of ADF and NDF fractions of dried legumes (Cheeke and Carlsson, 1978) may be indicative of these carbohydrate-protein interactions.

Rabbits are herbivorous animals, but they are not able to utilize fiber as efficiently as the ruminant animal. For some legumes, such as albizia, leucaena and Sesbania sesban, the NDF digestibility exceeded 50%. It was unclear why the variability in digestibility values of fiber fractions was high, irrespective of forages, while for other nutrients was low. Cheeke (1974) reported a similar observation when the digestibility of barley ADF ranged from 8.1 to 51.8% in 5 individual rabbits.

The digestibility values of Ca in most grasses and P in most forages were negative (Table II. 6). The negative digestibilities might be attributed to binding to oxalate or phytate, or to endogenous excretion of these minerals.

In conclusion, this study has provided data on the nutritive value of some tropical forages that may play an important role in rabbit feeding. Among the three groups of forages, woody legumes appeared to be the most promising, in terms of being highest in nutrient composition, digestibility and palatability. However, it was obvious, regardless of the species, that forages cannot be fed alone to rabbits. Supplementation with concentrate diet is needed to improve the nutrient intake, particularly when grasses are fed. Tropical grasses are of very little nutritional value except as a source of indigestible fiber, as they have very low digestibilities of protein and energy.

Table II. 8. Composition, dry matter digestibility (DMD) and production of some tropical forages from different reports.

Forage	Composition, %				DMD (%)	Production, ton DM/ha/year	Author
	CP	CF	Ca	P			
Woody legumes:							
Calliandra calothyrsus	20.0						Skerman, 1977
Leucaena leucocephala	24.1-30.1	9.6-37.7	1.0	0.3	65.0-87.0		Skerman, 1977
	15.0-25.0	33.0-38.0				3.1-20.5	Bogdan, 1977
Sesbania sesban	25.27	49.43	1.1	0.3			Skerman, 1977
Non-Woody legumes:							
Centrosema pubescens	13.1-24.4	21.6-34.7	0.8-1.4	0.2-0.4			Skerman, 1977
	11.0-24.0		0.9	0.3	53.0-68.0	3.0-5.5	Bogdan, 1977
Desmodium heterophylum	17.0-18.0						Bogdan, 1977
Pueraria phaseoloides	15.4-20.5	13.1-40.0	0.4-1.6	0.1-0.5		19.7	Skerman, 1977
	11.0-19.0	36.9-41.1				5.0-10.0	Bogdan, 1977
Stylosanthes guianensis	12.1-18.1	32.3-37.7			61.7	2.5-10.0	Skerman, 1977
	15.8	40.2					Harris et al., 1981[c]
	12.0-18.0					15.0	Bogdan, 1977
Grasses:							
Brachiaria brisantha	8.4	37.6*-71.9**			56.8		Van Eys et al., 1984
Chloris gayana	7.0-14.7	28.9-33.1			35.6-78.9		Crowder and Chedda, 1982
	3.0-17.0					1.5-25.0	Bogdan, 1977
Panicum maximum	4.0-20.0	28.0-36.0		0.1-0.2	47.4-63.5	40.0-50.0	Bodgan, 1977
Pennisetum purpureum	6.3-20.8	24.6-42.2	0.3-0.6	0.1-0.3	48.9-74.8		Crowder and Chedda, 1982
	4.4-20.0	26.0-40.5	0.1-0.5	0.3-0.5	48.0-71.0	4.5-71.9	Bogdan, 1977
Setaria splendida	10.0				55.8-66.8	4.0-9.0	Bogdan, 1977
Agricultural by-product:							
(Manihot esculenta)	24.7	28.4*					Harris et al., 1981[c]

* ADF
** NDF

REFERENCES

Akin, D.E. 1979. Microscopic evaluation of forage digestion by rumen microorganisms. A review. J. Anim. Sci. 48:701-710.

AOAC. 1980. Official Method of Analysis. Thirteenth edition. Association of Official Analytical Chemists. Washington, D.C.

Aw, T.L. and B.G. Swanson. 1985. Influence of tannin on Phaseolus vulgaris protein digestibility and quality. J. Food Sci. 50:67-71.

Bogdan, A.V. 1977. Tropical Pasture and Fodder Plants (Grasses and Legumes). Longman, London and New York.

Buchanan, R.A. 1969. Effect of storage and lipid extraction on the properties of leaf protein. J. Sci. Food Agric. 20:359-364.

Champe, K.A. and D.V. Maurice. 1983. Response of early weaned rabbits to source and level of dietary fiber. J. Anim. Sci. 56:1105-1114.

Cheeke, P.R. 1979. Comparisons of comfrey and alfalfa : Composition, protein distribution and digestibility. J. Appl. Rabbit Res. 2(2):7-8.

Cheeke, P.R. 1983a. Rabbit production in Indonesia. J. Appl. Rabbit Res. 6:80-86.

Cheeke, P.R. 1983b. The significane of fiber in rabbit nutrition. J. Appl. Rabbit Res. 6:103-106.

Cheeke, P.R. and R. Carlsson. 1978. Evaluation of several crops as sources of leaf meal: Composition, effect of drying procedure and rate growth response. Nutr. Rep. Inter. 18:465-473.

Cheeke, P.R. and R.O. Myer. 1975. Protein digestibility and lysine availability in alfalfa meal and alfalfa protein concentrate. Nutr. Rep. Int. 12:337-344.

Cheeke, P.R. and N.M. Patton. 1979. Utilization of alfalfa by rabbits. In: The Domestic Rabbit: Potentials, Problems and Current Research. Proc. Symp. 71st Ann. Meet. ASAS. U.A., Tucson, Arizona, pp. 25-28. Published by OSU Rabbit Research Center.

Cheeke, P.R. and N.M. Patton 1980. Carbohydrate overload of the hind gut - A probable cause of enteritis. J. Appl. Rabbit Res. 3(3):20-23.

Cheeke, P.R. and L.R. Shull. 1985. Tannins and polyphenolic compounds. In 'Natural Toxicants in Feeds and Poisonous Plants'. pp. 322-357. AVI Publ. Co., Inc., Westport, Connecticut.

Cheeke, P.R., D.E. Akin, K.L. Robinson and N.M. Patton. 1985. Fragmentation of forages during mastication and digestion by rabbits. J. Appl. Rabbit Res. 8:26-30.

Cheeke, P.R., L. Telek, R. Carlsson and J.J. Evans. 1980. Nutritional evaluation of leaf protein concentrates prepared from selected tropical plants. Nutr. Rep. Inter. 22:717-721.

Crowder, L.V. and H.R. Chedda. 1982. Tropical Grassland Husbandry. Longman, London and New York.

Farrell, D.J. and Y.C. Raharjo. 1984. The Potential for meat production from rabbits. Central Research Institute for Animal Science. Box 123. Bogor, Indonesia.

Fernandez, R., L.G. Elias, J.E. Braham, and R. Bressani. 1982. Trypsin inhibitors and hemagglutinins in beans (Phaseolus vulgaris) and their relationship with the content of tannins and associated polyphenols. J. Agric Food Chem. 30:734-739.

Goering, H.K. and P.J. Van Soest. 1970. Forage fiber analysis. Agric. Handbook No. 379, pp. 1-20. Agric Res. Service, USDA.

Hagerman, A.E. and L.G. Butler. 1978. Protein precipitation method for the quantitative determination of tannins. J. Sci. Food Chem. 26: 809-812.

Harris, D.J., P.R. Cheeke and N.M. Patton. 1981a. Utilization of high alfalfa diets by rabbits. J. Appl. Rabbit Res. 4:30-34.

Harris, D.J., P.R. Cheeke, N.M. Patton and J.L. Brewbaker. 1981b. A note on the digestibility of leucena leaf meal in rabbits. J. Appl. Rabbit Res. 4:99.

Harris, D.J., P.R. Cheeke, L. Telek and N.M. Patton. 1981c. Utilization of alfalfa meal and tropical forages by weanling rabbits. J. Appl. Rabbit Res. 4:4-9.

Harris, D.J., P.R. Cheeke and N.M. Patton. 1983. Feed preference studies with rabbits fed fourteen different fresh greens. J. Appl. Rabbit Res. 6:121-122.

Hegarty, M.P., C.P. Lee, G.S. Christie, R.D. Court and K.P. Haydock. 1979. The goitrogen 3-hydroxy 4(1H) pyridone, a ruminal metabolite from Leucaena leucocephala: Effect in mice and rats. Aust. J. Biol. Sci. 32:27-40.

Jones, R.J. and R.G. Megarrity. 1983. Comparative toxicity responses of goats fed leucaena in Australia and Hawaii. Aust. J. Agric. Res. 34:781-790.

Lang, J. 1981. The nutrition of the commercial rabbit. 2. Feeding and general aspects of nutrition. Nutr. Abstr. Rev. 51(5): 287-299.

Lebas, F. 1983. Small scale rabbit production. Feeding and management system. World Anim. Rev. 46:11-17.

Lebas, F., J. Dolz and A. Espaignet. 1975. Effect of drying conditions of dehydrated lucerne on growth performences of rabbits recieving diets containing lucerne. Annal. Zootech. 24:144.

Ledward, D.A. 1979. Protein-polysaccharides interactions. In 'Polysaccharides in Food' (J.M.V. Blanshard and J.R. Mitchell, eds.), pp. 205-217. Butterworth and Co., Ltd., Sydney-Wellington-Durban-Toronto.

McQueen, R.E. and J.W.G. Nicholson. 1979. Modification of the neutral detergent fibre procedure for cereals and vegetables by using - amylase. J.A.O.A.C. 62:676-680.

Minson, D.J. and M.N. McLeod. 1962. The <u>in vitro</u> technique: Its modification for estimating digestibility of large numbers of tropical pasture samples. Aust. CSIRO Div. Trop. Pastures. Tech. Pap. 8.

Moore, J.A. 1985. Basic ventilation consideration for rabbit buildings. J. Appl. Rabbit Res. 8:54-56.

N.R.C. 1977. Nutrient Requirement of Domestic Animals. No. 9. Nutrient Requirement of Rabbits. Second revised edition. NAS, NRC, Washington D.C.

Oh, H.I., J.E. Hoff, G.S. Amstrong and L.A. Haff. 1980. Hydrophobic interaction in tannin-protein complexes. J. Agric. Food Chem. 28:394-398.

Owen, J.E. 1976. Rabbit production in tropical developing countries. Trop. Sci. 18:203-210.

Parigi-Bini, R., M. Cinetto and N. Carotta. 1984. Digestibility and nutritive value of <u>Leucaena leucocephala</u> in rabbit diets. III World Rabbit Congress. 1: 399-407. Rome, Italy.

Pierpoint, W.S. 1983. Reaction of phenolic compound with proteins and their relevance to the production of leaf protein. In: Leaf Protein Concentrates (L. Telek and H.D. Graham, eds), pp. 235-267. AVI Publ.Co. Inc., Westport, Connecticut.

Pond, K.R., W.C. Ellis and D.E. Akin. 1984. Ingestive mastication and fragmentation of forages. J. Anim. Sci. 58:1567-1574.

Pusztai, A. 1985. Constraints on the nutritional utilization of plant proteins. Nutr. Abstr. Rev. 55(7):363-369.

Raharjo, Y.C. and P.R. Cheeke 1985. Palatability of tropical tree legume forage to rabbits. Nitr. Fixing Tree Res. Rep. 3:31-32.

Raharjo, Y.C., P.R. Cheeke and N.M. Patton. 1986. Growth and reproductive performance of rabbits on a moderately low crude protein diet with or without methionine or urea supplementation. J. Anim. Sci. 63:795-803.

Robinson, K.L., P.R. Cheeke and N.M. Patton. 1985. Effect of prevention of coprophagy on the digestibility of high forage and high concentrate diets by rabbits. J. Appl. Rabbit Res. 8:57-59.

Sitorus, P., S. Sastrodiharjo, Y.C. Raharjo, I.G. Putu, Santoso, B. Sudaryanto and A. Nurhadi. 1982. Report of the survey on the rabbit raising in Java. Central Research Institute for Animal Science, Box 123, Bogor, Indonesia.

Skerman, P.J. 1977. Tropical Forage Legume. FAO Plant Production and Protection Series. No. 2. FAO of the U.N. Rome, Italy.

Slade, L.M.and H.F. Hintz. 1969. Comparisons of digestion in horses, ponies, rabbits and guinea pigs. J. Anim. Sci. 28:842-843.

Smith, C.A. 1962. The utilization of Hyperhenia for the nutrition of cattle in the dry season. III. Studies on the digestibility of the produce of mature veld and veld hay and the effect of feeding supplementary protein and urea. J. Agric. Sci. 53:173-178.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. A Biometrical Approach. Second ed. McGraw Hill Book Co., New York.

Tangendjaja, B., Y.C. Raharjo and J.B. Lowry . 1985. Evaluation of leucaena leaf meal and its toxicity to rabbits. Research report. Research Institute for Animal Production. Box 123, Bogor, Indonesia.

Telek, L. and F.W. Martin. 1983. Tropical plant for leaf protein concentrates. In: Leaf Protein Concentrates (L. Telek and H.D. Graham, eds.), pp.81-116. AVI Publ. Co., Inc., Wesport, Connecticut.

Van Eys, J.E., I.W. Mathius, H. Pulungan and W.L. Johnson. 1984. Utilization of fresh and ensiled Pennisetum purpureum, Panicum maximum and Brachiaria brizantha by growing sheep. Proc. Sci. Meeting on small Ruminant Research, pp. 50-54. Bogor, Indonesia.

Voris, L.R., L.F. Marcy, E.J. Tracker and W.W. Wainio. 1940. Digestible nutrients of feedingstuffs for the domestic rabbits. J. Agric. Res. 61:673-683.

Woodham, A.A. 1983. The nutritional evaluation of leaf protein concentrates. In: Leaf Protein Concentrates (L. Telek and H.D. Graham, eds.), pp. 415-484. AVI Publ. Co., Inc., Westport, Connecticut.

CHAPTER III

EVALUATION OF TROPICAL FORAGES AND BY-PRODUCT FEEDS FOR RABBIT PRODUCTION

2. COMPOSITION, CONSUMPTION AND DIGESTIBILITY IN GROWING RABBITS[1,2]

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SUMMARY

Eighty nine-week old crossbred (Flemish Giant x New Zealand White) rabbits were used to study the intake, composition and nutrient digestibility of forages. The forages were legumes : leucaena, gliricidia and sesbania; grasses : pennisetum and brachiaria; and agricultural by-products : banana leaves, cassava tops, corn leaves and papaya leaves. Four replicates, each of two rabbits, were used to test each forage, which were hand-chopped and fed fresh. A concentrate diet (55g/rabbit/day) was fed as a supplement. Intake and feces excretion were measured for 7 days. Dry matter (DM), gross energy (GE), crude protein (CP), acid and neutral detergent fiber (ADF and NDF), ash, calcium (Ca) and phosphorus (P) were determined.

Intake, composition and nutrient digestibility were most favorable for the legumes, except for the digestibility values of gliricidia. The legume digestibility values were in the range of 50 to 70 %, except for ADF, NDF and P. The nutrient digestibility values for gliricidia were about 30 to 50 %, which were comparable to the values obtained from agricultural by-products and pennisetum. Brachiaria

grass had extremely low digestibility values, which were less than 16 %. Irrespective of the species of forages, most Ca and P digestibility were negative, suggesting a possible deficiency of these minerals unless supplementation is provided.

INTRODUCTION

Tropical forages, particularly legumes, contain high contents of crude protein, vitamins and fiber. Rabbit production may be an efficient means of converting these forages to human food. However, before these forages can be most effectively used as rabbit feedstuffs, more information on their composition and digestibility by rabbits is required. There is a paucity of information available on their composition and there are large variations in the nutrient composition (Skerman, 1977; Gohl, 1981; Crowder and Chedda, 1982), and digestibility (Raharjo et al, 1986) among forage species. Thus there is a need to investigate the nutritive value of forage species individually in order to most effectively utilize them.

In the previous paper, Raharjo et al.(1986) showed that adult rabbits were able to digest legume species, especially woody (tree) legumes, more efficiently than other forages. Lower digestibility values may be expected with the growing animal, in which cecal fermentation is less extensive (Houpt, 1963; Lang, 1981). Other available data concerning nutrient digestibility of forages are usually presented as values of the mixture of a concentrate diet with a particular forage (Harris et al, 1981b; Parigi-Bini et al, 1984; Robinson et al, 1985; Tangendjaja et al, 1985), which could be greatly influenced by the ratio of forage to concentrates and/or the amount of feed consumption. Consequently, interpreting these values as the nutritive value of the forage could be misleading. In an attempt to find out the nutritive value of some forages and agricultural by-products, many of which were not tested in the previous study conducted with adult rabbits (Raharjo et al, 1986), an experiment was carried out with growing rabbits. Results presented in this paper deal only with the composition, consumption and digestibility values. The growth performance data are presented in a subsequent paper.

MATERIALS AND METHODS

This experiment was carried out at Balai Penelitian Ternak (Research Institute for Animal Production), Bogor, Indonesia. Eighty 9-week old cross bred (Flemish Giant x New Zealand White) rabbits were used. Four replicates, each of two rabbits, were used for each test forage. Three groups of test forages, i.e. woody legumes : leucaena (*L. leucocephala*), sesbania (*S. grandiflora*) and gliricidia (*G. maculata*); grasses :elephant grass (*Pennisetum purpureum*), and brachiaria (*B brisantha*); and agricultural by-products : corn leaves (*Zea mays*), cassava tops (*Manihot esculenta*),banana leaves (*Musa paradisiaca*) and papaya leaves (*Carica papaya*) were evaluated. They were fed free choice (*ad libitum*). A premixed concentrate diet (Table III. 1) was used as a supplement and fed in the morning at 55 g/rabbit/day. Housing, diet preparation, management and chemical and statistical analyses were the same as those described by Raharjo *et al*. (1986), except that the duration of fecal collection in this trial was 7 days. Nutrient digestibility of individual forages was calculated 'by-difference'.

RESULTS AND DISCUSSION

Proximate composition values of the concentrate diet and forages are shown in Table III. 1 and 2, respectively. Chemical composition of forages, although varying greatly among species, was largely comparable among species within groups. For example, nutrient contents of leucaena were similar to those of sesbania and gliricidia, with the exception of crude protein (CP) and gross energy (GE) of sesbania, which were markedly higher. Likewise, nutrient contents of agricultural by-products were similar, except for the high CP and calcium (Ca) and low fiber content of papaya leaves. Grasses, on the other hand, contained low dry matter (DM), CP, Ca and phosphorus (P), but were high in fiber. The CP content of grasses ranged from 7.10 to 9.50 %, while in the legume forages CP was 22.60 - 33.10 %. Although most of these nutrient composition values are in agreement with those reported by Gohl (1981), some were markedly different. The CP contents of sesbania and banana leaves in this study were higher than those of Gohl (1981), i.e. 33.10 vs 25.10 % and 19.70 vs 9.70 %, respectively. Lower fiber contents were also reported by Gohl (1981). These differences were not surprising as nutrient composition of forages is infuenced by factors such as plant part (leaf, stem, branch), plant maturity at cutting, level of fertilization, and geographical location (Bogdan, 1977; Skerman, 1977). Gohl (1981) also reported that under good management, sesbania in Sri Lanka contained 33.10 % CP, while

Table III. 1. Composition of concentrate diet used for supplementation.

Dietary Composition		Chemical Composition (Dry Matter Basis)	
Ingredient	%		
Corn	31.0	Crude protein (%)	23.1
Soybean meal	25.0	Gross energy (kcal/kg)	3936
Fish meal	5.0	Acid detergent fiber (%)	21.0
Rice bran	15.0	Neutral detergent fiber	38.9
Elephant grass*	20.0	Ash (%)	10.7
Molasses	3.0	Calcium (%)	0.8
Limestone	0.5	Phosphorus	0.8
Mineral/Premix A**	0.25		
Salt	0.25		

* Dried and ground.

** Pfizer broiler starter, providing (/kg) vit. A, 2,000,000 IU; D_3, 200,000 IU; E, 1400 mg; K_3, 200 mg; B_1, 200 mg; B_2, 1200 mg, B_6, 100 mg; niacin, 2000 mg; pantothenic acid, 1100 mg; choline-Cl, 2000 mg; B_{12}, 8000 mg; DL-methionine, 45,400 mg; ethoxyquin, 2000 mg; Mg, 1000 mg, Fe, 2000 mg; Cu, 400 mg; Zn, 2000 mg; and I, 20 mg.

Table III. 2. Chemical composition of forages used in the experiment (% DM).

Forage	DM*	OM	GE (kcal/kg)	CP	ADF	NDF	EE	Ash	Ca	P
Woody legumes										
Leucaena leucocephala	32.45	93.20	4272	22.80	21.45	33.10	4.20	6.80	1.34	.21
Gliricidia maculata	30.57	90.70	4608	26.10	23.50	38.40	4.60	9.30	1.22	.24
Sesbania grandiflora	30.99	92.10	5088	33.10	24.30	34.70	5.60	7.90	1.33	.22
Grasses										
Elephant grass	19.32	87.50	3840	9.50	38.20	61.40	3.41	12.50	.29	.36
Brachiaria brizantha	18.44	88.90	4000	7.10	47.90	71.20	2.39	11.10	.17	.49
Agricultural by-products										
Corn leaf	30.00	89.80	4248	13.60	29.70	57.90	3.10	10.20	.53	.31
Cassava tops	29.76	91.70	4824	16.79	28.01	38.13	5.80	8.30	1.76	.28
Banana leaf	19.02	88.20	4440	19.70	27.30	53.90	5.90	11.80	1.14	.25
Papaya leaf	23.60	84.40	4080	25.70	16.30	30.70	5.20	15.60	3.02	.36

DM = dry matter
OM = organic matter
GE = gross energy
CP = crude protein
ADF = acid detergent fiber
NDF = neutral detergent fiber
EE = ether extract
Ca = calcium
P = phosphorus

Ayoade et al. (1985) reported a CP value of 17.72 % for banana leaves in Malawi. The nutrient contents of most forages tested, except for P of legumes and agricultural by-products and CP for corn leaf, were higher than the corresponding values required for lactation and growth of rabbits (NRC, 1977 ; Raharjo et al, 1986a). Thus, these results suggested the importance of evaluating the nutritive value of individual forages for their diversity and the ability to support rabbit production.

Feed consumption and body weight gain of rabbits are presented in Table III. 3. In general, forage intake was highest with the legume species. Leucaena was found to be the most consumed, consistent with previous observations (Raharjo and Cheeke, 1985 ; Raharjo et al, 1986b). Banana leaf and brachiaria, on the other hand, were the least consumed. Banana leaf has an astringent property, which may decrease feed intake (Jones et al, 1976). The problems with brachiaria grass include high fiber (Van Eys et al, 1984), oxalate (Crowder and Chedda, 1982),and low CP (Smith, 1962) content and the physical structure of the leaves, which are prickly and sharp (Sitorus et al, 1982). Comfrey, which is coarse and hairy was also reported to be somewhat unpalatable to rabbits (Harris et al, 1983). Consumption of cassava tops, corn leaf, papaya leaf and elephant grass were comparable. All rabbits gained body weight during this trial, partly because of nutrients supplied by the concentrate supplement. Further discussion on the body weight gain is presented in the subsequent paper.

Nutrient digestibility values of concentrate + forage (C+F) and the forage alone are presented in Table III. 4. There was high variability in digestibility values among nutrients and/or within

Table III. 3. Forage consumption and body weight gain of rabbits during 7d digestibility trial.

	Feed Consumption (g/rabbit)*		Body Weight Gain (g/rabbit)
	As Is Basis	Dry Matter Basis	
Woody legumes			
Leucaena leucocephala	394^{**}	132^{a}	93^{a}
Gliricidia maculata	333^{a}	100^{abc}	65^{ab}
Sesbania grandiflora	357^{a}	110^{ab}	75^{a}
Grasses			
Elephant grass	350^{a}	74^{bcd}	69^{a}
Brachiaria brizantha	178^{c}	34^{d}	31^{c}
Agricultural by-products			
Corn leaf	290^{ab}	97^{abc}	46^{bc}
Cassava tops	201^{bc}	58^{cd}	68^{ab}
Banana leaf	156^{c}	30^{d}	26^{c}
Papaya leaf	312^{ab}	79^{bc}	27^{c}
SEM	44.9	13.6	9.4

* in addition to the supplementation of concentrate diet of 55 g/day.

** values with different superscripts are significantly different ($P < .05$).

Table III. 4. Nutrient digestibility of combined concentrate diet + forage and forage alone in 9-10 week old rabbits.

Diet/Forage	Digestibility (%)								
	DM	OM	GE	DE (kcal/kg)	CP	ADF	NDF	Ca	P
Combined									
Concentrate (C)	64.06[e*]	65.97[d]	66.24[c]	2606[c]	85.55[e]	23.95[bc]	43.31[d]	29.92[b]	42.73[f]
C + Leucaena	61.91[de]	62.37[c]	61.33[b]	2465[bc]	76.89[b]	31.06[d]	39.95[cd]	50.20[d]	26.38[e]
C + Gliricidia	53.23[a]	54.77[a]	57.00[a]	2323[ab]	71.34[a]	7.47[a]	28.62[a]	4.63[a]	-3.85[a]
C + Sesbania	64.82[e]	66.55[d]	69.24[d]	2903[d]	79.24[bcd]	34.65[d]	45.58[d]	47.28[d]	16.84[cd]
C + elephant grass	58.22[c]	58.92[b]	60.56[b]	2375[ab]	80.88[d]	23.12[bc]	33.86[ab]	17.63[abc]	21.35[de]
C + Brachiaria	53.99[ab]	55.20[a]	55.28[a]	2179[a]	79.55[cd]	18.39[b]	31.34[ab]	12.56[ab]	8.32[b]
C + corn leaves	57.68[c]	58.96[b]	60.65[b]	2422[bc]	78.75[bcd]	28.65[cd]	42.48[d]	18.76[abc]	13.05[bc]
C + cassava tops	56.26[bc]	57.74[ab]	58.34[ab]	2366[ab]	71.22[a]	19.61[b]	35.05[bc]	34.16[cd]	20.62[de]
C + banana leaves	59.01[cd]	59.67[bc]	60.90[b]	2419[bc]	78.02[bc]	20.61[b]	42.72[d]	21.41[abc]	11.96[bc]
C + papaya leaves	59.20[cd]	60.39[bc]	60.73[b]	2408[b]	77.99[bc]	23.80[bc]	41.09[cd]	23.88[bc]	22.08[de]
SEM	1.498	1.622	1.441	71.5	1.305	3.236	2.895	8.179	5.970
Forage[**]									
Leucaena	57.30[c]	55.08[c]	54.97[d]	2347[b]	57.87[e]	45.96[fg]	33.37[bc]	75.83[d]	-116.26[c]
Gliricidia	33.67[b]	34.98[b]	42.75[c]	1970[c]	48.84[de]	-18.92[a]	2.28[a]	-24.30[b]	-291.52[b]
Sesbania	66.09[d]	67.63[d]	73.89[e]	3758[a]	70.31[f]	53.14[g]	50.56[c]	67.30[cd]	-183.53[bc]
Elephant grass	37.67[b]	33.88[b]	40.41[bc]	1553[d]	41.92[cd]	21.53[cd]	12.83[ab]	-99.60[b]	-152.88[c]
Brachiaria	16.68[a]	15.32[a]	15.47[a]	626[e]	7.80[a]	9.48[b]	7.21[a]	-284.83[a]	-209.56[bc]
Corn leaves	40.37[b]	38.66[b]	46.72[cd]	1985[c]	44.03[cd]	37.85[ef]	37.78[c]	-9.15[bc]	-178.27[bc]
Cassava tops	37.79[b]	38.88[b]	43.13[c]	2081[c]	25.90[b]	12.54[bc]	15.42[ab]	37.93[bcd]	-129.61[c]
Banana leaves	35.08[b]	29.66[b]	33.00[b]	1466[d]	36.47[c]	13.90[bc]	40.74[c]	-5.00[bc]	-461.56[a]
Papaya leaves	38.59[b]	35.56[b]	39.03[bc]	1594[d]	50.31[de]	28.77[de]	32.33[bc]	9.53[bcd]	-195.90[bc]
SEM	4.03	5.05	4.00	136.7	5.07	5.25	10.04	36.66	56.82

[*] Values bearing different superscripts within the same column are different statistically ($P < 0.05$).
[**] Calculated by difference, assuming the nutrient digestibility of concentrate diet remains unaffected.

nutrients between species. The variations, however, were less within combined C+F than within forages alone. For instance, the range of values for DM, organic matter (OM), GE and CP digestibilities in the combined C+F were 53.23 to 64.82, 54.77 to 66.55, 55.28 to 69.24 and 71.22 to 85.55 %, respectively. The corresponding values for forages were 16.68 to 66.09, 15.32 to 67.63, 15.47 to 73.89 and 7.80 to 70.31 % respectively. This lower variability in the combined C+F values was due to the 'buffer action' of concentrate diet. A small contribution of forage to concentrate intake caused only small changes in digestibility values. Consequently, these values do not reflect the actual digestibility of forages.

Among forages, nutrient digestibility values for sesbania were highest. Its digestible energy (DE) value was surprisingly high, 3758 kcal/kg, which is comparable to barley or sorghum (NRC, 1977). The fiber (ADF and NDF) digestibility was also high (50 %). Leucaena was the next most digestible, with its principal nutrients, DM, OM, CP and GE, digested more than 50 %. High digestibility values of leucaena were also reported by Harris et al. (1981), Parigi-Bini et al. (1984) and Raharjo et al (1986b). Gliricidia, a promising tree legume for ruminants (Chadhokar, 1982), was less digestible than other woody legumes. Its digestibility values were low, particularly for its fiber fractions. A negative digestibility value for (ADF) was obtained, suggesting that some type of artifact occurred. Possible interaction of polyphenols and proteins (Cheeke and Shull, 1985 ; Pusztai, 1985) and the additional excretions of endogenous materials due to the presence of tannins (Mitjavilla et al, 1977) might artifactually contribute to the undigested fiber fractions. Digestibility values of agricultural by-products were comparable for DM, OM, and GE but not for CP and fiber. Among the by-products, papaya and corn leaves had the highest, while cassava tops had the lowest CP digestibility. Among grasses, elephant grass had values similar to those of most by-products. In our previous results with adult rabbits (Raharjo et al, 1986b), elephant grass was comparable to non-woody legumes such as Centrosema pubescens, Pueraria phaseoloides and Stylosanthes guianensis. Brachiaria was the least digestible. This might be related to the fact that brachiaria contained the highest fiber level (Table III. 2). High fiber not only increases the rate of passage, which reduces digestion time, but may also encrust other nutrients in the cell wall, particularly when lignin is high, making them undigestible (Cheeke and Myer, 1975). Increased excretion of endogenous materials in the feces when high fiber diets are fed could also be a factor contributing to the lower DM and CP digestibility. The less easily degraded components such as vascular tissues, parenchyma bundle sheaths and epidermis, which are usually contained in high quantity in warm season grasses (Akin, 1979) might also be the case with brachiaria. Negative relationships of fiber contents and nutrient digestibility were reported in our previous results (Raharjo et al, 1986b).

Among nutrients, except in brachiaria, CP seemed to be best digested. This is probably related to the practise of cecotrophy by rabbits, in which undigested CP undergoes microbial fermentation in the cecum and is subsequently reconsumed as cecotropes (soft feces). Rabbits, although they are herbivorous, are unable to utilize fiber efficiently, as indicated by the low ADF and NDF digestibility values.

However, indigestible fiber is necessary to maintain normal functioning of the digestive tract, particularly normal motility. This aids in preventing enteritis problems (Cheeke et al, 1986). In the case of Ca and P, the digestibility values were low and in some cases were negative. This may lead to a deficiency state unless supplementation is provided. The low mineral digestibilities might be a consequence of the sequestering of these minerals to indigestible fiber.

Compared to the previous results (Raharjo et al, 1986) using adult rabbits, the values obtained in this study are generally lower. Lebas (1973) also reported higher digestibility values of DM, OM and CP of feed in adults than in growing rabbits. This is also consistent with Houpt (1963) and Lang (1981), who suggested a better utilization of nutrients in adult rabbits due to more extensive microbial fermentation. No differences, however, were detected by Robinson et al. (1986). Irrespective of this, the previous study and this experiment have shown similar patterns of forage digestibility. Woody legumes were far better utilized than grasses, while non-woody legumes (previous study) and agricultural by-products (this experiment) were intermediate between these 2 groups.

REFERENCES

Akin, D.E. 1979. Microscopic evaluation of forage digestion by rumen microorganisms. A Review. J. Anim. Sci. 48:701-710.

Ayoade, J.A., T.P.E. Makhambera and M. Kayange. 1985. Studies in the nutrition of rabbits in Malawi. A preliminary study on the chemical composition of some central Malawi plants eaten by rabbits. J. Appl. Rabbit Res. 8:81-82.

Bogdan, A.V. 1977. Tropical Pasture and Fodder Plants (Grasses and Legumes). Longman, London and New York.

Chadhokar, P.A. 1982. Gliricidia maculata, a promising legume fodder plant. Wrld. Anim. Rev. 44:36-43.

Cheeke, P.R. and M.O. Myer. 1975. Protein digestibility and lysine availability in alfalfa meal and alfalfa protein concentrate. Nutr. Rep. Inter. 12:337-344.

Cheeke, P.R. and L.R. Shull. 1985. Tannins and polyphenolic compounds. In 'Natural Toxicants in Feeds and Poisonous Plants', pp.322-357. AVI Publ. Co. Inc., Westport, Connecticut.

Cheeke, P.R., M.A. Grobner and N.M. Patton. 1986. Fiber digestion and utilization. J. Appl. Rabbit Res. 9:25-30.

Crowder, H.V. and H.R. Chedda. 1982. Tropical Grassland Husbandry. Longman, London and New York.

Gohl, B. 1981. Tropical Feeds : Feed Information, Summaries and Nutritive Value. FAO Animal Production and Health Series. No. 12, pp. 302-307. FAO of the UN, Rome, Italy.

Harris, D.J., P.R. Cheeke and N.M Patton. 1983. Feed preference studies with rabbits fed fourteen different greens. J. Appl. Rabbit Res. 6:120-122.

Harris, D.J., P.R. Cheeke, N.M. Patton and J.L. Brewbaker. 1981. A note on the digestibility of leucaena leaf meal in rabbits. J. Appl. Rabbit Res. 4:99.

Houpt, T.R. 1963. Urea utilization by rabbits fed a low protein ration. Am. J. Physiol. 205:1144-1150.

Jones, W.T., R.B. Broadhurst and J.W. Lyttleton. 1976. The condensed tannins of pasture legume species. Phytochem. 15:1407-1409.

Lang, J. 1981. The nutrition of commercial rabbits. I. Physiology, digestibility and nutrient requirements. Nutr. Abstr. Rev. 51:197-225.

Lebas, F. 1973. Variations in apparent digestibility coeffients of dry matter, organic matter and nitrogen, according to age, breed and sex in the rabbit. Ann. Biol. Anim. Bioch. Biophys. 13;699-706.

Mitjavilla, S., C. Lacombe, G. Carrera and R. Derache. 1977. Tannic acid and oxidized tannic acid on the functional state of rat intestinal epithelium. J. Nutr. 107:2113-2121.

NRC. 1977. Nutrient requirement of Domestic Animals. No. 9. Nutrient Requirement of Rabbit. Second revised edition. NAS, NRC, Washington, D.C.

Parigi-Bini, R., M.Cinetto and N. Carrota.1984. Digestibility and nutritive value of Leucaena leucocephala in rabbit diets. III Wrld. Rabbit Congress. 1:399-407. Rome, Italy.

Pusztai, A. 1985. Constraints on the nutritional utilization of plant proteins. Nutr. Abstr. Rev. 55:363-369.

Raharjo, Y.C. and P.R. Cheeke. 1985. Palatability of tropical tree legume forage to rabbits. Nitr. Fixing Tree Res. Rep. 3:31-32.

Raharjo, Y.C., P.R. Cheeke and K. Supriyati. 1985. The nutritive value of leucaena leaf for rabbits. Leucaena Res. Rep. 6: 92-94.

Raharjo, Y.C., P.R. Cheeke and N.M. Patton. 1986. Growth and reproductive performance of rabbits on a moderately low crude protein diet with or without methionine or urea supplementation. J. Anim. Sci. 63:795-803.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1986. Evaluation of tropical forages and by-product feeds for rabbit production. 1. Nutrient digestibility and effect of heat treatment. J. Appl. Rabbit Res. 9:56-66.

Robinson, K.L., P.R. Cheeke and N.M. Patton. 1985. Effect of prevention of coprophagy on the digestibility of high forage and high concentrate diets by rabbits. J. Appl. Rabbit Res. 8:57-59.

Robinson, K.L., P.R. Cheeke, N.M. Patton and I.W. Mathius. 1986. Effect of age and cecotrophy on urea utilization by rabbits. J. Appl. Rabbit Res. 9:76-79.

Sitorus, P., S. Sastrodihardjo, Y.C. Raharjo, I.G. Putu, Santoso, B. Sudarjanto and A. Nurhadi. 1982. Report on the Survey of rabbit raising in Java. Central Research Institute for Animal Science. PO BOX 123 Bogor, Indonesia.

Skerman, P.J. 1977. Tropical Forage Legume. FAO Plant Production and Protection Series. NO. 2. FAO of the UN., Rome, Italy.

Smith, C.A. 1962. The utilization of hyperrhenia for the nutrition of cattle in the dry season. III. Studies on the digestibility of the produce of mature veld and veld hay and the effect of feeding supplementary protein and urea. J. Agric. Sci. 53:173-178.

Tangendjaja, B., Y.C. Raharjo and J.B. Lowry. 1985. Evaluation of leucaena leaf meal and its toxicity to rabbits. Res. Rep. Research Institute for Animal Production, CRIAS, PO BOX 123, Bogor, Indonesia.

Van Eys, J.E., I.W. Mathius, H. Pulungan and W.L. Johnson. 1984. Utilization of fresh and ensiled Pennisetum purpureum, Panicum maximum and Brachiaria brisantha by growing sheep. Proc. Sci. Meeting on Small Ruminant Research. pp.50-54. CRIAS, PO BOX 123, Bogor, Indonesia.

CHAPTER IV

EVALUATION OF TROPICAL FORAGES AND BY-PRODUCT FEEDS FOR RABBIT PRODUCTION

3. GROWTH PERFORMANCE OF RABBITS FED DIFFERENT FORAGES AND AGRICULTURAL BY-PRODUCTS[1,2]

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SUMMARY

Two feeding experiments were conducted to study the growth performance of rabbits fed various tropical forages. In both experiments, five-week old crossbred (Flemish Giant x New Zealand White) rabbits were used. In the first experiment four replicates, each of three rabbits, were used for each treatment. Test forages were leucaena, cassava tops, sweet potato leaves, elephant grass and native grass. Pelleted rice bran was used as a concentrate supplement. Both rice bran and forages were fed free choice. The trial was terminated at the third week because of the poor performance of the animals. In the second experiment, each treatment consisted of four replicates, each of two rabbits. Test forages were leucaena, gliricidia, sesbania, cassava tops, corn leaves, banana leaves, papaya leaves, elephant grass and brachiaria grass. A mixture of test forages was introduced one week prior to the feeding trial. A premixed concentrate diet was fed as a supllement to the forages at 40, 50, 50, 55 and 55 g/rabbit/day in week 1, 2, 3, 4 and 5 respectively, for body weight maintenance. Various quantities of the concentrate diet, without forages were also fed for comparison.

Poor performance associated with the low intake of rice bran and forages was observed in the rabbits in the first experiment. Dry matter intake (DMI) of the feeding rice bran alone was 13.6 g and caused body weight (BW) loss of 6 g/rabbit/day. Sweet potato leaves, elephant grass and native grass, supplemented with rice bran, also caused negative weight gain. Highest total DMI (forage + rice bran) was observed in rabbits fed leucaena (46.3 g) and cassava tops (30.5 g), but this intake produced only 3.4 and 1.0 g BW gain/rabbit/day, respectively.

In the second experiment, feeding the concentrate diet alone free choice produced significantly higher DMI and BW gain, 72.1 and 23.8 g/rabbit/day respectively, than other forage-fed rabbits. Rabbits fed leucaena, sesbania and cassava tops gained more BW, 14.1, 12.7 and 12.3 g/rabbit/day respectively, than those fed other forages. The total DMI (forage + concentrate diet) of the corresponding treatments were 62.2, 61.3 and 58.7 g/rabbit/day respectively. Body weight gain and feed intake on these treatments were higher than those obtained by rabbits fed 60 g concentrate diet alone daily. Brachiaria and banana leaves were the least consumed, 51.5 and 50.g and rsulting 2.4 and 4.4 g BW gain/rabbit/day respectively. Highly significant correlations were observed between the intake of nutrients with the body weight gain of rabbits. Low dietary intake was probably related to the palatability of individual forages and the environmental factors.

INTRODUCTION

Forages have been widely used for rabbit production in many tropical and sub-tropical countries (Owen, 1976) such as Brazil (Cheeke, 1985), Cameroon (Lukefahr et al, 1985), Indonesia (Sitorus et al, 1982 ; Cheeke, 1983 ; Prawirodigdo, 1985), Malawi (Ayoade et al, 1985 ; Mc.Nitt, 1980) and Malta (De Batista, 1985). However, only a few studies have been conducted to evaluate the nutritional value of tropical forages for rabbits. Harris et al(1981) obtained satisfactory performance when a number of tropical forages were used at 40% of the diet. Raharjo et al (1986) studied a number of Indonesian forages. The digestibility of the tropical legumes studied in general was quite high, while most tropical grasses were very poorly utilized. The objective of this experiment was to study the effect of feeding individual tropical forages on the growth performance of weanling rabbits. Because feeding forages alone resulted in weight loss, a supplement of rice bran, which is usually fed as a supplement in the village rabbit raising program (Sitorus et al, 1982 ; Cheeke, 1983), or premixed concentrate diet was also offered, either free choice or restricted.

MATERIALS AND METHODS

Two growth trials were carried out at Balai Penelitian Ternak (Research Institute for Animal Production), Bogor, Indonesia. Unless otherwise specified, housing, management, chemical and statistical analyses were carried out as described by Raharjo et al (1986, 1987).

In both trials, 5-week old weanling rabbits were used. Sulfamix, a drug containing sulfa dimethyl pyrimidine and methyl parasept and used against diarrhea, was included in the drinking water at 5 ml/l.

In the first experiment each treatment consisted of 4 replicates of 3 rabbits. Test forages were leucaena, cassava tops, sweet potato leaves, elephant grass and native grass. Native grass is usually a mixture of 2 or 3 roadside grasses. Their botanical identification, except one species (Isachne globosa), was not obtained. Rice bran, which was pelleted, was used as a concentrate supplement. Both rice bran and forages were offered free choice. This trial was terminated at the third week because of the poor performance of the animals.

In the second experiment each treatment consisted of 4 replicates, each of 2 rabbits. A mixture of test forages was introduced for one week prior to the feeding trial. Test forages were the same as those described in the previous paper (Raharjo et al, 1987), viz. leucaena, sesbania, gliricidia, elephant grass, brachiaria, corn leaf, cassava tops, banana leaf and papaya leaf, and were offered free choice. A premixed concentrate diet (Raharjo et al, 1987) was used as the supplement to forages and was fed at 40, 50, 50, 55 and 55 g/rabbit/day in week 1, 2, 3, 4 and 5 respectively during the experimental period. Various quantities of concentrate diet were also fed for comparison. During the fifth week of the trial a digestibility study was conducted; the results have been presented in the previous paper (Raharjo et al, 1987).

Intakes of dry matter (DMI), crude protein (CPI) and digestible energy (DEI), body weight gain (BWG) and calculated feed/gain ratio (FCR) were computed weekly. Results of each experiment were analysed statistically using a one-way analysis of variance. Differences between means were compared by LSD and linear regression of nutrient intake versus BWG were performed according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

Chemical composition of the concentrate diet, rice bran and test forages is presented in Table IV. 1. Most of the forage composition data have been presented and discussed in the previous papers (Raharjo et al, 1986b, 1987).

Performance of rabbits fed rice bran with or without forages free choice is shown in Table IV. 2. Regardless of dietary treatments, poor growth of rabbits was observed. This growth depression was obviously due to extremely low DMI. For rice bran alone, the DMI was only 13.6 g/rabbit/day, which is about 10 % of the intake of pelleted diet achieved under temperate conditions (Raharjo et al, 1986a), 20 % of the intake of concentrate diet diet offered free choice by rabbits at BPT and only one-third of the intake for maintenance (Table 3). In addition, rice bran contains lower CP, amino acids and calcium than the requirements (NRC, 1977). Inclusion of forages significantly increased rice bran intake and total DMI and reduced the weight loss of animals. Leucaena, with the total intake of 46.8 g/rabbit/day, was the only forage that gave a positive but small BWG. Inclusion of cassava tops was only adequate to maintain body weight (.99 g/rabbit/day). Sweet potato leaf, which was reported to be very palatable (Sudaryanto et al, 1984 ; Raharjo and Cheeke, 1985), apparently did not increase the consumption to a level that resulted an increased

Table IV. 1. Chemical composition of concentrate diet, rice bran and forages used in the experiment (% dry matter basis).

Foodstuff/Forage	DM	GE (kcal/kg)	CP	ADF	NDF	EE	Ash	Ca	P
Concentrate diet	90.38	3936	23.10	21.00	38.90	4.85	10.70	.79	.84
Rice bran	89.90	4584	14.10	23.03	43.00	11.30	9.20	.11	1.71
Leucaena	32.45	4272	22.80	21.45	33.10	4.20	6.80	1.34	.21
Gliricidia	30.57	4608	26.10	23.50	38.40	4.60	9.30	1.22	.24
Sesbania	30.99	5088	33.10	24.30	34.70	5.60	7.90	1.33	.22
Elephant grass	19.32	3840	9.50	38.20	61.40	3.41	12.50	.29	.36
Brachiaria grass	18.44	4000	7.10	47.90	71.20	2.39	11.10	.17	.49
Corn leaves	30.00	4248	13.60	29.70	57.90	3.10	10.20	.53	.31
Cassava tops	29.76	4824	16.79	28.01	38.13	5.80	8.30	1.76	.28
Banana leaves	19.02	4440	19.70	27.30	53.90	5.90	11.80	1.14	.25
Papaya leaves	23.60	4080	25.70	16.30	30.70	5.20	15.60	3.02	.36
Sweet potato leaves	10.55	4536	14.80	--	43.8	3.90	9.30	.28	.79
Native grass	24.00	3864	14.7	--	67.7	2.47	12.50	.54	.37

Table IV. 2. Performance of growing rabbits fed rice bran without or with different forages from 5 to 8 weeks old.

Treatment	Intake, g/rabbit/day				Body Weight Gain g/rabbit/day	Mortality
	Dry Matter			Crude Protein		
1. Rice bran (RB)	13.6^{a*}	--	13.6^{a}	1.93^{a}	-5.95^{a}	5/12
2. RB + Leucaena	21.6^{c}	25.2^{c}	46.8^{d}	8.86^{e}	3.44^{d}	3/12
3. RB + Cassava tops	18.3^{bc}	12.2^{b}	30.5^{c}	4.67^{d}	0.99^{c}	7/12
4. RB + Sweet potato leaves	20.3^{c}	7.7^{a}	28.0^{c}	4.06^{d}	-0.79^{bc}	0/12
5. RB + elephant grass	12.9^{a}	7.4^{a}	20.3^{b}	2.54^{b}	-1.46^{b}	5/12
6. RB + native grass	15.1^{ab}	7.7^{a}	22.3^{b}	3.39^{c}	-0.02^{bc}	4/12
SEM	1.83	1.94	2.52	0.239	1.067	

* ^{a,b,c,d,e} within the same column are different ($P < .05$).

BWG. In contrast to these results, Sudaryanto et al (1984) reported growth of rabbits (5 - 13 g/rabbit/day) fed various grasses, cassava tops, sweet potato leaves and combination of cassava tops + elephant grass (1:1) supplemented with rice bran. In their results, however, the lowest rice bran consumption was 71 g/rabbit/day. This difference might be due in part to environmental temperature. Sudaryanto et al (1984) grew the rabbits in Tugu, where the altitude is about 800 m and the average range of daily temperature is 15 to 18^{o} C, while this study was conducted in Ciawi-Bogor, where the altitude is about 250 m and during the dry season the temperature may surpass 30^{o} C. Lebas (1983) noted that above 28^{o} C feed intake by rabbits decreased below the level necessary to provide a DE intake adequate for production. Changing the diet has also been reported to decrease feed intake (Grobner et al, 1983 ; Fekete, 1985). In this study, the animals were usually fed the concentrate diet prior to the feeding trial. On the other hand, rabbits used by Sudaryanto et al (1984) were accustomed to rice bran and forages as their normal feeding regime. Reduction of feed intake can also be caused by physical properties and antinutritive substances. Coarse, hard and hairy leaves, as mostly occur in grasses, are unpalatable to rabbits (Sitorus et al, 1982 ; Harris et al, 1983). Nitrates, oxalates (Crowder and Chedda, 1982), tannins (Jones and Mangan, 1977) and some alkaloids (Cheeke and Shull, 1985) reduce the forage consumption and cause growth depression. Nevertheless, under this situation, it was not possible to predict the effect of antinutritive or toxic factors. The high number of mortalities were mostly caused by inadequate nutrient intake. Dead rabbits were thin and emaciated. Some in the early stages showed signs of diarrhea. Although the results gained in this experiment were poor, it is interesting to note that inclusion of fresh forages increased the intake of rice bran. This might be associated with the increased water intake from the consumption of forages, even though drinking water was available at all times.

Growth performance of rabbits fed concentrate with or without forages is presented in Table IV. 3. Restricted feeding of the concentrate diet limited the growth rate. Feeding 40 g/rabbit/day in the first week, followed by 50, 50, 55 and 55 g/rabbit/day in the consecutive 4 weeks was sufficient to only slightly exceed the requirements for maintenance. The BWG was 5.5 g/rabbit/day. Because the concentrate diet was provided at a maintenace level, any differences among treatments can be attributed to the forages.

In comparing the forages, sesbania and leucaena were consumed in the highest amounts and gave significantly (P<.05) more weight gain than did the other forages. Nonetheless, the consumption of sesbania or leucaena was not sufficient to support the optimal growth of rabbits raised in this environment, i.e. 23.8 g/rabbit/day shown by feeding the concentrate diet free choice.

Gliricidia, corn leaves, papaya leaves and cassava tops were comparable in their intake of DM and DE, but not of CP nor digestible CP. Intakes of CP and digestible CP for gliricidia were similar to intakes with papaya leaves, and significantly higher than those of corn leaves and cassava tops. Nevertheless, rabbits fed cassava tops gained significantly more weight than those fed these other forages. Likewise, although leucaena provided less DE and digestible CP intakes than sesbania, weight gains were slightly greater with leucaena. It

Table IV. 3. Performance of growing rabbits fed concentrate diets with or without different forages from 5 to 10 weeks old.

Treatment	Intake (g/rabbit/day)						Weight Gain	Feed/Gain Ratio	Mortality
	Dry Matter			CP	Total Digestible				
	C	Forage	Total	Total	Energy (kcal)	CP	(g/rabbit/day)		
1. Concentrate* (C)	45.2	--	45.2^{g}	10.44^{i}	119^{f}	8.93^{fg}	5.5^{fg}	8.24^{b}	1/8
2. C, 50 g/rabbit/day	45.2	--	45.2^{g}	10.44^{i}	119^{f}	8.93^{fg}	7.7^{e}	5.89^{ab}	0/8
3. C, 60 g/rabbit/day	54.3	--	54.3^{de}	12.54^{f}	143de	10.73^{c}	10.3^{d}	5.28^{ab}	0/8
4. C, ad libitum	72.1	--	72.1^{a}	16.66^{a}	189^{a}	14.25^{a}	23.8^{a}	3.03^{a}	0/8
5. C + Leucaena**	45.2	17.0^{a+}	62.2^{b}	14.32^{c}	157^{c}	11.01^{c}	14.1^{b}	4.48^{ab}	2/8
6. C + Gliricidia	45.2	13.4^{b}	58.6^{bc}	13.94^{cd}	143de	9.94^{de}	6.8^{ef}	8.78^{b}	0/8
7. C + Sesbania	45.2	16.1^{a}	61.3^{b}	15.77^{b}	176	12.50^{b}	12.7^{b}	4.91^{ab}	2/8
8. C + Elephant grass	45.2	9.4^{c}	54.6^{de}	11.33^{gh}	134^{e}	9.16^{fg}	7.8^{e}	7.35^{b}	3/8
9. C + Brachiaria	45.2	6.3^{d}	51.5^{ef}	10.89^{hi}	124^{f}	8.96^{g}	2.4^{h}	22.57^{d}	4/8
10. C + Corn leaves	45.2	12.7^{b}	57.9^{c}	12.17^{fg}	144^{d}	9.58^{ef}	7.4^{e}	7.99^{b}	3/8
11. C + Cassava tops	45.2	13.5^{b}	58.7^{bc}	12.71^{ef}	146^{d}	9.05^{fg}	12.3^{bc}	4.95^{ab}	1/8
12. C + Banana leaves	45.2	5.4^{d}	50.6^{f}	11.50^{gh}	127^{f}	8.97^{fg}	4.4^{g}	14.57^{c}	6/8
13. C + Papaya leaves	45.2	11.7^{bc}	56.9^{cd}	13.45^{de}	139de	10.49^{cd}	10.7^{cd}	5.33^{ab}	5/8
SEM		.59	.92	.210	3.4	.167	.64	1.207	--
OSU #14 diet++	109.8	--	109.8	19.97	295	--	41.1	2.94	--

* Fed 40, 50, 50, 55, and 55 during week 1, 2, 3, 4 and 5, respectively.
** All forages were supplemented with the same amount of concentrate fed in treatment 1.
\+ Values bearing different superscripts within the same column are different ($P < .05$).
++ Raharjo *et al.*, (1986a).

is apparent that numerous factors may be involved in determining the growth performance achieved when a particular forage is fed. These factors could include nutrient composition, palatability, digestibility, presence of toxins or other deleterious factors, leaf texture and physical properties. For example, gliricidia has a pungent smell and astringent taste (to humans). There appeared to be an adaptation to it, because intake was very low in the first week but increased markedly in the second week. Factors in gliricidia that might influence palatability include cyanide and raton (Dukes, 1981) and tannins (Chadhokar, 1982).

The bitter taste of papaya leaves did not seem to affect its feed intake by rabbits. Cheeke et al (1977) reported that rabbits are relatively tolerant of bitter substances. Elephant grass had nutritive values comparable to those of corn leaves. Physical characteristics such as leaf rigidity, sharpness and hairiness were similar between them, but elephant grass had a higher fiber content. Feeding elephant grass or corn leaves in addition to concentrate diet produced BWG of almost 8 g/rabbit/day. Brachiaria grass, on the other hand, had almost no value other than as a source of indigestible fiber. Its nutrient digestibility was poor (Raharjo et al, 1987), its consumption and efficiency of nutrient utilization, as indicated by high FCR, were extremely low. Brachiaria leaf is more rigid, sharper and more hairy than elephant grass. Other feed intake depressing factors were discussed in the previous paper (Raharjo et al, 1987). The nutritive value of banana leaves was also poor. The astringent property of banana leaf suggests that banana leaf may contains tannins, which precipitate proteins (Hagerman and Butler, 1981 ; Pierpoint, 1983) and inhibit enzyme activities (Elias et al, 1979 ; Fernandez et al, 1982). Ngoupayou et al (1985), however reported that 3% tannins in the diet did not affect the performance of rabbits providing the nutrients in the diet were well-balanced. Fomunjam (1984), in contrast to this study showed that inclusion of 30% banana leaves, fresh and or dry in the diet (CP = 15.7%, DE = 2500 kcal/kg) gave a range of intake of 44.6 to 67.4 g/rabbit/day and, surprisingly, produced the BWG of 20 g/rabbit/day.

From the above results, it can be concluded that feed intake was the major limiting factor for the growing rabbits in this study. There was a linear and close relationship betwen the total nutrient intake (concentrate diet plus forage) with the BWG (Table IV. 4). Applying the nutrient intake value of the OSU diet # 14 to the equations in Table IV. 4 gave a comparable BWG value to the actual BWG of rabbits fed OSU diet # 14 (Table IV. 5). The lower feed intake may be a consequence of heat stress under the tropical conditions in which the study was conducted.

There was no indication of toxicity associated with any of the forages. Rabbits are resistant to the effects of some plant toxicants, such as pyrrolizidine alkaloids in comfrey (Cheeke and Shull, 1985 ; Grobner et al, 1985).

In conclusion, the nutritive value of individual forages varied depending on the species. Except for brachiaria and banana leaves, most of them supported growth of rabbits when fed with a concentrate supplement. Although the nutritive value of these forages appears to be low, further study is warranted to evaluate different tropical

Table IV. 4. Linear regression of intake (x) and body weight gain (y) of rabbits fed diet with different forages.

x (Intake)	A (Intercept)	B (Slope)	r (Coefficient of Correlation)
Dry matter (rice bran + forage)	-7.24	.25	.90
Crude protein (rice bran + forage)	-5.16	1.08	.85
Dry matter (concentrate + forage)	-25.50	.63	.84
Crude protein (concentrate + forage)	-19.41	2.28	.83
Digestible energy (concentrate + forage)	-21.32	.22	.87
Digestible crude protein (concentrate + forage)	-19.88	2.91	.88

Table IV. 5. Applicability of the equations from forage trials to predict the body weight gain of rabbits using DM, CP and DE intake of OSU diet #14.

Equation*	Trial	x**	BWG (g/rabbit/day)	
			Estimated	Reference**
y = -7.24 + .25x	Rice bran + forage	109.8, DMI	20.21	41.41 (DMI 109.8, CPI 19.97, DEI 295.0)
y = -5.16 + 1.08x	Rice bran + forage	19.97, CPI	16.41	
y = -25.50 + .63x	Concentrate + forage	109.8, DMI	43.67	
y = -21.32 + .22x	Concentrate + forage	295.0, DEI	43.58	
y = -19.88 + 2.91x	Concentrate + forage	19.97, CPI	38.23	

* from Table 6.
** from Raharjo *et al*. (1986a).

forages to determine how they can best be utilized in rabbit feeding, and to develop feeding programs which will optimize their use.

REFERENCES

Ayoade, J.A., T.P.E. Makhambera and M.Kayange. 1985. Studies the nutrition of rabbits in Malawi. I. A Preliminary study on the chemical composition of some central Malawi plants eaten by rabbits. J. Appl. Rabbit Res. 8:81-82.

Chadhokar, P.A. 1982. Gliricidia maculata, a promising legume fodder plant. Wrld. Anim. Rev. 44:36-43.

Cheeke, P.R. 1983. Rabbit production in Indonesia. J. Appl. Rabbit Res. 6:80-86.

Cheeke, P.R. 1985. Rabbit production and research in Brazil. J. Appl. Rabbit Res. 8:123-125.

Cheeke, P.R. and L.R. Shull. 1985. Alkaloids. In 'Natural Toxicants in Feeds and Poisonous Plants'. pp. 92-172. AVI Publ. Co. Inc., Westport, Connecticut.

Cheeke, P.R., J.H. Kinzell and M.W. Pedersen. 1977. Influence of saponins on alfalfa utilization by rats, rabbits and swine. J. Anim. Sci. 45:476-481.

Crowder, L.V. and H.R. Chedda. 1982. Tropical Grassland Husbandry. Longman. London and New York.

DeBattista, J.R. 1985. Rabbit production in Malta. J. Appl. Rabbit Res. 8:83-84.

Dukes, J.A. 1981. Handbook of Legumes of World Economic Importance. pp. 313-315. Plenum Press. New York and London.

Elias, L.G., D.G. De Fernandez and R. Bressani. 1979. Possible effects of seed coat polyphenolics on the nutritional quality of bean protein. J. Food Sci. 44:524-527.

Fekete, S. 1985. Rabbit feeds and feeding with special regards to tropical conditions. J. Appl. Rabbit Res. 8:167-173.

Fernandez, L., L.G. Elias, J.E. Braham and R. Bressani. 1982. Trypsine inhibitors and hemagglutinine in beans (Phaseolus vulgaris) and their relationship with the content of tannins and associated polyphenols. J. Agric. Food Chem. 30:734-739.

Fomunjam, R.T. 1984. Cabbage and banana plantain leaf in rabbit diets. III Wrld Rabbit Congress. 1:244-251. Rome - Italy.

Grobner, M.A., P.R. Cheeke and N.M. Patton. 1983. Diet switching and enteritis. J. Appl. Rabbit Res. 6:25-28.

Grobner, M.A., P.R. Cheeke and N.M. Patton. 1985. Effect of feeding comfrey on growth and tissue copper levels of rabbits. J. Appl. Rabbit Res. 6:97-98.

Hagerman, A.E. and L.G. Butler. 1981. The specificity of anthocyanidin - protein interaction. J. Biol. Chem. 256:4494-4497.

Harris, D.J., P.R. Cheeke, L. Telek and N.M. Patton. 1981. Utilization of alfalfa meal and tropical forages by weanling rabbits. J. Appl. Rabbit Res. 4:4-9.

Harris, D.J., P.R. Cheeke and N.M. PAtton. 1983. Feed preference studies with rabbits fed fourteen different greens. J. Appl. Rabbit Res. 6:120-122.

Jones, W.T. and J.L. Mangan. 1977. Complexes of the condensed tannins of sainfoin (Onobrichis viciifolia Scop.) with fraction 1 leaf protein and with submaxillary mucoproteins and their reversal by polyethylene glycol and pH. J. Sci. Food Agric. 28:126-136.

Lebas, F. 1983. Small scale rabbit production. Feeding and management system. Wrld. Anim. Rev. 46:11-17.

Lukefahr, S.D. and M. Goldman. 1985. A technical assessment of production and economic aspects of small scale rabbit farming in Cameroon. J. Appl. Rabbit Res. 8:126-135.

Ngoupayou, J.D.N., P.M. Maiorino, W.A. Schurg and B.L. Reid. 1985. Jojoba meal in rabbit diets. Nutr. Rep. Int. 31:11-19.

NRC. 1977. Nutrient Requirement of Domestic Animals . No. 9. Nutrient requirements of rabbits. Second revised edition. NAS, NRC. Washington, D.C.

Owen, J.L. 1976. Rabbit production in tropical developing countries. Trop. Sci. 18:203-210.

Pierpoint, W.S. 1983. Reaction of phenolic compounds with proteins and their relevance to the production of leaf protein. In 'Leaf Protein Concentrates' (L. Telek and H.D. Graham, editors). pp. 235-267. AVI Publ. Co. Inc. Westport, Connecticut.

Prawirodigdo, S. 1985. Green feeds for rabbits in West and Central Java. J. Appl. Rabbit Res. 8:181-182.

Raharjo, Y.C. and P.R. Cheeke. 1985. Palatability of tropical tree legume forage to rabbits. Nitr. Fixing Tree Res. Rep. 3:31-32.

Raharjo, Y.C., P.R. Cheeke and N.M. Patton. 1986a. Growth and reproductive performance of rabbits on a moderately low crude protein diet with or without methionine or urea supplementation. J. Anim. Sci. 63:795-803.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1986b. Evaluation of tropical forages and by-product feeds for rabbit production. 1. Nutrient digestibility and effect of heat treatment. J. Appl. Rabbit Res. 9:56-66.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1987. Evaluation of tropical forages and by-product feeds for rabbit production. 2. Composition, consumption and digestibility in growing rabbits.

Sitorus, P., S. Sastrodihardjo, Y.C. Raharjo, I.G. Putu, Santoso, B. Sudaryanto and A. Nurhadi. 1982. Report on the survey of rabbit raising in Java. Central Research Institute for Animal Science. PO BOX 123, Bogor, Indonesia.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. A Biometrical Approach. Second edition. Mc Graw Hill Book Co., New York.

Sudaryanto, B., Y.C. Raharjo and M. Rangkuti. 1984. Effects of greens on the performance of weanling rabbits raised in the village. Ilmu dan Peternakan. 1:259-263. CRIAS - PO BOX 123, Bogor, Indonesia.

CHAPTER V

EVALUATION OF TROPICAL FORAGES AND BY-PRODUCT FEEDS FOR RABBIT PRODUCTION

4. EFFECT OF COMBINATIONS OF LEUCAENA WITH GLIRICIDIA, PAPAYA LEAF OR ELEPHANT GRASS ON THE PERFORMANCE OF GROWING RABBITS[1,2]

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SUMMARY

Fifty five-week old crossbred (Flemish Giant x New Zealand White rabbits) were used to study the effect of a combination of a fresh leucaena leaves with other forages. Rabbits were caged individually and each dietary treatment consisted of 10 rabbits. A concentrate diet was given to all forage-fed rabbits at 40, 50, 50, 55 and 55 g/rabbit/day in weeks 1, 2, 3, 4 and 5, respectively, for bodyweight maintenance. Hand-chopped forages were fed as leucaena alone (LEU) or as a mixture with gliricidia (LEU+GLI), papaya leaves (LEU+PAP) or elephant grass (LEU+ELE) in a ratio at 1:1, w/w (wet basis) and were offered free choice. Concentrate diet alone was also fed free choice for comparison. Duration of the trial was 5 weeks.

Results indicated that the total dry matter intake was significantly highest in LEU+PAP (71.7 g/rabbit/day) and lowest in LEU+GLI (65.2 g/rabbit/day). Intake of concentrate diet alone was only 65.3 g/rabbit/day. In bodyweight, the concentrate diet produced the highest gain, 18.6 g/rabbit/day, which was followed by LEU (18.6 g), LEU+PAP (15.3 g), LEU+ELE (12.3 g) and finally LEU+GLI (10.8 g). Efficiency of

feed utilization followed the pattern of bodyweight gain. Results suggested that a combination of forages may have beneficial effect to improve the utilization of poor quality forages.

INTRODUCTION

Feeding individual forages can be used as a screening method for evaluation of the nutritive value or potential of a particular forage. However, the system for forage feeding, particularly under village conditions, usually involves a mixture of two or more forage species (Lebas, 1983 ; Sitorus et al, 1982). In some cases, this method of feeding might be more successful than feeding each forage alone. For example, leucaena may be toxic when fed as the sole forage, but when fed in a mixture the toxin (mimosine) may be diluted to a non-toxic level.

In our previous results on feeding individual forages to rabbits (Raharjo et al, 1987), leucaena appeared to be the most palatable and produced the most weight gain, while gliricidia, elephant grass and papaya leaf produced weight gains of 50 to 75 % of those achieved with leucaena. A combination of leucaena with any of these forages might elevate the intakes and reciprocally contribute some nutrients, which in turn may increase the growth response of rabbits. Any possible adverse effects caused by each forage alone may be reduced by combining two or more forages.

The objective of this experiment was to evaluate the effects of feeding forages combined with leucaena on the feed intake and growth of rabbits.

MATERIALS AND METHODS

Each treatment consisted of ten 5-week old weanling rabbits (Flemish Giant X New Zealand White), which were caged individually. All rabbits received the same amount of concentrate diet required for maintenance, the same as previously described (Raharjo et al, 1987). Hand-chopped forages were fed : leucaena alone (LEU) or as a mixture of leucaena + gliricidia (LEU+GLI), leucaena + papaya leaves (LEU+PAP) or leucaena + elephant grass (LEU+ELG) at 1:1, w/w (wet basis). Housing, management, preparation of forages and observations were the same as those described by Raharjo et al (1986,1987). Proximate analyses followed the procedure of AOAC (1975). Results were analysed using a one-way analyis of variance and differences between means were compared by LSD following the procedure of Steel and Torrie (1980).

RESULTS AND DISCUSSION

The chemical composition of the concentrate diet and forages is shown in Table V. 1. Except for LEU+ELG, which was lower in crude protein (CP) and higher in fiber, other nutrient contents among forages were comparable. LEU, however, had a higher digestible energy (DE) content. Except for DE and phosphorus (P), other nutrient contents of forages appeared to be adequate to meet the requirements (NRC, 1977 ; Lebas, 1980).

Table V. 1. Chemical composition of concentrates and combined forages (%).

Item	DM	GE (kcal/kg)	DE* (kcal/kg)	CP	ADF	NDF	EE	Ash	Ca	P
Concentrates	90.89	3940	2606	23.10	21.00	38.90	4.85	10.70	.79	.84
Leucaena (L)	33.45	4272	2347	22.80	21.45	33.10	4.20	6.80	1.34	.21
L + Gliricidia	31.81	4430	2168	24.36	22.41	25.59	4.39	7.98	1.28	.22
L + Papaya leaves	29.38	4392	2022	24.03	19.23	32.03	4.64	10.59	2.06	.27
L + Elephant grass	27.23	4105	2040	17.66	27.91	44.00	3.69	9.00	.93	.27

* Calculated from Raharjo et al., (1987b).

DM = dry matter
GE = gross energy
DE = digestible energy
CP = crude protein
ADF = acid detergent fiber
NDF = neutral detergent fiber
EE = ether extract
Ca = Calcium
P = phosphorus

Nutrient intake and growth response of the rabbits fed concentrate diet and/or LEU with or without other forages are presented in Table V. 2 and 3 respectively. The concentrate diet produced the highest body weight gain (BWG) and best efficiency of feed utilization.

Irrespective of their type, inclusion of forages significantly increased the total daily intake of nutrients. This could in part be due to moisture in the succulent forages that might alleviate the effect of heat stress caused by the hot environment. Similar observations were noted in the previous study (Raharjo et al, 1987), although the present results showed higher nutrient intake and body weight gain (BWG). Total intake and BWG of LEU, for example, were 26.3 and 16.8 g/rabbit/day respectively, while the corresponding values in the previous experiment were 17.0 and 14.1 g/rabbit/day. It would be interesting to see if feeding concentrate diet free choice combined with forages free choice will elevate the total feed intake closer to the value obtained in the feeding of OSU diet # 14 (109 g/rabbit/day). Nevertheless, in terms of BWG and FCR, the results showed that rabbits fed forages gained less body weight and utilized feed less efficiently than those fed the concentrate diet. Similar results were reported in the previous experiment (Raharjo et al,1987), in which it was suggested that lower nutrient digestibility values and insufficient quantity and quality of nutrients to support optimal growth in forages were factors responsible. The animals may attempt to compensate for these deficiencies by consuming more feed, as was true in the case of LEU+PAP, thus increasing the BWG. Nonetheless, this did not happen with LEU+GLI nor LEU+ELG, perhaps because of the

Table V. 2. Mean daily intake of dry matter, crude protein (CP), digestible crude protein (DCP) and energy (DE) by rabbits from 35 to 70 days old.

Treatment	Intake (g/rabbit/day)					
	Dry Matter			CP	DCP	DE (kcal)
	C	Forage	Total			
Concentrates (C)	65.3	--	65.3^{a}	15.08^{a}	12.90^{c}	170^{ab}
C + Leucaena (CL)	45.4	26.3^{b}	71.7^{b}	16.48^{b}	12.44^{bc}	180^{b}
CL + Gliricidia	45.4	19.7^{a}	65.2^{a}	15.28^{a}	11.53^{a}	161^{a}
CL + Papaya leaves	45.4	33.3^{c}	78.8^{c}	18.48^{c}	13.32^{c}	185^{b}
CL + Elephant grass	45.4	27.7^{b}	73.2^{b}	15.37^{a}	11.64^{ab}	175^{b}
OSU #14 diet**	109.8	--	109.8	19.97	--	295
SEM		.73	.91	.36	.33	4.7

* Values in the same column bearing different superscripts are significantly different ($p < .05$).

** Raharjo *et al*. (1986).

Table V. 3. Growth performance of rabbits fed Leucaena combined with various forages supplemented with restricted amount of concentrates.

Treatment	Body Weight Gain (g/rabbit/day)	Feed Conversion Ratio	Mortality
Concentrates (C)	18.6^{c*}	3.47^{a}	1/10
C + Leucaena (CL)	16.8^{c}	4.34^{ab}	2/10
CL + Gliricidia	10.8^{a}	6.89^{d}	3/10
CL + Papaya leaves	15.3^{bc}	4.96^{bc}	2/10
CL + Elephant grass	12.3^{ab}	6.08^{cd}	1/10
OSU #14 diet**	41.1	2.94	--
SEM	.72	.351	--

* Values bearing different superscripts are significantly different ($P < .05$).

** Raharjo et al. (1986).

high fiber content and low digestibility values that limit the gut capacity. The intake of these forages increased with time (Figure V. 1 and 2), suggesting that rabbits may adapt to the forages, as was also noted with gliricidia and brachiaria in the previous trial (Raharjo et al, 1987). This may be a palatability adaptation. Rabbits, which were 'accustomed' to a continuous feeding of forages, even grasses, were reported to gain weight considerably (Sudaryanto et al, 1984).

The fact that combinations of forages or inclusion of a good forage with a poorer one promoted better growth, which was true with LEU+PAP, suggested that there is an advantage in using a combination of forages. This advantage might be due to the balancing of possible inadequate nutrients when those forages are fed alone. Papaya leaf, for example, contributes a high Ca level while leucaena has higher DE and amino acid contents. This would also be the case for LEU+ELG or for LEU+GLI, in which the BWG of rabbits fed ELG or GLI alone (Raharjo et al, 1987) was increased from 7.8 to 12.3 and from 6.8 to 10.8 g/rabbit/day, respectively. In addition, the advantage of combinations is to reduce the amount of possible toxicants present, so that their detrimental effects are decreased.

In terms of their applicability, these results are important to the areas where leucaena, but not papaya, gliricidia or elephant grass, are in short supply or hard to grow, such as in the high altitude locations (NAS, 1979). Mixed forage feeding may also be advantageous with leucaena to prevent chronic mimosine toxicity.

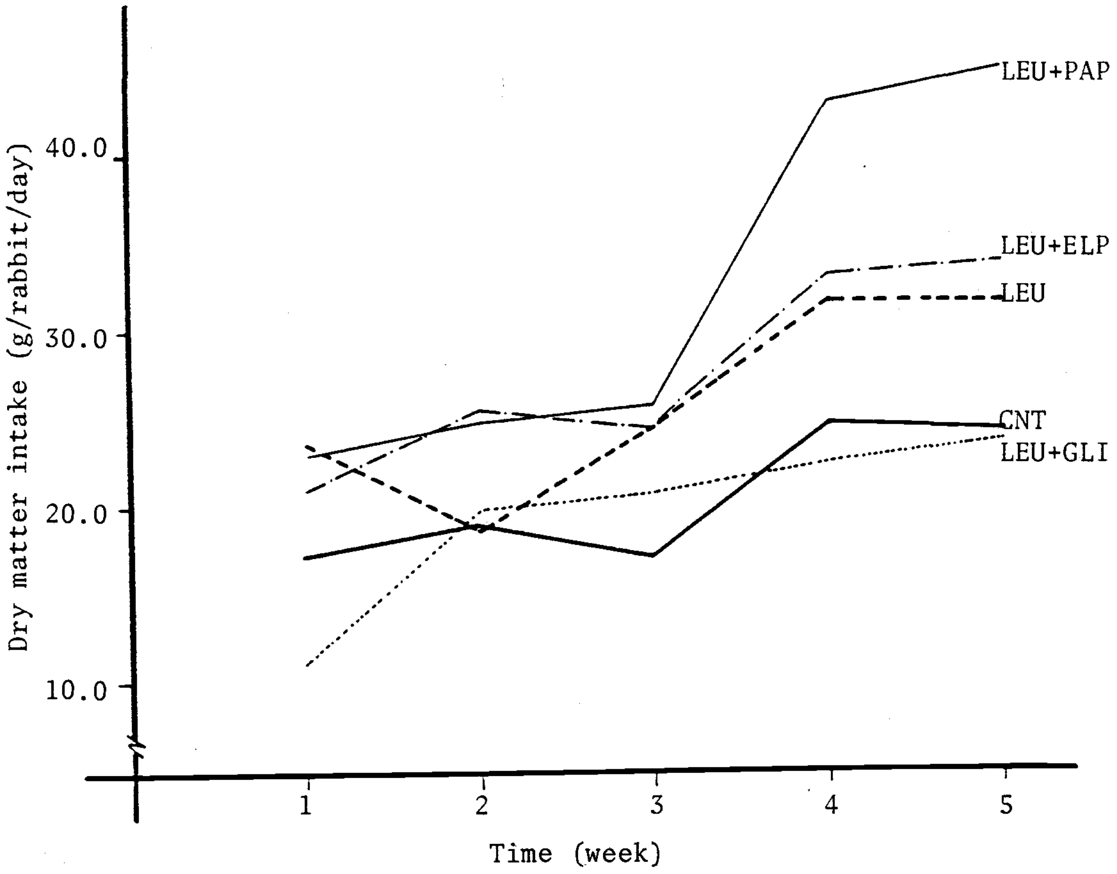

Figure V. 1. Patterns of feed consumption of leucaena (LEU) or mixture of LEU with gliricidia (LEU+GLI), elephant grass (LEU+ELP), and with papaya leaves (LEU+PAP) and of concentrate diet (CNT) in rabbits in a non-cumulative weekly basis.

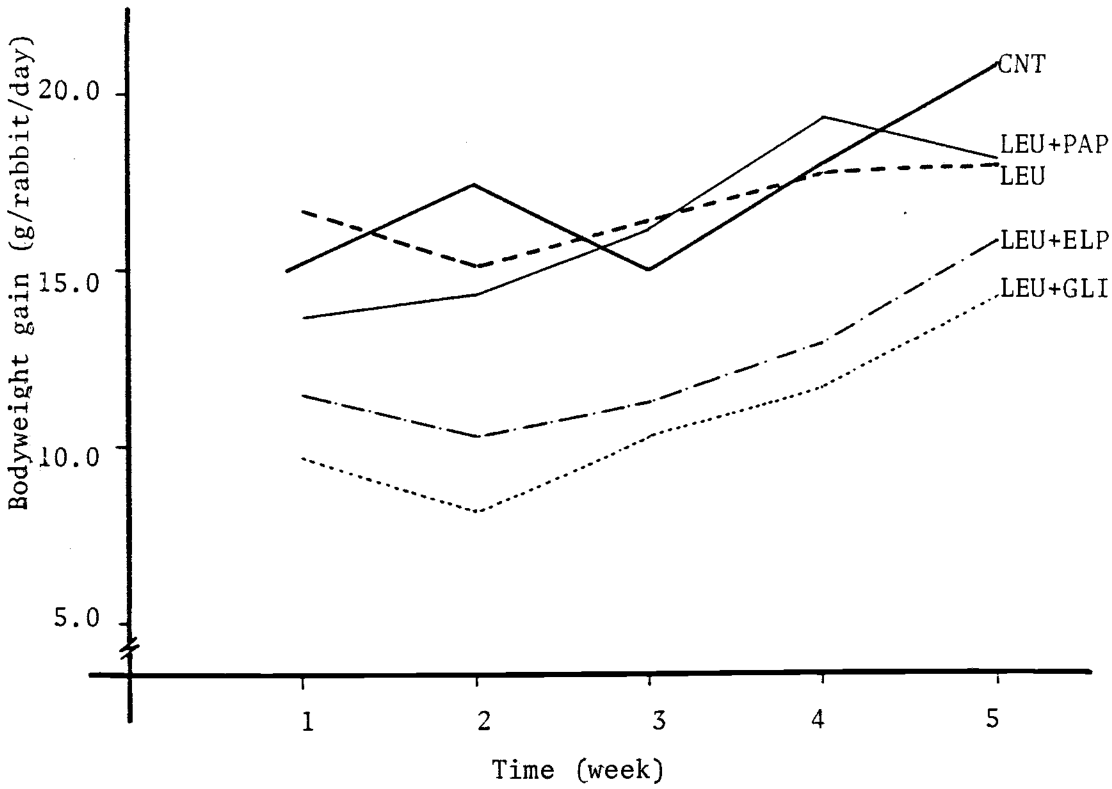

Figure V. 2. Patterns of bodyweight gain of rabbits fed leucaena (LEU) or mixture of LEU with gliricidia (LEU+GLI), elephant grass (LEU+ELP), and with papaya leaves (LEU+PAP) and concentrate diet (CNT) in a non-cumulative weekly basis.

REFERENCES

AOAC. 1980. Official Methods of Analysis. Thirteenth edition. Association of Official Analytical Chemists. Washington, D.C.

Lebas, F. 1980. Researches on rabbit feeding and nutrition. Evaluation during the last 20 years and development in the future. Proc. II Wrld. Rabbit Congress. 2:1-16. Barcelona, Spain.

Lebas, F. 1983. Small scale rabbit production. Feeding and management system. Wrld. Anim. Rev. 46:11-17.

NAS. 1979. Tropical Legumes. Resources for the future. National Academy of Sciences. WAshington, D.C.

NRC. 1977. Nutrient Requirements of Domestic Animals. No.9. Nutrient Requirements of Rabbits. Second revised edition. NAS. NRC. Washington, D.C.

Raharjo, Y.C., P.R. Cheeke and N.M. Patton. 1987. Evaluation of tropical forages and by-product feeds for rabbit production. 3. Growth performance of rabbits fed various forages and agricultural by-products.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1986. Evaluation of tropical forages and by-product feeds for rabbit production. 1. Nutrient digestibility and effect of heat treatment. J. Appl. Rabbit Res. 9:56-66.

Sitorus, P., S. Sastrodihardjo, Y.C. Raharjo, I.G. Putu, Santoso, B. Sudaryanto and A.Nurhadi. 1982. Report on the survey of rabbit raising in Java. Central Research Institute for Animal Science. PO BOX 123, Bogor, Indonesia.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. A Biometrical Approach. Second edition. Mc. Graw Hill Book Co., New York.

Sudaryanto, B., Y.C. Raharjo and M. Rangkuti. 1984. Effects of greens on the performance of weanling rabbits raised in the village. Ilmu dan Peternakan 1:259-263. CRIAS - PO BOX 123, Bogor, Indonesia.

CHAPTER VI

EVALUATION OF TROPICAL FORAGES AND BY-PRODUCT FEEDS FOR RABBIT PRODUCTION

5. RICE BRAN : NUTRITIVE VALUE, UTILIZATION AND EFFECTS OF SUPPLEMENTS[1,2]

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1 Research protocol no. III/4:2/1/Ø1 and III/4:2/1/Ø6. This experiment is part of the study of the rice bran utilization. The participation of Dr. B. Tangendjaja is acknowledged.
2 Oregon Agr. Exp. Sta. Tech. Paper No.
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CHAPTER VI

EVALUATION OF TROPICAL FORAGES AND BY-PRODUCT FEEDS FOR RABBIT PRODUCTION

5. RICE BRAN : NUTRITIVE VALUE, UTILIZATION AND EFFECT OF SUPPLEMENTS

Yono C. Raharjo, P.R. Cheeke, B. Tangendjaja and N.M. Patton

SUMMARY

Two experiments were carried out to study the utilization of rice bran by five-week old crossbred (Flemish Giant x New Zealand White) rabbits. Four replications, each of 3 animals, were used for each dietary treatment in each experiment. In the first experiment, sixty rabbits were randomly allocated into 5 dietary treatments. Rice bran was included in the diet at 0, 40, 60, 80 and 92.5 %. Except for the 92.5 % rice bran-containing diet, all diets were isocaloric and iso-nitrogenous. Diets were pelleted and fed free choice to the animals. A digestibility trial was conducted in the last week of the trial. In the second experiment, seventy two rabbits were divided into six treatment groups. Dietary treatments were (1) rice bran without supplement, (2) rice bran + limestone + salt, (3) diet 2 + vitamin/ mineral premix, (4) diet 3 + molasses, (5) diet 4 + lysine, and (6) diet 5 + methionine. Rice bran diets were given in a pellet form and offered free choice. A mixture of hand-chopped leucaena, cassava tops and elephant grass in a ratio of 1:1:1, w/w (wet basis) was also offered free choice. Duration of each experiment was 5 weeks.

Feed intake, bodyweight gain (BWG) and feed conversion ratio

(FCR) were comparable in rabbits fed diets containing 0, 40 or 60 % rice bran. The values for BWG were 25.7, 24.1 and 23.3 g/rabbit/day and for FCR 3.39, 3.12 and 3.26 respectively. At 80 and 92.5 % inclusion, rice bran depressed BWG to 14.8 and 10.3 g/rabbit/day and FCR to 4.01 to 5.40, respectively. Digestibility values varied among nutrients. Digestibility of gross energy, ether extract and acid and neutral detergent fibers increased with the increase of dietary rice bran level. For crude protein, ash, calcium and phosphorus, the digestibility values decreased with the increase of rice bran level. In the second experiment, supplementation of limestone and salt doubled the BWG and efficiency of feed utilization. Neither vitamin/mineral premix nor molasses produced appreciable growth improvement. The combination of these supplements improved growth significantly. The best performance was observed in rabbits receiving all supplements including lysine and methionine, in which the BWG was 18.7 and 20.9 g/rabbit/day, respectively. Supplementation did not improve forage consumption.

INTRODUCTION

Rice bran, a major by-product of rice milling, has been widely and successfully used as an energy and/or protein supplement in diets for broilers (Zombade and Ichhponani, 1983), layers (Sugandi _et al_, 1978) and pigs (Tuah and Boateng, 1983) at levels up to 30 % of the diet. At higher levels, rice bran depresses growth of broilers (Kratzer _et al_, 1974) and pigs (Brooks and Lumanta, 1975a). A delay in sexual maturity and decrease in egg production was also reported in laying hens fed 60% raw rice bran in the diet (Din _et al_, 1979). High level of fiber and phytin phosphorus (Piliang et al, 1982; Roble and Ewans, 1982), and the presence of lipolytic enzymes (Kratzer and Payne, 1977) are among the limiting factors in rice bran.

Rice bran has also been used as a principal concentrate for supplementation of hand-harvested forages for rabbit production in Indonesia (Sitorus et al, 1982; Cheeke, 1983). Compared to other nonruminant species, rabbits might be expected to be able to utilize rice bran more efficiently because of cecal fermentation, cecotrophy and their tolerance to high fiber levels. There is, however, a possibility that feeding rice bran alone may not support a good growth since the nutrient composition of rice bran is less than that corresponding to the nutrient requirement (Lebas, 1980; NRC, 1982). In addition, low feed intake by rabbits fed rice bran has been reported (Raharjo et al, 1987). A combination of rice bran and forages, a rabbit feeding system practised in villages in Java, Indonesia (Sitorus et al, 1982), might overcome some nutrient deficiencies. Further supplements including minerals, vitamins, molasses an/or amino acids might be expected to improve growth as was reported with chickens (Piliang et al, 1982) and pigs (Huck and Brooks, 1972; Maust et al, 1977).

Two experiments were designed to evaluate the effects of rice bran with or without forages on the growth performance of fryer rabbits. The objective of the first experiment was to study the composition, digestibility and growth response to various dietary levels of rice bran. The second experiment was designed to study the effects of supplements to rice bran, combined with forage feeding, on the growth performance.

MATERIALS AND METHODS

Unless otherwise specified, housing and management of the rabbits were the same as those previously described (Raharjo *et al*, 1987a). Fresh rice bran from the same rice cultivar, purchased directly from a local rice mill, was used in each experiment. Sulfamix, a drug containing sulfa dimethyl-pyrimidine and methyl parasept was included in the drinking water (5 ml/l) to prevent diarrhea and was given at all times in both experiments. Crossbred (Flemish Giant x New Zealand White) rabbits of 5 weeks of age were used. Feed consumption, body weight gain and efficiency of feed utilization, incidence of diarrhea and mortality was observed weekly for 5 weeks.

Experiment 1. Sixty rabbits were randomly allocated into 5 dietary treatments. Every treatment consisted of 4 replicates, each with 3 animals. Rice bran was included in the diet at levels of 0, 40, 60, 80 and 92.5 %. Except for the diet with 92.5% rice bran, other dietary treatments were isocaloric and isonitrogenous. The diets and their chemical composition are presented in Table VI. 1. Diets were pelleted and fed free choice (*ad libitum*) throughout the study. During the last week of observation, a plastic screen was placed underneath each cage for feces collection to determine the digestibility of the dietary nutrients.

Experiment 2. Seventy two rabbits were divided randomly into 6 treatment groups. Each treatment had 4 replicates, each of 3 rabbits. Supplementation of salt and limestone, vitamin/mineral premix, molasses, lysine and/or methionine to rice bran were the variables. Dietary composition is given in Table VI. 7. A mixture of hand-chopped

Table VI. 1. Dietary composition of various levels of rice bran included in rabbit diet (%).

Ingredient	Treatment No.				
	1	2	3	4	5
Corn	35.3	21.3	12.7	—	—
Soybean meal	20.0	18.5	15.6	13.3	—
Fish meal	5.0	—	—	—	—
Rice bran	--	40.0	60.0	80.0	92.5
Elephant grass	33.0	13.5	5.0	—	—
Limestone	1.0	1.0	1.0	1.0	1.0
Vitamin/mineral premix A*	.5	.5	.5	.5	.5
Molasses	5.0	5.0	5.0	5.0	5.0
Salt	.5	.5	.5	.5	.5
Lysine	—	—	—	—	.2
Methionine	.20	.25	.25	.25	.30
Chemical composition**, %					
Gross energy, kcal/kg	4056	4104	4152	4248	4296
Crude protein	17.32	16.50	16.28	16.25	11.90
Ether extract	2.10	6.50	7.80	9.60	12.70
Acid detergent fiber	17.20	13.60	11.72	10.54	12.30
Neutral detergent fiber	23.90	19.20	17.35	17.65	18.57
Ash	8.70	8.90	8.90	8.80	10.20
Calcium	1.41	1.06	.94	.84	.87
Phosphorus	.50	.92	1.13	1.38	1.51
Lysine	.89	.82	.83	.85	.79
Methionine	.45	.47	.43	.44	.50

* Pfizer broiler starter premix provides (/5 kg): Vit. A 10,000,000 IU; D_3 1,000,000 IU; E 7,000 mg; K 1,000 mg; B_1 1,000 mg; B_2 6,000 mg, B_6 500 mg; Niacin 10,000 mg; Pantothenic acid 5,500 mg; choline-Cl 10,000 mg; B_{12} 4,000 mg; minerals - Mg 50,000 mg; Fe 10,000 mg; Cu 2,000 mg, Mn 15,000 mg; zinc 10,000 mg; I 100 mg; Ethoxyquin 10,000 mg; methionine 227 g.

** Analyzed, except for lysine and methionine.

leucaena, cassava tops and elephant grass at ratio 1:1:1 (wet basis) was also offered.

Chemical analysis of dry matter (DM), gross energy (GE), ether extract (EE), crude protein (CP), acid and neutral detergent fiber (ADF and NDF), ash, calcium (Ca) and phosphorus (P) was conducted using the procedures described earlier (Raharjo et al, 1986b). Amino acids were determined using a Beckman Amino Acid Autoanalyzer following the procedure described by Beckman's manual.

Results were subjected to a one-way analysis of variance. Differences between treatment means were compared by least significant difference (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

No mortality or diarrhea were observed in either experiment.

Experiment 1. Proximate composition of rice bran is presented in Table VI. 2. Data from other authors are also included for comparison. Except for ADF and NDF, which were lower than the NRC (1982) values, other nutrient contents were comparable. The CP level of 12.9 and EE of 13.7 % were also relatively close to the values reported by Houston and Kohler (1970) and Barber and de Barber (1980). Variability in the composition of rice bran is common, depending greatly upon rice cultivars, rice milling processes and degree of contamination with rice hulls (Palipane and Swarnasiri, 1985). Raharjo et al (1984) reported levels of 16.8 to 18.6 % EE in rice bran from 5 rice cultivars. A high level of EE is beneficial in providing more energy. Nevertheless, it also causes rancidity, particularly with the presence

Table VI. 2. Chemical composition of rice bran (% DM) and mixed forages.

Nutrient	Rice bran: This Trial	Rice bran: Brooks and Lumanta (1975a)	Rice bran: NRC (1982)	Mixed Forage (Exp. 2)[++]
Dry matter	89.1	91.3	91.0	26.82
GE, kcal/kg	4644	--	--	4369
DE, kcal/kg	3327	3100*	3384*	2305
Crude protein	12.9	12.2	12.7	17.8
Ether extract	13.7	13.5	13.7	4.3
Acid detergent fiber	13.3	11.3+	16.0	23.9
Neutral Detergent Fiber	20.1	--	30.3	38.3
Ash	11.0	9.3	11.6	8.5
Calcium	.24	.12	.07	1.12
Phosphorus	1.63	1.34	1.54	.26

* DE in pigs.
** Gross energy.
\+ Crude fiber.
++ Chopped wilted Leucaena + cassava tops + elephant grass at ratio 1:1:1 (as is).

of lipase in rice bran (Kratzer and Payne, 1977; Hussein and Kratzer, 1982). Rice bran has a low Ca (.24%), but high P (1.63%) content. Rice bran P, however, is only 20% available to chicks (Ashton, 1960) as it is present in phytate form (Kratzer et al, 1974). Low Ca and low availability of P may lead to deficiency of these minerals.

Amino acid (AA) composition of the rice bran was similar to values reported by other authors (Table VI. 3). Most essential AA, however, were less than the quantity required for growing rabbits (Lebas, 1980). In addition, these AA may not be fully available.

Performance of the rabbits fed various levels of rice bran and their corresponding dietary nutrient digestibility values are presented in Tables VI. 4 and 5 respectively. Results indicated that rice bran can be satisfactorily included up to a level of 60 % in the diet of growing rabbits. This value is higher than the 20 % level reported by Oanh (1984), although the digestibility values of nutrients were similar to those obtained in this trial.

At levels higher than 60%, rice bran significantly decreased feed intake, body weight gain (BWG) and efficiency of feed utilization, particularly with the 92.5 % level, in which protein and energy came solely from rice bran. Significantly lower CP, Ca and P digestion might contribute to this depression. A level of 12.9 % CP of rice bran with 62.58 % digestibility provided only 8.07 % available CP. Eighty one (O'Dell et al, 1972) to 91 % (Piliang et al, 1982) of rice bran phosphorus occurs in phytate form, which can result in phosphorus deficiency (Corley et al, 1980). In this trial, available Ca and P in diet no. 5 (92.5 % rice bran) were .17 and .28 % respectively, which were lower than the suggested requirement levels.

Table VI. 3. Amino acid composition of rice bran (% DM).

Amino Acid	This Trial	Brooks and Lumanta (1975a)	NRC (1982)
Lysine	.59	.55	.49
Histidine	.36	.46	.23
Arginine	.79	.46	.72
Aspartic acid	1.80	1.56	--
Threonine	.47	.65	.43
Serine	.62	.77	.77
Glutamic acid	2.14	2.58	--
Proline	.56	.76	--
Glycine	.80	1.07	.80
Alanine	.48	.69	--
Cystine	.16	.12	.10
Valine	.77	.46	.69
Methionine	.20	.44	.23
Isoleucine	.52	.24	.46
Leucine	.96	1.19	.70
Tyrosine	.63	.29	.69
Phenylalanine	.58	.63	.44

Table VI. 4. Mean (± SEM) of feed intake, body weight gain and feed conversion ratio of rabbits fed different levels of rice bran from 5 to 10 weeks of age.

Treatment	Initial Body Weight (g/rabbit)	Feed Intake (g/rabbit/day)	Body Weight Gain (g/rabbit/day)	Feed Conversion Ratio
1. 0% Rice bran diet	592^{a}	86^{a}	25.7^{a}	3.39^{a}
2. 40% Rice bran diet	568^{a}	74^{a}	24.1^{a}	3.12^{a}
3. 60% Rice bran diet	617^{a}	76^{a}	23.3^{a}	3.26^{a}
4. 80% Rice bran diet	589^{a}	58^{b}	14.8^{b}	4.01^{ab}
5. 92.5% Rice bran diet	604^{a}	50^{b}	10.3^{b}	5.40^{b}
SEM	32.3	4.2	5.40	.50

^{a,b} Within the same column are significantly different ($P < .05$).

Table VI. 5. Nutrient digestibility (%) of rice bran-containing diets in rabbits.

Nutrient	Treatment No. 1	2	3	4	5	SEM
	Level of Rice Bran (%)					
	0	40	60	80	92.5	
Dry matter	68.34[a]	69.42[a]	70.08[a]	71.02[a]	69.54[a]	2.20
Gross energy	66.98[a]	72.40[ab]	73.34[ab]	74.37[b]	71.64[ab]	2.41
Crude Protein	74.19[a]	72.07[ab]	71.10[ab]	66.96[bc]	62.58[c]	2.61
Ether extract	72.06[a]	86.24[b]	85.73[b]	84.89[b]	87.06[b]	1.13
Acid detergent fiber	24.23[a]	19.37[a]	21.58[a]	21.08[a]	26.96[a]	3.47
Neutral deterrgent fiber	21.30[ab]	18.68[a]	22.23[abc]	35.34[c]	33.54[bc]	3.61
Ash	52.71[b]	42.99[ab]	39.47[ab]	35.32[a]	40.31[ab]	3.15
Calcium	65.71[a]	45.02[ab]	23.82[ab]	18.68[b]	19.81[b]	14.63
Phosphorus	40.13[a]	29.38[a]	23.93[a]	24.10[a]	18.94[a]	10.37

[a,b,c] Within the same line are significantly different ($P < .05$).

Increasing levels of rice bran in the diet increased the GE, EE and NDF digestibility significantly. This is in contrast to the findings with pigs (Robles and Ewans, 1982), chickens (Kratzer and Payne, 1977) and ducks (Raharjo et al, 1984). The higher fiber level in the rice bran-containing diets is apparently the reason for the lower digestibility values in swine and poultry. On the other hand, the high rice bran diets in this study had lower fiber contents than did the control diet. This, together with high EE content and highly unsaturated fat in rice bran (Kohler and Houston, 1970) could be the factors responsible for the increase of EE and GE digestibility. The digestible energy (DE) value of 3327 kcal/kg obtained in this experiment was similar to that in pigs (Table VI. 2), but higher than commonly reported in chickens, i.e. 2120 kcal/kg (NRC, 1982), although Kratzer and Payne (1977) reported an ME value as high as 3012 kcal/kg. The higher NDF digestibility in the rice bran diets suggested that the fiber fractions of rice bran are more digestible than those of elephant grass, which supplied most of the fiber in the control diet. There are high correlations between dietary ADF content and the digestibility of DM and GE, but not with CP (Table VI. 6). Lower CP digestibility with the increasing levels of rice bran, although dietary fiber contents decreased correspondingly, suggested that there may be factors responsible for the reduction of CP utilization other than fiber itself.

Experiment 2. The proximate composition of the mixtures of forages and the growth performance of rabbits fed rice bran with various supplements and forages are shown in Tables VI. 2 and 8 respectively. Feeding rice bran without supplements, together with

Table VI. 6. Regression of the dietary ADF content and the digestibility of dry matter, gross energy and crude protein in rabbits.

	Digestibility of		
	DM	GE	CP
Intercept (A)	75.Ø8	85.76	54.22
Slope (B)	- .4Ø	- 1.Ø7	1.16
Coefficient of correlation (r)	- .93	-.96	.64

Table VI . 7. Composition of rice bran diet with various supplementation.

Ingredient	Treatment No.					
	1	2	3	4	5	6
Rice bran	100.00	97.5	97.0	92.0	91.8	91.5
Limestone	--	2.0	2.0	2.0	2.0	2.0
Salt	--	.5	.5	.5	.5	.5
Vitamin/mineral Premix A*	--		.5	.5	.5	.5
Molasses	--	--	--	5.0	5.0	5.0
Lysine	--	--	--	--	.2	.2
Methionine	--	--	--	--	--	.3

* See table 1.

Table VI. 8. Mean of feed consumption, weight gain and feed conversion ratio of rabits fed rice bran diet with or without supplements, together with feeding of mixture of forages.

Dietary treatment	Feed Consumption (g/rabbit/day)									Body Weight Gain (g/rabbit/day)	FCR
	Rice Bran			Forage			Total				
	DM	CP	DE*	DM	CP	DE	DM	CP	DE		
1. Rice bran	29^{c**}	3.72	96.5	33^{a}	5.87	76.1	62^{b}	9.59	172.6	3.5^{d}	17.77^{c}
2. As # 1 + lime and salt	37^{ab}	4.76	123.1	34^{a}	6.04	78.4	71^{a}	10.80	201.5	8.2^{c}	8.78^{b}
3. As # 2 + vitamin/ mineral premix	35^{b}	4.50	116.4	35^{a}	6.23	80.7	70^{a}	10.73	197.1	9.5^{bc}	7.46^{b}
4. As # 3 + molasses	35^{b}	4.50	116.4	35^{a}	6.23	80.7	70^{a}	10.73	197.1	11.8^{b}	5.93^{ab}
5. As # 4 + lysine	37^{ab}	4.76	123.1	34^{a}	6.04	78.4	72^{a}	10.80	201.5	18.7^{a}	3.85^{a}
6. As # 5 + methionine	42^{a}	5.40	139.7	35^{a}	6.23	80.7	77^{a}	11.63	220.4	20.9^{a}	3.69^{a}
Concentrate alone***							72	16.66	189.0	23.8	3.03
OSU #7+	--	--	--	--	--	--	122		297.6	41.1	2.94
SEM	1.1			1.5						.78	1.09

* kcal/g.

** a,b,c,d within the same column are significantly different ($p < .05$).

*** Raharjo et al., (1987).

\+ Raharjo et al. (1986).

forages, was only adequate for little more than maintenance, with an average daily gain of 3.5 g. This result, however, was better than those previously reported (Raharjo et al, 1987), in which feeding rice bran with individual forages, either leucaena, cassava tops or elephant grass resulted in body weight loss of the rabbits. This suggests that feeding a mixture of forages is better than feeding individual forages, or that the forage used in the present study had a higher nutritive value than those used previously.

Irrespective of their type, supplements significantly improved feed intake, BWG and efficiency of feed utilization. Supplementation with limestone and salt doubled the BWG and feed efficiency. Similar results were reported by Deolankar and Singh (1979) in broiler chickens. Supplementation with a vitamin/mineral premix increased weight gain and fed efficiency numerically, but not statistically. Likewise, addition of molasses to diet no. 3 only slightly improved the performance. Both supplements (vitamin/ mineral premix and molasses), however, produced a significant effect on BWG (diet no. 4 vs no. 2).

Supplementation with amino acids did not change feed consumption, except for methionine, but markedly ($P<.05$) improved BWG and feed efficiency among supplemented-rice bran groups. Huck and Brooks (1972) reported an improvement of ration digestibility in swine with methionine supplementation. Din et al (1979) reported a growth improvement of pullets fed 68 % rice bran diet with .2 % lysine and .2 % methionine. Robles and Ewans (1982) used .1 % lysine and .2 % methionine in their rice bran-based diets for pigs. Kratzer et al (1974), on the other hand, reported no significant improvement with the addition of .2 % lysine and .2 % methionine to steamed rice bran included at 60 % in a broiler ration. The steaming process may improve the nutritive value of rice bran by inactivating trypsin inhibitors (Barber et al, 1978; Deolankar and Singh, 1979), lipase (Hussein and Kratzer, 1982) and hemagglutinins (De Barber and Barber, 1978).

General discussion. Feeding rice bran without supplementation to rabbits will not support significant growth. Low feed intake, lower nutrient content than the requirement and low levels of available Ca and P may lead to a deficiency state of these nutrients. Furthermore, rice bran contains silica, particularly when contaminated with rice hulls. Silica is abrasive to the gut lining and consequently reduces the digestive capacity. Maust et al (1972) reported a 7 % depression of digestive capacity in pigs in the presence of silica in the rice bran. Most of the phosphorus in rice bran is in the form of phytate, causing a low digestibility of phosphorus, zinc and other bivalent metals (Cheeke and Shull, 1985) rendering them unavailable. Phytates may also account for the low Ca digestibility (19.8 %). Supplementation with limestone in the second experiment doubled the BWG, indicating an inadequacy of Ca in the rice bran-containing diet. Further addition of vitamin/mineral premix did not elevate growth performance to a significant level. Kratzer et al (1974) reported similar results in laying chickens fed 60 % rice bran. Piliang et al (1982), however, produced results comparable to the control diet in laying hens fed 91 % of rice bran diet supplemented with zinc carbonate and free choice grit. Addition of molasses did not significantly increase feed intake. Brooks (1972) and Brooks and Lumanta (1975b) similarly did not obtain any appreciable effect of feeding molasses as a source of energy to pigs fed rice bran, although usually increased feed consumption was recorded.

Amino acid contents of rice bran were also lower than the requirements. Addition of mixed forages ad libitum apparently did not produce a significant effect. Cecotrophy might improve amino acid utilization and provide some bacterial protein, but amino acid deficiency might still occur, particularly with the sulphur-containing amino acids. Supplementation with lysine and methionine (Table 8) caused a large increase in BWG and feed efficiency without increasing feed intake. These results confirmed other reports that feeding high levels of rice bran to non-ruminant animals requires lysine and methionine supplementation.

Compared with results from feeding OSU diet no.14 (Raharjo et al, 1986a) feed intakes in these two studies were very low. These results, however, were consistent with our previous findings, even with the concentrate diet (Raharjo et al, 1987). Possible explanations for this low dietary intake include a less favorable environment for rabbits in some areas in Indonesia than in Oregon.

In conclusion, this study showed that rice bran can be satisfactorily included up to 60 % in rabbit diets. Supplementation with Ca, vitamin/mineral premix and molasses, and lysine and methionine are necessary in a rice bran-forage feeding system. Moist-heating and/or other processing treatments as a means to improve rice bran utilization is another area should be evaluated as to their effects on rabbit performance.

REFERENCES

Ashton, W.W., C.Evans and P.C. Williams. 1960. Phosphorus compounds of oats. II. The utilization of phytate phosphorus by growing chicks. J. Sci. Food Agric. 11:722-727.

Barber, S. and C.B. deBarber. 1980. Rice bran :Chemistry and Technology. In 'Rice : Production and Utilization' (B. S. Luh, editor). pp 790-862. AVI Publ. Co. Inc., Westport, Connecticut.

Barber, S., C.B. deBarber, M.J. Flores and J.J. Montes. 1978. Toxic constituents of rice bran . 1. Trypsin inhibitor activity of raw and heat-treated bran. J. Agric. Chem. Food Technol. 18:80-88.

Brooks, C.C. 1972. Molasses, sugar, corn, tallow, soybean oil and mixed fat as sources of energy for growing swine. J. Anim. Sci. 34:217-224.

Brooks, C.C. and I.G. Lumanta Jr. 1975a. Rice bran composition and digestibility by the pigs. Proc. West. Sec. Am. Soc. Anim. Sci. 26:112-114.

Brooks, C.C. and I.G. Lumanta Jr. 1975b. Effect of rice bran on pig performance and carcass. Proc. West. Sec. Am. Soc. Anim. Sci. 26:115-117.

Cheeke, P.R. 1983. Rabbit production in Indonesia. J. Appl. Rabbit Res. 6:80-86.

Cheeke, P.R. and L.R. Shull. 1985. Natural Toxicant in Feeds and Poisonous Plants. pp. 314-331. AVI Publ. Co. Inc., Westport, Connecticut.

Corley, J.R., D.H. Baker and R.A. Easter. 1980. Biological availability of phosphorus in rice bran and wheat bran as affected by pelleting. J. Anim. Sci. 50:286 - 292.

deBarber, C.B. and S. Barber. 1978. Toxic constituents of rice bran. II. Hemagglutinating activity of raw and heat-treated bran. J. Agric. Chem. Food. Technol. 18: 89-94.

Deolankar, R.P. and K.S. Singh. 1979. Trypsin inhibitor, mineral availability and performance of broiler chickens fed on diets based on rice bran. Anim. Feed Sci. Technol. 4:133-141.

Din, M.G., M.L.Sunde and H.R. Bird. 1979. Effect of feeding plant by-product diets on growth and egg production. Poult. Sci. 58:1274-1283.

Houston, D.F. and G.O. Kohler. 1970. Nutritional properties of rice. National Academy of Sciences. Washington, D.C.

Huck, D.W. and C.C. Brooks. 1972. Effect of methionine, pig weight, sex and diet on digestion. Proc. West. Sec. Am. Soc. Anim. Sci. 23:118-121.

Hussein, A.S. and F.H. Kratzer. 1982. Effect of rancidity on the feeding value of rice bran for chickens. Poult. Sci. 61:2450-2455.

Kratzer, G.H. and C.G. Payne. 1977. Effect of autoclaving, hot water treating, parboiling and addition of ethoxyquin on the value of rice bran as a dietary ingredient for chickens. Bri. Poult. Sci. 18:475-482.

Kratzer, G.H., L.Earl and C. Chiaravanont. 1974. Factors influencing feeding value of rice bran for chickens. Poult. Sci. 53:1795-1800.

Lebas, F. 1980. Researches on rabbit feeding and nutrition. Evaluation during the last 20 years and development in the future. Proc. II Wrld Rabbit Congress. 2:1-16. Barcelona, Spain.

Maust, L.E., W.G. Pond and M.L. Scott. 1972. Energy value of a cassava-rice bran diet with or without zinc for growing swine. J. Anim. Sci. 35:953-957.

Mayun, G.K. and C.G. Payne. 1977. Autoclaved rice bran in layer diets. Bri. Poult. Sci. 18:201-203.

NRC. 1982. United States-Canadian tables of feed composition. National Academy Press. Washington, D.C.

Oanh, D.K. 1984. Utilization of by-products from rice processing in rabbit feed. Nutr. Abstr. Rev. 54:554 (4308).

O'Dell, B.L., A.R. deBoland and S. Koirtyohan. 1972. Distribution of phytate and nutritionally important elements among the morphological components of cereal grain. J. Agric. Sci. Food Chem. 20:718-720.

Palipane, K.B. and C.D.P. Swarnasiri. 1985. Composition of raw and parboiled rice bran from common Sri Lankan varieties and from different type of rice mills. J. Agric. Food Chem. 33:732-734.

Piliang, W.G., H.R. Bird and M.L. Sunde. 1982. Rice bran as a major energy source for laying hens. Poult. Sci. 61:357-363.

Raharjo, Y.C., P.R. Cheeke and N.M. Patton. 1986a. Growth and reproductive performance of rabbits on a moderately low crude protein diet with or without methionine or urea supplementation. J. Anim. Sci. 63: 795-803.

Raharjo, Y.C., P.R. Cheeke and N.M. Patton. 1987. Evaluation of tropical forages and by-product feeds for rabbit production. 3. Growth performance of rabbits fed different forages and agricultural by-products.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1986b. Evaluation of tropical forages and by-product feeds for rabbit production. 1. Nutrient digestibility and effect of heat treatment. J. Appl. Rabbit Res. 9:56-66.

Raharjo, Y.C., J. Diment, A.J. Evans and D. Muslih. 1984. Effect of cultivars of paddy (rice) and rice hull dilutions on the nutrient composition and metabolisability of rice bran in Alabio and Tegal ducks. Res. Rep. 10 pp. Balai Penelitian Ternak. PO BOX 123, Bogor, Indonesia.

Robles, A. and R.C. Ewans. 1982. Utilization of energy of rice and rice bran by young pigs. J. Anim. Sci. 55: 572-577.

Sitorus, P., S. Sastrodihardjo, Y.C. Raharjo, I.G. Putu, Santoso, B. Sudaryanto and A. Nurhadi. 1982. Survey report on the rabbit raising in Java. 77 pp. Central Research Institute for Animal Science. PO BOX 123, Bogor, Indonesia.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. A Biometrical Approach. Second edition. McGraw Hill Book Co., New York.

Sugandi, D., H.R. Bird, Y. Wahyu and R. Anggorodi. 1978. Poultry feed formulas based on ingredients indigenous to the tropics. Poult. Sci. 57:740-746.

Tuah, A.K. and S.H. Boateng. 1983. The effect of rice mill feed ('rice bran') in the finishing diets on the growth performance and carcass quality of pigs fed basal maize diet. Nutr. Abstr. Rev. 53:72 (415).

Zombade, S.S. and J.S. Ichhponani. 1983. Nutritive value of raw, parboiled, stabilized and deoiled rice bran for growing chicks. J. Sci. Food Agric. 34:783-788.

CHAPTER VII

EVALUATION OF TROPICAL FORAGES AND BY-PRODUCT FEEDS FOR RABBIT PRODUCTION

6. FEED PREFERENCE STUDY OF TROPICAL FORAGES AND AGRICULTURAL BY-PRODUCTS BY RABBITS[1,2]

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SUMMARY

A series of experiments consisting of 12 short trials was conducted to study the feed preference of 4 groups of tropical forages by crossbred (Flemish Giant x New Zealand White) rabbits. Ten woody legumes, twenty three non-woody legumes, six agricultural by-products and twenty four grasses were tested. Fresh forages were hand-chopped, fed free choice and were presented in small quantities but frequently. The designs for the trials varied depending on the availability of rabbits and forages.

Great variations of dry matter intake (DMI) occurred among groups and among species within groups of forages. In general, woody legumes were the most preferred, as indicated by their high consumption. Grasses were poorly acceptable to rabbits. Leucaena, a woody legume, was the most palatable (103 g DMI/rabbit/day) among forages. Native grass and elephant grass were superior among grasses. Consumption of non-woody legumes and agricultural by-products were comparable. Lablab (54 g) and cassia (64 g) were the best among non-woody legumes, while sweet potato leaves were the most palatable (70 g) among agricultural

by-products. Physical and chemical factors of the leaves greatly influenced the voluntary DMI of forages. Significant relationships were observed between nutrient content and digestibility, particularly dry matter and digestible energy, with the voluntary DMI of forages. A sufficient adaptation period, prior to data collection was suggested to reduce the variability of DMI among forages.

INTRODUCTION.

Animal production in tropical developing countries will increasingly depend primarily on forage feeding. There are many forage species available (Bogdan 1977;Skerman, 1977) but only limited data on their nutritive value, particularly for rabbits, are available. Assessment of the nutritive or feeding value does not rely only on the nutrient composition, but also on the quantity of forage consumed, because great variations occur in voluntary intake of forages between individual animals and/or between forage species within animals (Crowder and Chedda, 1982). Ingals et al (1965) suggested that 70% of the variation in animal productivity can be accounted from voluntary intake differences. Harris et al (1983) indicated a distinct preference for certain green feeds by rabbits. Furthermore, Cordova et al (1978) suggested that selected, high producing animals are likely to have the highest feed intake. Rabbits require a high level of intake of forages in order to meet their energy requirements. The digestive strategy of small herbivores such as the rabbit is to maintain a high feed intake, and selectively excrete the fibrous fraction while retaining the non-fibrous components for fermentation in the cecum (Cheeke, 1983). This implies that the feed for rabbits should be acceptable at all times in order to assure the optimal feed intake and growth. Any restriction in feed intake, therefore, may limit the economic returns.

Forages are major feed sources for tropical rabbit production (Owen, 1981; Lebas, 1983). Compiled data on forage species (and/or their chemical composition) offered to rabbits in Indonesia (Sitorus et al, 1982; Prawirodigdo, 1986) and Malawi (Ayoade et al, 1985) have been reported. Nonetheless, no data on voluntary intake were indicated. The purpose of this experiment was to test the acceptability of various tropical forages, including woody legumes, non woody legumes, agricultural by-products and grasses, offered to the rabbit in a short period of exposure.

MATERIALS AND METHODS

Due to the irregular and limited supply of forage species, which could only be stored without spoilage no more than for 10 days at $4^{o}C$, and limited number of rabbits available at a time, the experiment was divided into small trials and each was carried out in a relatively short period of time.

Unless otherwise specified, each trial followed the procedures obtained below.

Animals. Sixteen-week old crossbred (Flemish Giant x New Zealand White) rabbits were used. Two rabbits were placed in each cage, which served as a replicate within each trial. Housing of the animals followed the procedure described by Raharjo et al (1986).

Forage. Ten woody legumes (WL), twenty three non-woody legumes (NWL), six agricultural by-products (AG-BP) and 24 grasses (GR) were evaluated for their acceptability by rabbits. Forages were prepared as previously described (Raharjo et al, 1986). Test forages were offered free choice (ad libitum), and presented in a small quantity but frequently (about every 4 hours), to prevent spillage. Forage intake was recorded. Forage residues and spillages were collected daily and pooled in a ziplock bag. Dry matter analyses were performed on the sample of forages before feeding and on the total residues after the feding period.

Trial 1 - 3. Five different forages, each placed in a feeder, were offered to rabbits in each cage. Ten replicates were used in each trial. The test period was 48 hours.

Trial 4. Forages were offered individually and were rotated to each cage in a 10 x 10 Latin square design. The test period was 24 hours per cage. Each test forage had 10 replicates.

Trial 5 - 10. Forages were offered individually and were rotated randomly to different cages. The test period for each forage was 48 hours. Trial 6, 7, 8, and 10 had 5 replicates while trial 5 and 9 had 4 and 3 replicates respectively.

Trial 11 - 12. Forages were offered individually. The test period was 5 days. Feed intake was measured daily. Each trial had 4 replicates.

Chemical and statistical analysis followed the procedures earlier described (Raharjo et al, 1986). Due to some technical difficulties, some of the forage composition were not reported.

RESULTS AND DISCUSSION.

Chemical composition of forages is presented in Table VII.1. Great variation occurred in nutrient composition between species. In general, however, WL contained a higher content of dry matter (DM), digestible energy (DE) and crude protein (CP) and lower contents of acid and neutral detergent fiber (ADF and NDF) than GR; while NWL and AG-BP were intermediate between the two groups (Figure VII. 1). Similar patterns of composition have been reported elsewhere (Skerman, 1977; Crowder and Chedda, 1982). Possible sources of variations were described briefly in previous papers (Raharjo et al, 1986, 1987a).

Results from trial 1 - 3, presented in Table VII. 2, showed that there were variations in the voluntary intake of forages among species and also between individual animals within the same forage. These results confirmed the findings of Harris et al. (1983) suggesting that there are distinct preferences for various forage species by rabbits. Although legumes were generally preferred over AG-BP and GR (Figure VII. 2), as also reported in ruminant animals (Crowder and Chedda, 1982), some of them such as gliricidia and albizia (see also Table VII. 3 and VII. 6), were exceptional. Gliricidia was unpalatable to rabbits (4.7 g intake/rabbit/day), although it is reported as a promising legume for ruminants (Chadhokar, 1982). Raharjo et al. (1987b), in a 28 day feeding trial with fryer rabbits, also found a low intake of gliricidia leaf. Leucaena, on the other hand, was highly palatable. More than 50 % of the total dry matter intake (DMI) of 5 forages in trial 2 was supplied by leucaena.

Table VII. 1. Chemical composition of some tropical forages used in the experiment (% DM).

Forage name: Scientific	Forage name: Common	DM	GE (kcal/kg)	DE (kcal/kg)	CP	ADF	NDF
a. Woody legumes							
Albizia falcataria	albizia	35.91	4326	3042	16.31	26.43	38.02
Calliandra calothyrsus	calliandra	37.85	4756	2446	21.80	29.06	44.67
Erythrina lithosperma	erythrina	34.17	4752	—	21.20	41.06	45.00
Gliricidia maculata	gliricidia	30.57	4608	1970	26.10	23.50	38.40
Leucaena leucocephala	leucaena	35.63	4206	2925	21.88	21.80	35.00
Sesbania formosa	sesbania	26.72	4469	2938	19.94	20.78	34.13
S. grandiflora	humming bird	30.99	5088	3758	33.10	24.30	34.70
S. sesban	sesbania	34.85	4254	3298	17.81	29.11	35.40
b. Nonwoody legumes							
Aeschynomene falcata	joint vetch	46.08	4488	—	20.50	23.20	37.00
Calopogonium mucunoides	calopo	38.60	4608	—	20.00	32.40	41.90
Casia rotundifolia	casia						
CPI 49713		37.72	3991	1602	15.00	47.00	59.30
Q 10057		24.65	3848	1416	16.25	48.90	60.60
C. pilosa	—	34.00	4536	—	18.60	32.60	44.70
Centrosema plumieri	butterfly pea	26.03	4680	—	23.00	26.60	35.50
C. pubescens	centro pea	31.60	3885	2105	21.38	35.27	51.41
Desmodium heterophyllum	desmodium	30.93	3752	1828	13.44	37.10	48.51
Neonotonia wightii cv. Tinaroo	Rhodesian kudzu	28.72	3442	1370	13.13	43.30	55.80
Pueraria phaseoloides	tropical kudzu	22.04	3872	1716	15.63	39.90	50.70
Stylosanthes quianensis	Brazilian lucerne	25.44	3107	1713	14.81	33.08	41.55
c. Agricultural by-products, leaf							
Carica papaya	papaya	23.60	4080	1594	25.70	16.30	30.70
Ipomoea batata	sweet potato	10.55	4536	--	14.80	--	43.80
Manihot esculenta	cassava	27.34	4804	2260	16.81	28.20	38.93
Musa paradisiaca	banana	19.02	4440	1466	19.70	27.30	53.90
Orlocarpus integra	jack fruit	35.73	4224	—	12.60	—	52.20
Zea mays	corn	30.00	4248	1985	13.60	29.70	57.90
d. Grasses							
Brachiaria brizantha	signal grass	18.99	2820	690	6.69	36.81	59.31
Chloris gayana	rhodes grass	19.95	3705	1343	7.63	44.60	70.20
Digitaria decumbens	pangola grass	20.69	3636	—	8.94	40.11	65.61
Isachne globosa	native grass	24.00	3864	—	14.70	—	67.70
Panicum maximum	guinea grass						
cv. Green Panic		23.85	3537	447	5.81	48.70	69.40
cv. Guinea		21.03	3585	384	6.63	47.10	66.20
Paspalum plicatulum	brown seed millet	21.34	4230	1427	6.50	44.70	65.10
Pennisetum purpureum	elephant grass	17.59	3824	1730	11.95	38.20	61.40
Setaria sphacelata	foxtail grass	14.30	3864	—	5.60	--	49.00
S. splendida	giant setaria	14.60	2629	248	6.94	39.70	55.44

DM = dry matter
GE = gross energy
DE = digestible energy
CP = crude protein
ADF = acid detergent fiber
NDF = neutral detergent fiber

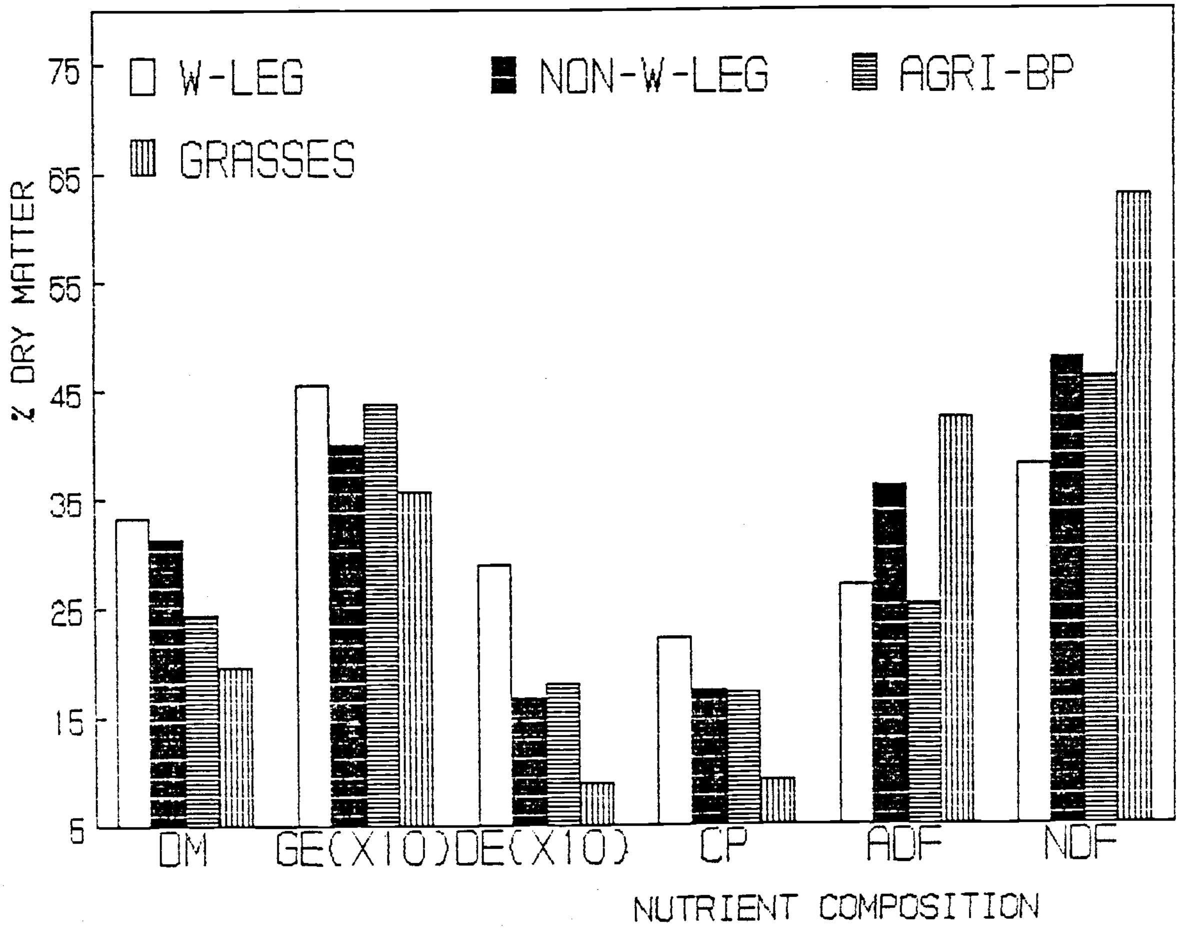

Figure VII. 1. Chemical composition of four different groups of tropical forages.

* The values for GE and DE were expressed in kcal/100 g.

Table VII. 2. Feed preference of fresh tropical forages (leaves) by rabbits as measured by voluntary dry matter intake (DMI) in 2 day period of observation.

Trial Group		Forage	DMI* (g/rabbit/day)	Intake as % of Total Consumed
1.	G**	Pennisetum purpureum	$9.7 \pm 1.7^{a+}$	10.67
	AGBP	Ipomoea batata	20.7 ± 3.4^{b}	22.77
	AGBP	Manihot esculenta	21.7 ± 5.1^{b}	23.87
	L	Calliandra calothyrsus	19.4 ± 4.9^{b}	21.34
	L	Sesbania grandiflora	19.4 ± 2.8^{b}	21.35
	TOTAL		90.9	
2.	G	Isachne globosa	15.0 ± 4.3^{b}	18.29
	G	Setaria sphacelata	2.5 ± 0.7^{a}	3.05
	AGBP	Carica papaya	13.7 ± 1.2^{b}	16.71
	L	Gliricidia maculata	4.7 ± 0.5^{a}	5.73
	L	Leucaena leucocephala	46.1 ± 1.2^{c}	56.22
	TOTAL		82.0	
3.	G	Panicum maximum	5.6 ± 0.8^{a}	7.81
	AGBP	Orlocarpus integra	13.9 ± 1.9^{b}	19.39
	AGBP	Musa paradisiaca	8.6 ± 1.1^{a}	11.99
	L	Albizia falcataria	26.2 ± 1.1^{c}	36.54
	L	Erythrina lithosperma	17.4 ± 2.1^{b}	24.27
TOTAL			71.7	

* Dry matter intake.
** G = grasses, AGBP = agricultural by-product, L = legume
+a,b,c Within the same column within each trial are significantly different ($P < .05$).

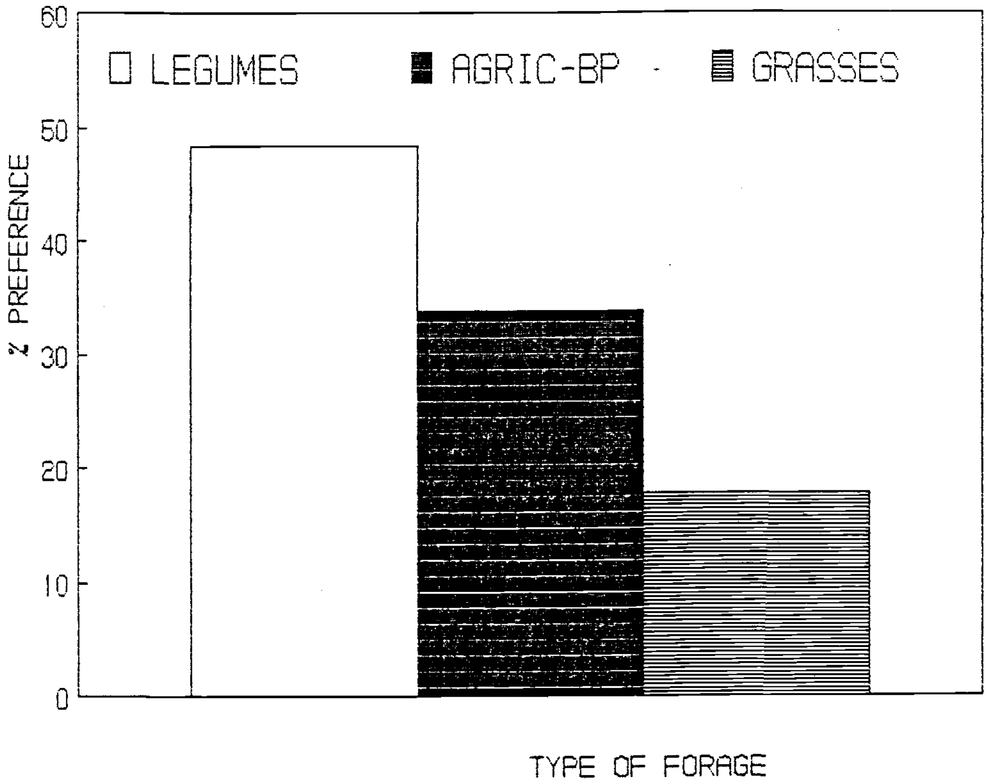

Figure VII. 2. Feed preference (%) of the type of forages by rabbits.

Grasses had low acceptability, except for native grass (Isachne globosa). The DMI of native grass was 18.3 %, second to leucaena, and was better than papaya leaf (Trial 2). Nonetheless, the rankings of preference values, indicated by percentage of total consumption, were not absolute values as changes in the combination of forages offered within trials may change the quantity of voluntary intakes.

In trial 4 (Table VII. 3), in which forages were fed individually and total consumption was used to rank the preferences, leucaena was superior. Similar to the previous results (Trial 2), native grass was also consumed in a good quantity compared with other forages. The high palatability of leucaena, as also reported by other authors (Harris et al, 1981; Parigi-Bini et al, 1984) is of interest because it contains the toxic amino acid mimosine and its metabolite, 3-hydroxy-4(1H)pyridone (DHP)(Hegarty et al, 1964), which are goitrogenic and reduce feed consumption in ruminants (Jones, 1984) and are toxic to rabbits (Cheeke and Shull, 1985).

The AG-BP, except sweet potato leaf, were poorly consumed. Banana and papaya leaf consumptions were even less than that for elephant grass. Tannins (Gohl, 1981) and oxalates (Martin, 1977) in banana leaves may be among the factors responsible for the low voluntary intake of them. The bitter taste of papaya leaf may affect its consumption, although Cheeke et al (1977) reported that rabbits are relatively tolerant of bitterness.

Table VII. 4 shows voluntary intake of NWL offered individually (trial 5, 6 and 7). Results, except those in trial 5, were generally comparable between species. Cassia sp., Neonotonia sp., and Lablab sp. had slightly, but significantly higher intakes, while Centrosema

Table VII. 3. Average intake (as is and dry matter basis) of individual forages when fed alone to rabbits in a 10 x 10 Latin square design.

Trial	Group	Forage/Leaves	Intake (g/rabbit/day)	
			Dry Matter	As Is
4	G	elephant grass	35.1 ± 12.1^{bc*}	167 ± 57.5^{c}
	G	native grass	52.0 ± 14.7^{de}	186 ± 52.5^{c}
	AGBP	banana	26.3 ± 8.4^{ab}	161 ± 51.5^{c}
	AGBP	cassava	44.3 ± 9.0^{cd}	143 ± 29.0^{bc}
	AGBP	papaya	29.6 ± 8.6^{ab}	115 ± 33.5^{b}
	AGBP	sweet potato	69.7 ± 4.8^{f}	442 ± 30.5^{e}
	L	albizia	21.2 ± 7.2^{a}	60 ± 20.5^{a}
	L	erythrina	63.9 ± 23.1^{ef}	187 ± 67.5^{c}
	L	leucaena	103.0 ± 17.3^{g}	294 ± 49.5^{d}
	L	sesbania	30.5 ± 8.7^{ab}	142 ± 40.5^{bc}

* Values in the same column bearing different superscripts are significantly different ($P < .05$).

Table VII. 4. Average intake (as is and dry matter basis) of non-woody legumes fed individually to rabbits.

Trial	Forage	Intake (g/rabbit/day)	
		As Is	Dry Matter
5.	Aeschynomene falcata	83.0 ± 29.8[a*]	38.2 ± 13.7[a]
	Alysicarpus rugosus	52.2 ± 16.1[a]	22.2 ± 6.9[a]
	Calopogonium mercunoides	82.0 ± 18.1[a]	31.7 ± 7.0[a]
	Centrosema virginianum	86.3 ± 46.3[a]	26.5 ± 14.2[a]
	Desmodium intortum	87.0 ± 18.9[a]	28.2 ± 6.1[a]
	D. uncinatum	91.3 ± 19.8[a]	30.4 ± 6.6[a]
6.	Cassia rotundifolia CPI 34721	185.5 ± 22.0[ab]	66.9 ± 7.9[c]
	C. rotundifolia CPI 49713	165.6 ± 22.6[a]	62.5 ± 8.5[c]
	C. rotundifolia Q 10057	182.0 ± 48.1[ab]	44.9 ± 11.9[ab]
	C. pilosa	185.6 ± 49.2[ab]	37.7 ± 10.0[a]
	Neonotonia wightii cv. clarence	192.3 ± 33.0[ab]	58.8 ± 10.1[bc]
	N. wightii cv. cooper	218.7 ± 29.6[b]	61.2 ± 7.6[c]
	N. wightii cv. Tinaroo	198.1 ± 29.3[ab]	56.9 ± 8.5[bc]
	Pueraria phaseoloides	189.4 ± 11.3[ab]	41.8 ± 2.5[a]
7.	Centrosema plumieri	172.1 ± 34.2[b]	44.8 ± 8.9[bc]
	C. pubescens cv. Centro	67.4 ± 38.9[a]	21.3 ± 12.3[a]
	C. pubescens CPI 58575	178.2 ± 47.8[b]	43.2 ± 13.6[bc]
	Lablab purpureus cv. Highworth	187.5 ± 22.0[b]	53.7 ± 14.4[c]
	L. purpureus cv. Rongai	187.5 ± 22.0[b]	55.6 ± 6.5[c]
	Lotononis bainesii	212.8 ± 73.7[b]	54.0 ± 18.7[c]
	Macroptilium atropurpureum	154.2 ± 27.1[b]	46.7 ± 8.2[bc]
	M. lathyroides	152.0 ± 24.5[b]	44.1 ± 7.1[bc]
	Macrotilloma axillare cv. archer	174.5 ± 43.4[b]	35.2 ± 8.7[ab]

*a,b,c Within the same column within each trial are significantly different ($P < .05$).

pubescens cv Centro was poorest. The range of DMI of NWL was 21.3 to 66.9, with an average of 48.8 g/rabbit/day. The lower intakes obtained in trial 5 are probably due to the lower bodyweight of the rabbits used (1600-2000 g), whereas in the other trials bodyweights ranged from 2000 to 2400 g.

Voluntary intakes of various grasses are presented in Table VII. 5. Although there was considerable variation, statistically the results were comparable between species. High variabilities of intakes between animals, as indicated by high standard deviation (SD) values, contributed to the lack of statistical significance. Intakes of grasses in trial 10 were considerably higher than those in trial 8 and 9, because adult rabbits (>3500 g bodyweight) were used. The range of intake of grasses, without using the data from trial 10, was 14.8 to 29.3, with an average of 21.6 g/rabbit/ day, a value that less than a half of that obtained from NWL. Various levels of urea fertilization (Trial 9) slightly, but not significantly, improved voluntary intake. Similar results with ruminant animals have been reported (Holmes and Lange, 1963; Reid et al, 1966). Minson, however (1973) showed a 78 % increase in feed consumption of sheep fed fertilized rhodes, kikuyu and pangola grass. Cordova et al (1978) argued that this increase was likely due to the low level of less than 1 % nitrogen content used in the control diet.

Results from trial 11 and 12, in which forages were fed for 5 days to the same rabbits, are summarized in Table VII. 6. Results, similar to those previously obtained, indicated poor and moderately good intakes of grasses and legumes respectively. Sesbania, whose leaf is similar to leucaena in its shape and physical structure and

Table VII. 5. Average intake (as is and dry matter basis) of grasses offered individually to rabbits.

Trial	Grass Name		Intake (g/rabbit/day)	
	Scientific	Common	As Is	Dry Matter
8.	Andropogon nodosus	andropogon	106.2 ± 23.6[a*]	26.5 ± 5.9[a]
	Brachiaria millinianum	brachiaria	96.8 ± 34.6[a]	17.7 ± 6.3[a]
	B. ruziziensis	ruzi/congo grass	95.6 ± 11.7[a]	19.5 ± 2.4[a]
	Digitaria decumbens	Pangola grass	109.8 ± 17.1[a]	24.0 ± 3.8[a]
	Hyperhenia rufa	Jaragua grass	93.8 ± 21.7[a]	27.2 ± 6.3[a]
	Pennisetum clandistenum cv. Bat	Kikuyu grass	78.6 ± 30.9[a]	16.5 ± 6.1[a]
	P. clandistenum cv Wasp	" "	109.2 ± 13.6[a]	26.1 ± 3.3[a]
	Urochlora mozambiciensis	Sabi grass	81.4 ± 24.5[a]	17.6 ± 5.3[a]
9.	Digitaria decumbens A[**]	Pangola grass	107.9 ± 47.0[ab]	20.5 ± 8.9[a]
	D. decumbens B	" "	152.3 ± 42.3[bc]	29.3 ± 8.1[a]
	Panicum maximum A	Guinea grass	85.7 ± 8.7[a]	18.1 ± 1.8[a]
	P. maximum B	" "	116.9 ± 12.8[ab]	26.1 ± 2.9[a]
	Setaria splendida A	Giant setaria	121.9 ± 62.2[ab]	20.9 ± 9.9[a]
	S. splendida B	" "	139.6 ± 67.9[ab]	14.8 ± 7.5[a]
	S. splendida C	" "	150.9 ± 71.0[bc]	16.9 ± 8.2[a]
	S. splendida D	" "	209.4 ± 74.1[c]	24.6 ± 8.7[a]
10.[+]	Chloris gayana	Rhodes grass	140.4 ± 31.5[a]	28.0 ± 6.3[a]
	Panicum maximum cv. Green Panic	Guinea grass	192.2 ± 58.0[ab]	45.8 ± 13.8[bc]
	P. maximum cv. Guinea	" "	167.6 ± 25.5[a]	35.2 ± 5.4[ab]
	Paspalum plicatulum	Brownseed millet	264.8 ± 29.7[b]	56.5 ± 6.3[c]

*abc Within the same column within each trial are significantly different P < .05).
** Fertilized with urea; A = 0 kg/ha, B = 50 kg/ha, C = 100 kg/ha, D = 200 kg/ha.
+ Trial 10, conducted with adult (> 8 mo old) rabbits.

Table VII. 6. Average intake (as is and dry matter) of forages by rabbits fed individually.

Trial	Group	Forage	Intake (g/rabbit day)	
			As Is	Dry Matter
11.	G*	Brachiaria brizantha	52.3 ± 25.8[a**]	13.7 ± 6.8[a]
	G	Setaria sphacelata	79.1 ± 41.1[ab]	10.4 ± 5.4[a]
	NWL	Centrosema plumieri	90.5 ± 16.5[bc]	23.5 ± 4.3[ab]
	NWL	Desmodium heterophyllum	92.5 ± 15.1[bc]	33.4 ± 5.5[b]
	NWL	D. unciratum	116.9 ± 33.5[bc]	38.9 ± 11.1[b]
	NWL	Stylosanthes guianensis	140.0 ± 39.2[c]	38.2 ± 10.7[b]
12.	WL	Albizia falcataria	58.3 ± 11.4[a]	20.9 ± 4.1[a]
	WL	Calliandra calothyrsus	116.9 ± 19.8[b]	43.9 ± 7.5[bc]
	WL	Codariocalyx gyroides		
		CPI 76 104	126.4 ± 35.6[b]	50.9 ± 14.3[c]
		CQ 1465	95.6 ± 24.7[ab]	37.8 ± 9.8[bc]
	WL	Sesbania formosa	112.0 ± 31.1[b]	29.9 ± 8.3[ab]
	WL	S. grandiflora	113.3 ± 27.1[b]	36.0 ± 8.6[bc]
	WL	S. sesban	91.0 ± 23.4[ab]	31.7 ± 8.2[ab]

* G = grasses, NWL = non-woody legume, WL = woody legume.

**a,b,c Within the same column within each trial are significantly different ($P < .05$).

known to cause no toxicity to cattle (NAS, 1979), consistently gave low intake values. In a 28 day growth trial (Raharjo et al, 1987b), consumption of sesbania was not impressive either. The patterns of daily DMI of some forages are illustrated in figure VII. 3. Daily variations in intake of forages occurred regardless the species. Similar results were reported by Blaxter et al (1961), who reported that declines of 70 % of intake in the subsequent day during trial were occasionally observed with sheep.

General discussion. The nutritional value of forage species or cultivar depends, in part, on the daily intake of nutrients. Measurement of intake, however, is complex as it is related to most aspects that influence animal production (Church and Pond, 1978). Often the error term is very large, because of random variation of intake. In addition, changing the combination of forages offered (in feed preference study - trial 1, 2 and 3), is likely to change the amount or degree of preference of a particular forage consumed. Therefore the results obtained are relative rather than absolute values.

Regarding the high variations of voluntary intake indicated by high SD values and day to day variations (Figure VII. 3), it was probably desirable to conduct an adaptation period to establish a maximum intake prior to data collection. Although this practice is somewhat difficult, owing to different preferences by animals to a certain forage (Harris et al, 1983), Blaxter et al (1961) reported that a 24 day adaptation period for sheep was satisfactory. In rabbits, the period required may be less, as they are smaller, faster growing and have a higher rate of digesta passage. Raharjo et al (1987b) indicated that an extremely low consumption of gliricidia and

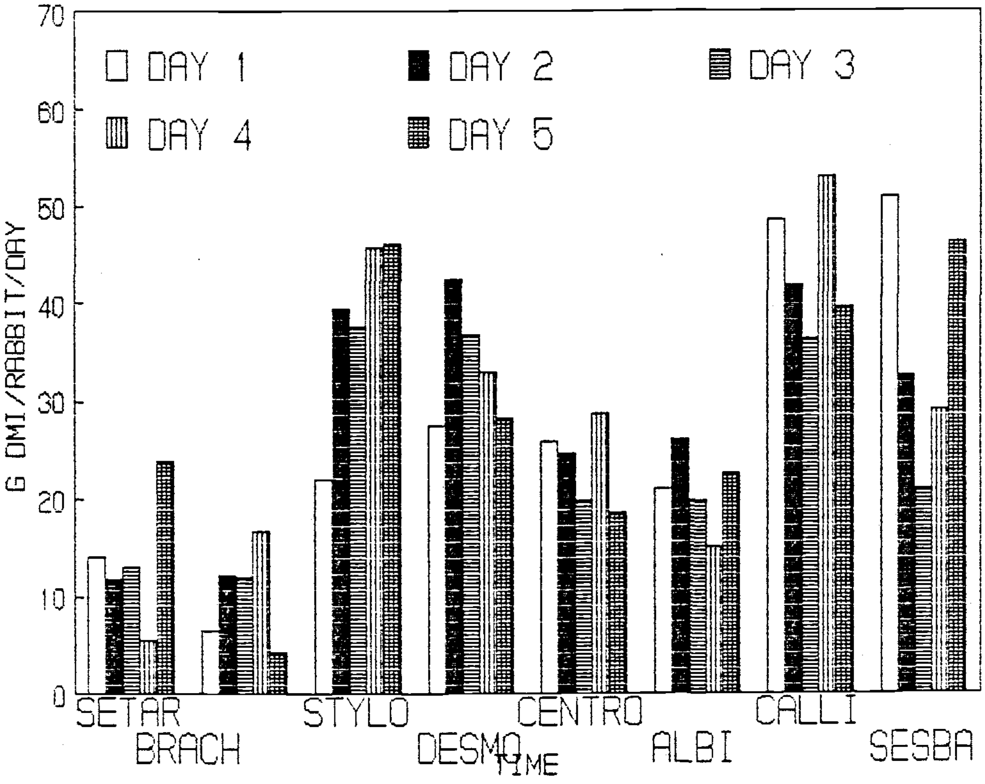

Figure VII. 3. Day by day variations of the dry matter intake of some tropical forages by rabbits.

Brachiaria, as also shown in these results (Table VII. 2 and 5), was increased significantly after a one week period of exposure.

These results suggested that tropical legumes are generally highly palatable, whereas tropical grasses are considered poorly acceptable to rabbits. The high palatability of legumes, particularly the woody species, which was also reported for ruminants (Thornton and Minson, 1973), and the low consumption of grasses may be related to their nutrient contents. A summary of relationships between factors in nutritive values such as DM, CP, ADF, NDF, dry matter digestibility (DMD) and digestible energy (DE), with the DMI of forages is presented Table VII. 7. Poor and non significant relationships were observed in most results, particularly in WL. Church and Pond (1978) suggested that high DM content reduces the volume of the feed, hence increases the capacity of consumption. This, however did not occur in these trials, except with grasses, in which the DM content was low. Likewise, CP content, which has been reported to correlate positively with voluntary intake of grasses in sheep (Smith, 1962; Minson, 1973), was poorly correlated with DMI in rabbits. Nevertheless, a significant negative correlation was observed in NWL and AG-BP. Cordova et al (1978) suggested that significant improvement of feed intake due to the increase of CP content occurs only when the initial CP content of forages is low. This is particularly true with feeding fertilized Panicum maximum to rabbits (Table VII. 5 - trial 9).

Fiber (ADF and NDF) content plays an important role in the voluntary intake of forages (Church and Pond, 1978). Physically, it is bulky and rapidly fills up the gut causing satiety. Chemically, it binds other nutrients, particularly when lignin is high (Cheeke and

Table VII. 7. Regression and correlation of nutrient content or digestibility with dry matter intake of 4 groups of forages.

Forage		DM	CP	ADF	NDF	DMD	DE
a. Woody legume	A	-59.3	41.5	38.8	-0.50	-36.2	158.6
	B	3.20	0.24	0.29	1.27	1.10	-0.36
	r	0.37	0.05	0.07	0.17	0.16	-0.38
b. Non-woody legume	A	40.3	76.4	7.9	4.2	14.63	119.2
	B	-0.01	-2.09	0.89	0.75	0.68	-0.05
	r	0.01	-0.62*	0.62*	0.56*	0.32	-0.82**
c. Agricultural by-product	A	77.6	104.0	19.3	43.1	-26.78	-6.4
	B	-1.74	-3.20	-0.59	-0.01	1.47	0.02
	r	.64	-.76*	0.40	-0.07	.99**	0.99**
d. Grasses	A	-32.2	13.5	-36.2	57.5	25.04	22.4
	B	3.16	1.99	1.54	-1.39	-0.03	0.01
	r	.72*	.40	0.54	-0.63*	-0.06	0.38
e. Overall forage	A	14.36	25.99	34.48	50.16	18.99	25.34
	B	0.82	0.66	0.01	-0.29	0.44	0.01
	r	0.36	0.23	0.05	-0.20	0.42*	0.40*

* P < .05
** P < .01

Myer, 1975). The fiber content was significantly and negatively correlated to GE and CP content and to DMD, DE and DMI in rabbits (Raharjo et al, 1986). Dry matter intakes observed in these trials, although showing poor correlation with the ADF and NDF, except for NWL and grasses, showed high correlation with DMD and DE of NWL and AG-BP. A poor correlation of DMD and DE with DMI in grasses was apparently due to high consumption values of two cultivars of Panicum maximum in trial 10 (with adult rabbits). Exclusion of these data increased the coefficient of correlation to 0.94 and 0.68, which is significant, for DMD and DE respectively. Minson (1972) similarly reported a positive and high correlation between DMI of 4 tropical grasses with their DMD in sheep. Blaxter et al (1961) extrapolated their results and suggested that DMI linearly correlated with DMD, until the latter reaches 75 %, after which voluntary intake starts to stabilize. Increased retention time of digesta and a slower rate of passage in sheep due to high fiber content were apparently responsible for low DMD and feed intake (Thornton and Minson, 1973). This would not be anticipated with rabbits, because of the rapid time of passage and excretion of fiber in this species.

Poor correlation of DMI with the above parameters indicate the complexity of factors regulating voluntary intake. Other factors which may influence feed intake include the presence of secondary compounds (Cheeke and Shull, 1985), physical structure of the leaf (Sitorus et al, 1982; Harris et al, 1983) and environment and animal management (Church and Pond, 1978). Oxalates, which occur in considerable amounts in most tropical grasses such as pennisetum, setaria, paspalum (Crowder and Chedda, 1982) or in banana leaf (Martin et al,

1977) reduce voluntary intakes. Tannins, which have an astringent property and causes irritation to the mouth and epithelial linings (Jones and Mangan, 1977) are contained in some legumes (Cheeke and Shull, 1985). A low phosphorus content, as occurs in most grasses, may cause pica, which can be treated with phosphorus supplementation (Ozanne et al, 1976). Hairy and sharp leaves such as brachiaria and digitaria are unpalatable to rabbits (Sitorus et al, 1982). Comfrey, a temperate herb which is hairy and prickly, was also poorly acceptable by rabbits (Harris et al, 1983). In addition to the above effects, the nutritive value of forages, including their voluntary intake, is highly influenced by the stage of cutting, which determine degree of lignification of plants (Bogdan, 1977).

Regardless of group or species of forages, daily intake of any forage was inadequate to support the growth of rabbits. Body weight loss occurred in all trials. This phenomenon was also observed in the digestibility trial with adult rabbits (Raharjo et al, 1986). Thus, unless appropriate supplementation is provided (Raharjo et al, 1987b; 1987c), growth depression is likely to occur in rabbits fed only forages.

In conclusion, voluntary intake is an important, yet complicated, factor in forage feeding systems. High variation in its measurement is almost inevitable, but an adaptation period prior to data collection may help to reduce variability. Among groups of tropical forages, legumes are generally most palatable. The tropical grasses are not only low in nutrient content, but also are unpalatable. They may, however, be useful as sources of indigestible fiber, which is essential for normal functioning of the gut in rabbits (Cheeke et al, 1986), particularly when used as supplements to high energy concentrate feeds such as rice bran.

REFERENCES

Ayoade, J.A., T.P.E. Makhambera and M.Kayange. 1985. Studies the nutrition of rabbits in Malawi. I. A Preliminary study on the chemical composition of some central Malawi plants eaten by rabbits. J. Appl. Rabbit Res. 8:81-82.

Blaxter, K.L., F.W. Wainman and R.S. Wilson. 1961. The regulation of food intake by sheep. Anim. Prod. 3:51- 61.

Bogdan, A.V. 1977. Tropical Pasture and Fodder Plants (Grasses and Legumes). Longman, London and New York.

Chadhokar, P.A. 1982. Gliricidia maculata, a promising legume fodder. Wrld. Anim. Rev. 44:36-43.

Cheeke, P.R. 1983. The significance of fiber in rabbit nutrition. J. Appl. Rabbit Res. 6:103-106.

Cheeke, P.R. and M.O. Myer. 1975. Protein digestibility and lysine availability in alfalfa meal and alfalfa protein concentrate. Nutr. Rep. Inter. 12:337-344.

Cheeke, P.R. and L.R. Shull. 1985. In 'Natural Toxicants in Feeds and Poisonous Plants'. AVI Publ. Co. Inc., Westport, Connecticut.

Cheeke, P.R., J.H. Kinzell and M.W. Pedersen. 1977. Influence of saponins on alfalfa utilization by rats, rabbits and swine. J. Anim. Sci. 45:476-481.

Cheeke, P.R., M.A. Grobner and N.M. Patton. 1986. Fiber digestion and utilization. J. Appl. Rabbit Res. 9:25-30.

Church, D.C. and W.G. Pond. 1978. Factors affecting feed consumption. In 'Basic Animal Nutrition and Feeding. pp. 203-214. O&B Books Publ. Co. Corvallis.

Cordova, F.J., J.D. Wallace and R.D. Pieper. 1978. Forage intake by grazing species : a Review. J. Range Management. 31 (6) : 430-438.

Crowder, L.V. and H.R. Chedda. 1982. Tropical Grassland Husbandry. Longman. London and New York.

Gohl, B. 1981. Tropical Feeds : Feed Information Summaries and Nutritive Value. FAO Animal Production and Health Series . No. 12, pp. 302-307. FAO of the UN, Rome, Italy.

Harris, D.J., P.R. Cheeke, L. Telek and N.M. Patton. 1981. Utilization of alfalfa meal and tropical forages by weanling rabbits. J. Appl. Rabbit Res. 4:4-9.

Harris, D.J., P.R. Cheeke and N.M. Patton. 1983. Feed preference studies with rabbits fed fourteen different greens. J. Appl. Rabbit Res. 6:120-122.

Hegarty, M.P., P.G. Schinckel and R.D. Court 1964. Reaction of sheep to the consumption of Leucaena glauca and to its toxic principle mimosine. Aust. J. Agric. Res. 15:153-167.

Holmes, J.C. and R.W. Lange. 1963. Effects of fertilizer nitrogen and herbage dry matter content on herbage intake and digestibility in bullocks. Anim. Prod. 5: 17-26.

Ingals, L.R., J.W. Thomas, E.J. Benne and M. Tesar. 1965. Comparative response of wether lambs to several cuttings of alfalfa, birdsfoot trefoil, brome grass and reed canary grass. J. Anim. Sci. 24:1159-1164.

Johnson, W.L., W.A. Hardison, A.L. Ordaveza and L.S. Castillo. 1968. Factors affecting voluntary intake by cattle and water buffaloes. J. Agric. Sci. 71:67-71.

Jones, R.J. 1984. Leucaena toxicity and ruminal degradation of mimosine. In ' Proceedings Australia - USA Poisonous Plant Symposium, (A.A. Seawright, M.P. Hegarty, L.F. James and R.F. Keeler. Eds.) pp. 111-119. Brisbane. Australia.

Jones, W.T. and J.L. Mangan. 1977. Complexes of the condensed tannins of sainfoin (Onobrichis viciifolia Scop.) with fraction 1 leaf protein and with submaxillary mucoproteins and their reversal by polyethylene glycol and pH. J. Sci. Food Agric. 28:126-136.

Lebas, F. 1983. Small scale rabbit production. Feeding and management system. Wrld. Anim. Rev. 46:11-17.

Martin, F.N., L.Telek and R. Ruberthe. 1977. Some tropical leaves as feasible sources of dietary protein. J. Agric (Uni. Puerto Rico) 51:32-40.

Minson, D.J. 1972. The digestibility and voluntary intake by sheep of six tropical grasses. Aust. J. Exptl. Agric. Anim. Husb. 12:21-27.

Minson, D.J. 1973. Effect of fertilizer nitrogen on digestibility and voluntary intake of Chloris gayana, Digitaria decumbens and Pennisetum clandistenum. Aust. J. Exptl. Agric. Anim. Husb. 13:153-157.

Minson, D.J. and M.A. Loredo. 1972. Influence of leafiness on voluntary intake of tropical grasses by sheep. Aust. Inst. Agric. Sci. J. 38:303-305.

NAS. 1979. Tropical Legumes. Resources for the future. National Academy of Sciences. Washington, D.C.

Owen, J.L. 1981. Rabbit meat for the developing countries. Wrld. Anim. Rev. 39:2-11.

Ozanne, P.G., M.D. Purser, E.M.W. Howes and I. Southay. 1976. Influence of phosphorus content on feed intake and weight gain in sheep. Aust. J. Exptl. Agric. Anim. Husb. 16:353-360.

Parigi-Bini, R., M. Cinneto and N. Carrota. 1984. Digestibility and nutritive value of Leucaena leucocephala in rabbit diets. III Wrld. Rabbit Congr. 1:399-407. Rome, Italy.

Prawirodigdo, S. 1985. Green feeds for rabbits in West and Central Java. J. Appl. Rabbit Res. 8:181-182.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1986. Evaluation of tropical forages and by-product feeds for rabbit production. 1. Nutrient digestibility and effect of heat treatment. J. Appl. Rabbit Res. 9:56-66.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1987a. Evaluation of tropical forages and by-product feeds for rabbit production. 2. Composition, consumption and digestibility in growing rabbits.

Raharjo, Y.C., P.R. Cheeke and N.M. Patton. 1987b. Evaluation of tropical forages and by-product feeds for rabbit production. 3. Growth performance of rabbits fed different forage and agricultural by-products.

Raharjo, Y.C., P.R. Cheeke, B. Tangendjaja and N.M. Patton. 1987. Evaluation of tropical forages and by-product feeds for rabbit production. 5. Rice bran : Nutritive value, utilization and effects of supplements.

Reid, R.L., G.A. Jung and S.J. Murray. 1966. Nitrogen fertilization in relation to the palatability and nutritive value of orchard grass. J. Anim. Sci. 25: 636-645.

Sitorus, P., S. Sastrodihardjo, Y.C. Raharjo, I.G. Putu, Santoso, B. Sudaryanto and A. Nurhadi. 1982. Report on the survey of rabbit raising in Java. Central Research Institute for Animal Science. PO BOX 123, Bogor, Indonesia.

Skerman, P.J. 1977. Tropical Forage Legumes. FAO Plant Production and Protection Series. No. 2. FAO of the UN., Rome, Italy.

Smith, C.A. 1962. The utilization of hyperrhenia for the nutrition of cattle in the dry season. III. Studies on the digestibility of the produce of mature veld and veld hay and the effect of feeding supplementary protein and urea. J. Agric. Sci. 53:173-178.

Thornton, R.F. and D.J. Minson. 1973. The relationship between apparent retention time in the rumen, voluntary intake and apparent digestibility of legume and grass diets in sheep. Aust. J. Agric. Res. 24: 889-898.

CHAPTER VIII

EVALUATION OF TROPICAL FORAGES AND BY-PRODUCT FEEDS FOR RABBIT PRODUCTION

7. EFFECTS OF DRYING AT DIFFERENT TEMPERATURES ON THE NUTRIENT DIGESTIBILITY OF TROPICAL LEGUMES AND CASSAVA TOPS[1,2]

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CHAPTER VIII

EVALUATION OF TROPICAL FORAGES AND BY-PRODUCT FEEDS FOR RABBIT PRODUCTION

7. EFFECTS OF DRYING AT DIFFERENT TEMPERATURES ON THE NUTRIENT DIGESTIBILITY OF TROPICAL LEGUMES AND CASSAVA TOPS

Yono C. Raharjo, P.R. Cheeke and N.M. Patton

SUMMARY

Twenty four adult crossbred (Flemish Giant x New Zealand White) rabbits were used to study the effect of various drying temperatures on the quality of _Albizia falcata_, _Calliandra calothyrsus_, _Gliricidia maculata_, _Leucaena leucocephala_, _Sesbania grandiflora_ and cassava tops (_Manihot esculenta_). Each forage was tested by using 4 individually caged rabbits. Forages were sundried or ovendried at 60° or 100° C. Stems and branches were removed prior to the feeding trial. Test forages were given for 14 days and intake and feces collection were recorded in the last 7 days. Solubility of proteins of these forages in the buffer solution at pH 7 was also tested.

No consistent effect of drying temperatures on the patterns of nutrient composition was observed. The crude protein (CP) content of albizia and calliandra increased, whle that of gliricidia decreased, with increasing drying temperatures. The gross energy (GE) of sesbania and tannin content of leucaena decreased at 60° C but increased at 100° C. In legumes, the content of nitrogen in the neutral detergent fiber (N-NDF) increased by drying, suggesting a formation of heat-tied up proteins. Increased drying temperatures caused a consistent stepwise decrease of the nutrient digestibility of forages. The rate of depression was greatest in the NDF (60 %) and N-NDF (59 %) fractions and followed by the GE (32 %) and CP (20 %) fractions. Lower effect on CP digestibility was associated with cecal fermentation and cecotrophy in the rabbits. Stepwise decreases of protein solubility, regardless of the forage species, also occurred with the increasing drying temperatures. Significant and negative relationships between N-NDF with the digestibility of nutrients were observed. Among forages, greatest depression occurred in calliandra and leucaena, which had the highest tannin content.

INTRODUCTION

The potential of tropical forages, particularly of the legume species, for rabbit production is described elsewhere (Lebas, 1983; Cheeke, 1986; Cheeke et al, 1987) In some areas, where potential legumes are deficient or absent, or during the dry season, supplementation of preserved legumes may be required. Drying is probably the most comon method used to preserve forages. Not only is it cheap, but drying is also necessary prior to pelleting. In many cases, drying may increase the nutritive value of feeds, particularly those containing growth-inhibitory enzymes (Kratzer and Payne, 1977; Sanchez et al, 1983). With the legume leaves, however, drying and/or pelleting may depress the digestibility of nutrients (Crowder and Chedda, 1982; Kennedy, 1985). Pelleted diets containing 40 % (Parigi-Bini et al, 1984) or 60 % (Tangendjaja et al, 1985) leucaena depressed crude protein (CP) digestibility from 78 to 52 % or from 73 to 40 % respectively. Increased neutral detergent fiber (NDF) fraction (Raharjo et al, 1986) or nitrogen in NDF fraction (N-NDF) (Cheeke and Carlsson, 1978) in dried forages might be responsible for the decrease of CP digestibility. Furthermore, higher nitrogen (N) digestibility of fresh grasses compared with dried alfalfa (Robinson et al, 1985) suggests that some proteins may be rendered unavailable during drying.

The bioavailability of nutrients of legumes may be depressed by tannins or phenolic compounds (Pierpoint, 1983), which are common in the legumes (Jones et al, 1976; Cheeke and Shull, 1985). Beside phenolics,Pirrie (1966) suggested that leaf proteins may also combine with carbohydrates and fatty acids during processing. In addition, Buchanan (1969) showed that at 100°C, or even at 60°C, leaf proteins underwent some modifications such as increased incidence of lipid-protein interaction. This caused a 40 % reduction of the CP digestibility. Combined effects of phenolics and heat treatment on the nutritive value of forage leaves, however, is unclear.

This experiment was conducted to study the effects of various drying temperatures on the digestibility of some tropical forages and cassava tops in rabbits. These forages are commonly used as feedstuffs for animal production in the tropics.

MATERIALS AND METHODS

Unless otherwise specified, materials and methods were similar to those described by Raharjo et al (1986).

Animals and Housing. Four adult (> 8 month old) crossbred (Flemish Giant X New Zealand White) rabbits were used for each test forage. Rabbits were placed individually in all-wire cages equipped with a plastic screen underneath for feces collection.

Forage and Management. Five woody legumes, i.e. *Albizia falcata*, *Calliandra calothyrsus*, *Gliricidia maculata*, *Leucaena leucocephala* and *Sesbania grandiflora* and cassava tops (*Manihot esculenta*) were tested for their nutrient composition and digestibility. They were sundried or ovendried at 60°C or 100°. Stems and branches were removed prior to feeding trials. Test forages were given twice daily for 14 days. Forage intake and feces collection were recorded during the last 7 days. Feces were collected daily, pooled in a ziplock bag and stored in a freezer. When the trial was completed , feces were ovendried at 60°C for 36 to 48 hours, and then ground for chemical analyses.

Chemical and statistical analysis were performed following the procedures of AOAC (1980) and Steel and Torrie (1980) (see also Raharjo *et al*, 1986). The N-NDF was analysed following the analysis of NDF. Tannin content was analysed according to a vanillin method, following a methanol-HCl extraction (Price *et al*, 1978).

RESULTS AND DISCUSSION

Chemical composition and effect of heat drying on the chemical composition are presented in Table VIII. 1. The effect of drying was dependant on the plant species. There was no consistent pattern of the nutrient composition between individual forages caused by different drying temperatures. For instance, the CP content of albizia and

Table VIII. 1. Chemical composition of forages subjected to various heat treatment.

Forage	Treatment	GE kcal/kg	Composition			
			CP %	NDF %	N-NDF %	Tannins %
Albizia falcata	W	4344	16.31	38.02	1.12	4.38
	SD	4152	18.75	42.80	1.90	4.11
	60°	4176	18.75	39.87	1.47	3.69
	100°	4296	21.25	38.14	1.64	3.87
Calliandra calothyrsus	W	4776	21.80	44.67	1.39	15.80
	SD	3936	23.13	38.03	1.67	14.11
	60°	3912	24.38	40.62	1.99	13.15
	100°	3768	25.00	38.30	1.84	10.61
Gliricidia maculata	W	4608	26.41	38.40	.68	1.79
	SD	4128	23.75	33.51	1.14	1.28
	60°	3912	18.75	36.27	1.37	1.28
	100°	3960	20.63	32.22	1.68	1.12
Leucaena leucocephala	W	4272	22.81	33.10	.87	5.52
	SD	4704	24.50	38.00	.96	4.62
	60°	4344	25.62	38.95	1.05	7.78
	100°	3936	20.00	39.80	1.04	9.62
Manihot esculenta	W	4824	16.81	38.90	1.09	2.81
	SD	4200	25.00	35.41	1.13	2.85
	60°	3888	24.38	36.62	1.06	1.98
	100°	4008	23.13	33.80	1.01	1.93
Sesbania grandiflora	W	5088	28.93	24.70	.44	1.45
	SD	4032	27.50	18.26	.51	1.12
	60°	4080	28.12	19.22	.49	1.09
	100°	4296	25.00	25.00	.95	1.29

calliandra was increased, while of gliricidia was decreased by the increasing drying temperature. The GE of sesbania was decreased at 60°C, but increased at 100°C. For other nutrients within forages, the values fluctuated. In legumes, N-NDF contents were increased by drying, although the values did not correlated linearly with the temperature (Table VIII. 3). Cheeke and Carlsson (1978) also found that the N-NDF content was increased in alfalfa, amaranthus and chenopodium when they were dried. These results suggested that some fractions of proteins are tied up during procesing and are incorporated into the NDF fractions. A classical example of heat-tied up proteins is Maillard reaction, in which amino group of lysine is tied up with the aldehyde group of sugars, making them unavailable biologically. Presence of tannins, which are able to complex proteins (Goldstein and Swanson, 1965; Elias *et al*, 1979), might also be responsible for the increase of N-NDF fractions. Nonetheless, it was unclear which of the two, drying or tannin content, had more effect on the increase of N-NDF. Tannin contents of forages, excepts those in leucaena, were reduced by heat treatment. Both calliandra and cassava tops lost about 32 % of tannins when dried up to 100°C. Price *et al* (1978) suggested that some monomeric flavonoids, which are not 'true' tannins, but give a positive vanillin test, may be destroyed by heat as well as by acids.

Effects of heat treatment on the nutrient digestibility of forages are presented in Table VIII. 2. In general, a consistent stepwise decrease of the nutrient digestibility occurred due to the increase of drying temperature (Figure VIII. 1). The rate of depression, however, was dependant on the temperature, nutrient and the species of forages.

Table VIII. 2. Effect of different drying temperatures on the nutrient digestibility of legumes in rabbits.

Nutrients	Drying (°C)	ALB	CAL	GLI	LEU	MAN	SES
DM	W	74.83	49.46	33.67	74.17	49.85	66.09
	SD	47.78[a]	48.42[a]	46.86[ab]	54.84[a]	66.68[a]	70.19[a]
	60	47.67[a]	31.76[b]	48.00[a]	54.61[a]	57.18[b]	65.56[a]
	100	40.69[b]	24.54[c]	42.49[b]	49.90[a]	52.37[b]	65.13[a]
GE	W	70.31	51.43	42.75	69.54	47.04	73.89
	SD	45.71[a]	61.12[a]	43.08[a]	48.31[a]	63.16[a]	56.86[a]
	60	41.31[a]	18.38[b]	44.95[a]	38.11[b]	44.05[b]	56.67[a]
	100	40.96[a]	7.69[c]	39.87[a]	30.09[b]	42.02[b]	56.44[a]
CP	W	73.40	49.79	48.84	75.93	41.96	70.31
	SD	43.38[a]	42.47[a]	62.57[a]	49.74[a]	87.61[a]	78.46[a]
	60	33.68[b]	28.12[b]	60.80[a]	52.59[a]	65.52[b]	70.48[b]
	100	37.32[ab]	15.59[c]	62.47[a]	41.31[b]	65.66[b]	67.20[b]
NDF	W	63.09	25.64	2.28	54.50	32.95	50.56
	SD	27.95[a]	24.79[a]	17.89[a]	9.12[a]	49.50[a]	28.48[a]
	60	19.32[b]	8.57[b]	8.68[b]	5.10[a]	44.49[a]	30.38[a]
	100	16.16[b]	-6.55[c]	5.56[b]	5.80[a]	17.64[b]	25.64[a]
N-NDF	SD	54.87[a]	24.71[a]	52.15[a]	43.07[a]	69.05[a]	54.55[a]
	60	13.59[c]	10.58[b]	55.26[a]	31.20[b]	32.24[b]	51.47[a]
	100	33.98[b]	-2.87[c]	34.08[b]	6.94[c]	20.82[c]	29.04[b]

* a,b,c within the same column within each nutrient are significantly different (P < .05).

W = wilted; data were obtained from Raharjo et al. (1986, 1987).

SD = sundried, DM = dry matter, GE = gross energy, CP = crude protein, NDF = neutral detergent fiber, N-NDF = nitrogen in the NDF.

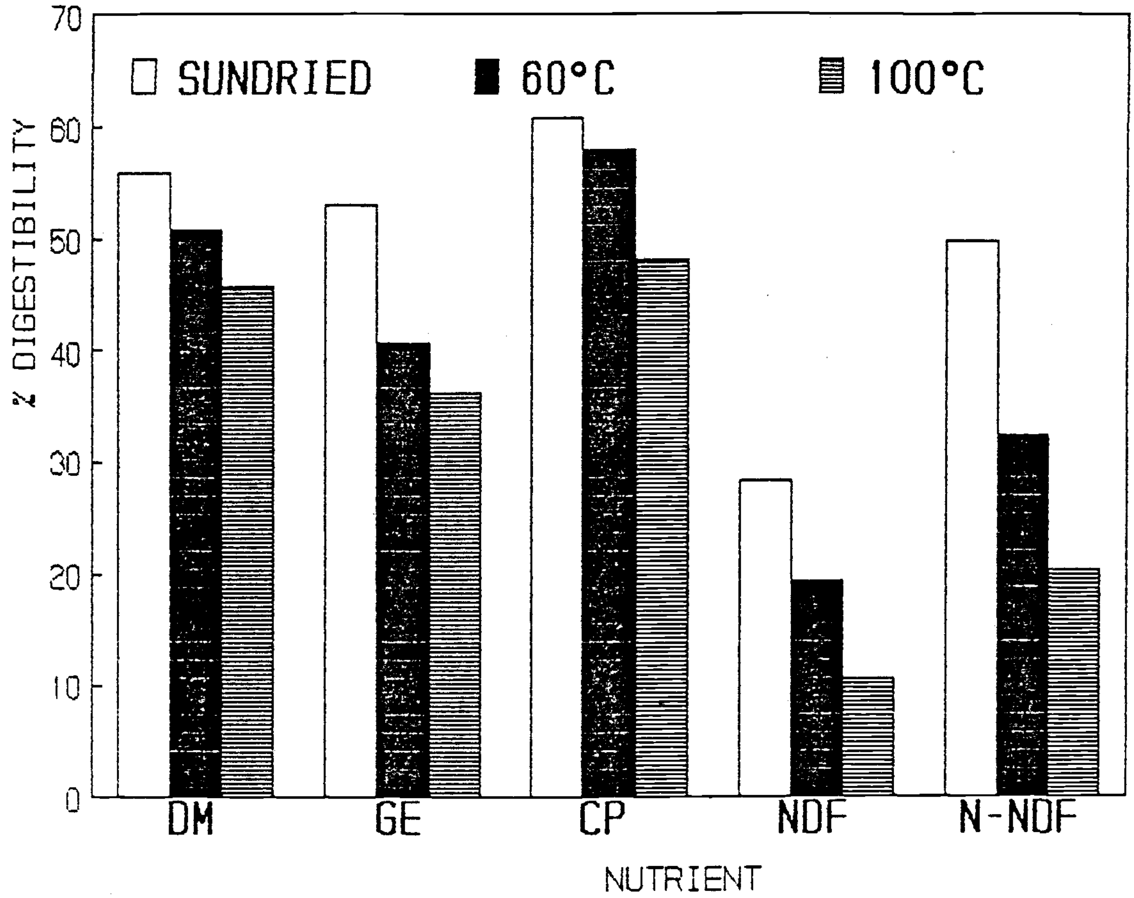

Figure VIII. 1. Effects of various drying on the digestibility of nutrients of tropical forages.

The digestibility of dry matter (DM) for albizia and leucaena, GE for gliricidia and sesbania, NDF for sesbania and N-NDF for gliricidia were comparable when were treated with sundried or ovendried at 60^{o}C. At 100^{o}C, however, drying caused depression of digestibility of all nutrients regardless of the forage species. In most cases, the depression in nutrient digestibility, particularly with the CP, caused by heat treatment is associated with the unavailability of amino acids (Pusztai, 1985). This was also supported by the results showing the depression of CP solubility in buffer solution at pH 7 (Figure VIII. 2)., regardless of the forage species. Again, the rate of depression is species dependent. Significant negative correlations were observed between drying temperature and the nutrient digestibility (Table VIII. 3). Apparently, the most depressing effect did not occur on the CP, but rather on NDF, N-NDF and GE. For N-NDF, it was indicated by its steeper slope (-0.44) compared with CP (-0.18). Figure VIII. 1 showed that rate of depression was 59 % for N-NDF, 60 % for NDF and 32 % for GE whereas it was only 20 % for CP. There are some possible explanations for these phenomena. The lower effect on CP digestibility than on other nutrients may be due to microbial fermentation and the practise of cecotrophy by the rabbits. Undigested CP that escaped absorption in the small intestine might be digested microbially in the hindgut and subsequently were reutilized by the rabbits through cecotrophy. Higher depressing effects on the GE could be due to some of the carbohydrate fractions being tied up during heating, e.g. caramelization, and/or that tannin-protein complexes reacting with soluble carbohydrates, such as pectin and carboxy methyl cellulose (Ledward, 1979; Festenstein, 1983) and rendering them unavailable. In leucaena,

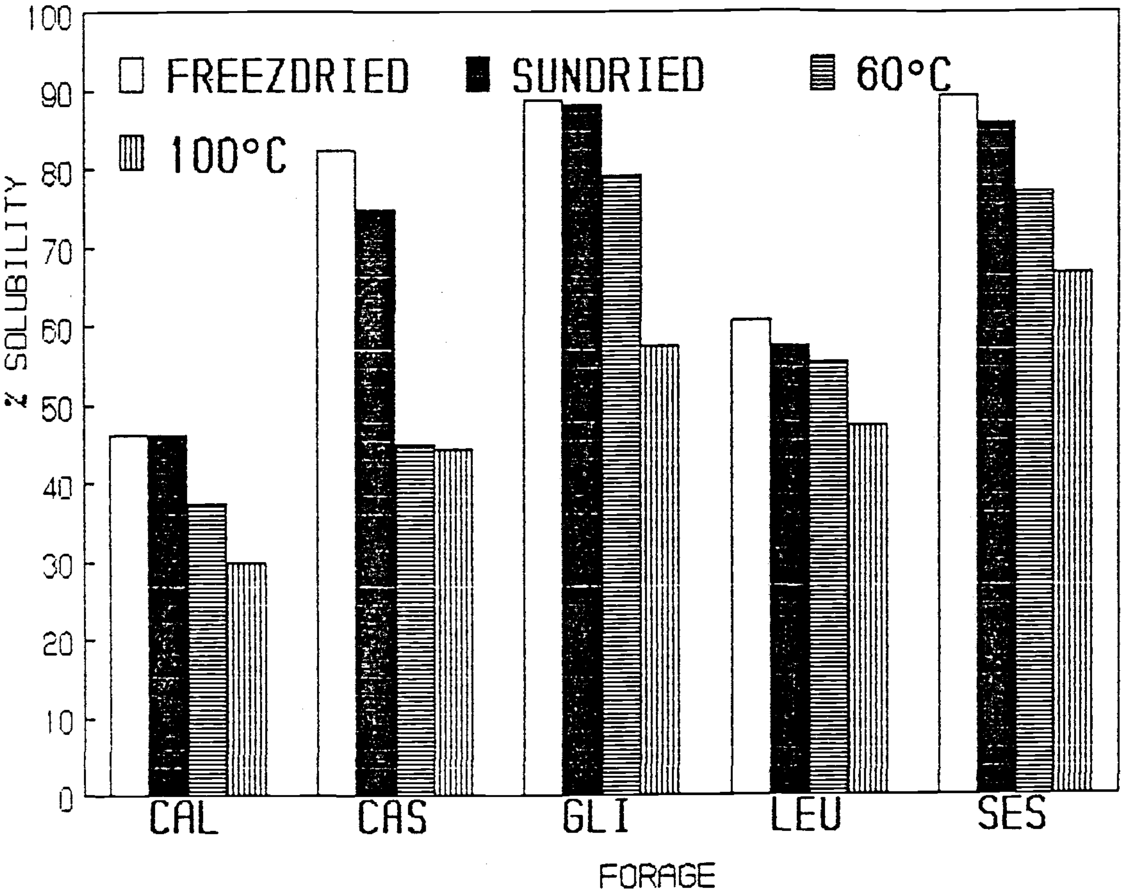

Figure VIII. 2. Effects of various drying on the crude protein solubility in the buffer solution at pH 7.0 of tropical forages.

Table VIII. 3. Relationships between temperature, content of tannins and N-NDF with the digestibility of nutrients of some tropical forages.

		N-NDF Content	% Digestibility				
			DM	GE	CP	NDF	N-NDF
Temperature+	A++	0.94	60.06	59.2	65.4	36.7	62.6
	B	0.005	-0.15	-0.24	-0.18	-0.26	-0.44
	r	0.31	-0.99**	-0.92*	-0.93*	-0.99**	-0.97*
Tannins	A	0.94	59.7	57.2	72.8	24.8	48.4
	B	.05	-1.57	-1.56	-3.25	-1.32	-2.89
	r	0.51*	-0.59*	-0.48	-0.82**	-0.40	-0.68*
N-NDF	A	--	82.4	66.9	91.8	38.1	59.4
	B	--	-25.30	-20.21	-29.40	-16.60	-23.02
	r	--	-0.87**	-0.58*	-0.69**	-0.47	-0.46

+ Assuming that sundried had $\pm$ 35^{o} C.
++ A = intercept, B = slope, r = coefficient of correlation.
* P < .05.
** P < .01.

mucilages such as galactomannans occur in considerable amounts (Lesniak et al, 1981; Telek, 1982) and decrease the nutrient digestibility when treated with moist heat. In addition, Buchanan (1969) indicated that at 100°C, lipid oxidation led to the formation of lipid-protein complexes, reducing energy digestibility.

The greatest depression in digestibility with heat treatment occurred with the NDF and N-NDF fractions. This might be due to the increase of N-NDF content with heating (see Table VIII. 1). A slight change of the N-NDF will have a marked effect on its digestibility because of its low content. The depression on the NDF was somewhat complex, because it may involve several factors, such as tannin-protein complexes, heat-tied up proteins etc.

Among forages, calliandra digestibility was most depressed by heat drying. Leucaena was the second, particularly when compared with the wilted materials obtained from other results (Raharjo et al, 1986, 1987). These low digestibility values might be related to the high tannin contents of these two legumes. Highly significant and negative correlations were observed between tannin content and CP digestibility (Table VIII. 3). While Maillard reaction involves aldehyde groups of carbohydrates and amino groups of proteins, tannins precipitate proteins by complexing the methylene groups of the amino acid side chains such as gelatins and prolines (Oh et al, 1980). At high temperature, proteins are denatured and open more sites for complex formation (Ledward, 1979) and consequently more undigested fractions may occur. Furthermore, Goldstein and Swain (1965) and Fernandez et al (1982) showed that tannins may complex with the protein-digesting enzymes (e.g. trypsin) and hence decrease the potential of protein digestion by the animals. The properties of tannin-protein complexes, however, are not fully understood. In addition, inconsistent results obtained from the tannin content analysis (Burns, 1971; Price and Butler, 1977; Price et al, 1978) increase the confusion of the data interpretation.

Tannins depressed the digestibility of other nutrients as indicated by the significant, negative relationship with DM, GE and N-NDF digestibility. In part, this depression may have been associated with the depression of CP digestibility.

There were also significant, negative relationships between N-NDF with DM, GE and CP digestibility (Table VIII. 3), suggesting that the increase of the N-NDF fraction, either by heat drying or by tannins or both, may be used as an indicator that depression of the nutrient digestibility may occur. Nevertheless, comparing the slight change of N-NDF content (due to drying) with the marked depression of the nutrients, these results suggested that heat tied up protein may not be the only factor responsible for the decrease of nutrient digestibility or most of the unavailable N (proteins) were not incorporated into NDF fractions. In addition, negative values of NDF and N-NDF digestibility of calliandra, which contains the highest tannin content, heated at 100^{o}C indicated that more of these materials were found in the feces than were actually consumed. Mitjavilla et al (1977) showed that tannins increased the endogenous protein secretions, complexed with them and were excreted in the feces. Consequently more materials, particularly those containing N, will be recovered. It is possible that the depression of N-NDF digestibility was due to the increase of complexed tannins with endogenous N, which were incorporated and recovered in the NDF fraction of feces, rather than due to the drying temperature.

In conclusion, drying and tannins effects on the digestibility of nutrients are confounding and may be additive. In general, however, drying depressed the digestibility, in which its extent of depression was dependent on the nutrient, temperature and species of forages.

REFERENCES

AOAC. 1980. Official Methods of analysis. Thirteenth edition. Association of Official Analytical Chemists. Washington, D.C.

Buchanan, R.A. 1969. Effect of storage and lipid extraction on the properties of leaf protein. J. Sci. Food Agric. 20:359-364.

Burns, R. E. 1971. Methods for estimation of tannins in grain sorghum. Agron. J. 63:511-512.

Cheeke, P.R. 1986. Potentials of rabbit production in tropical and subtropical agricultural systems. J. Anim. Sci. 63:1981-1986.

Cheeke, P.R. and R. Carlsson. 1978. Evaluation of several crops as sources of leaf meal: Composition, effect of drying procedure and rate growth response. Nutr. Rep. Inter. 18:465-473.

Cheeke, P.R. and L.R. Shull. 1985. Tannins and polyphenolic compounds. In 'Natural Toxicants in Feeds and Poisonous Plants'. pp. 322-357. AVI Publ. Co., Inc., Westport, Connecticut.

Cheeke, P.R., N.M. Patton, S.D. Lukefahr and J.M. McNitt. 1987. Rabbit Production. Sixth edition. The Interstate Printers and Publishers. Danville, Illinois.

Crowder, L.V. and H.R. Chedda. 1982. Tropical Grassland Husbandry. Longman, London and New York.

Elias, L.G., D.G. DeFernandez and R. Bressani. 1979. Possible effects of seed coat polyphenolics on the nutritional quality of bean protein. J. Food Sci. 44:524-527.

Fernandez, R., L.G. Elias, J.E. Braham, and R. Bressani. 1982. Trypsin inhibitors and hemagglutinins in beans (Phaseolus vulgaris) and their relationship with the content of tannins and associated polyphenols. J. Agric Fd. Chem. 30:734-739.

Festenstein, G.N. 1983. Carbohydrates in LPC and fractionated leaf extracts. In 'Leaf Protein Concentrates' (L. Telek and H.D. Grahams, editors). pp.215-234. AVI Publ. Co. Inc. Westport, Connecticut.

Goldstein, J.L and T. Swain. 1965. The inhibition of enzymes by tannins. Phytochem. 4:185-188.

Hagerman, A.E. and L.G. Butler. 1978. Protein precipitation method for the quantitative determination of tannins. J. Sci. Fd. Chem. 26:809-812.

Kennedy, P.M. 1985. Influences of cold exposure on digestion of organic matter, rate of passage of digesta in the gastro intestinal tract, and feeding and rumination behaviour in sheep given four forage diets in the chopped or ground and pelleted form. Bri. J. Nutr. 53:159-173.

Kratzer, F.H. and C.G. Payne. 1977. Effect of autoclaving, hot water treating, parboiling and addition of ethoxyquin on the value of rice bran as a dietary ingredients for chickens. Bri. Poult. Sci. 18:475-482.

Lebas, F. 1983. Small scale rabbit production. Feeding and management system. World Anim. Rev. 46:11-17.

Ledward, D.A. 1979. Protein-polysaccharides interactions. In 'Polysaccharides in Food' (J.M.V. Blanshard and J.R. Mitchell, eds.), pp. 205-217. Butterworth and Co., Ltd., Sydney-Wellington-Durban-Toronto.

Lesniak, K. 1981. Biochemical purification of the galactomannan in the leucaena seeds. Leucaena Res. Rep. 2:75-76.

Oh, H.I., J.E. Hoff, G.S. Amstrong and L.A. Haff. 1980. Hydrophobic interaction in tannin-protein complexes. J. Agric. Food Chem. 28:394-398.

Parigi-Bini, R., M. Cinetto and N. Carotta. 1984. Digestibility and nutritive value of Leucaena leucocephala in rabbit diets. III World Rabbit Congress. 1: 399-407. Rome, Italy.

Pierpoint, W.S. 1983. Reaction of phenolic compound with proteins and their relevance to the production of leaf protein. In: Leaf Protein Concentrates (L. Telek and H.D. Graham, eds), pp. 235-267. AVI Publ.Co. Inc., Westport, Connecticut.

Pirie, N.W. 1966. Leaf protein as a human food. Science 152:1701- 1705.

Price, M.L. and L.G. Butler. 1977. Rapid visual estimation and spectrophotometric determination of tannin content of sorghum grain. J. Agric. Food Chem. 25:1268-1274.

Price, M.L., S. Van Scoyoc and L.G. Butler. 1978. A critical evaluation of the vanillin reaction as an assay for tannin in sorghum grain. J. Agric. Food Chem. 26:1214-1218.

Pusztai, A. 1985. Constraints on the nutritional utilization of plant proteins. Nutr. Abstr. Rev. 55:363-369.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1986. Evaluation of tropical forages and by-product feeds for rabbit production. 1. Nutrient digestibility and effect of heat treatment. J. Appl. Rabbit Res. 9:56-66.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1987. Evaluation of tropical forages and by-product feeds for rabbit procuction. 2. Composition, consumption and digestibility in growing rabbits.

Robinson, K.L., P.R. Cheeke and N.M. Patton. 1985. Effect of prevention of coprophagy on the digestibility of high forage and high concentrate diets by rabbits. J. Appl. Rabbit Res. 8:57-59.

Sanchez, W.K., P.R. Cheeke and N.M. Patton. 1983. Evaluation of raw and extruded soybeans and extruded soy flour as protein sources for weanling New Zealand White rabbits. J Appl. Rabbit Res. 7:101-105.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. A Biometrical Approach. Second ed. McGraw Hill Book Co., New York.

Tangendjaja, B., Y.C. Raharjo and J.B. Lowry . 1985. Evaluation of Leucaena leaf meal and its toxicity to rabbits. Research report. Research Institute for Animal Production. Box 123, Bogor, Indonesia.

Telek, L. 1982. Preparation of leaf protein concentrates from Leucaena leucocephala. Leucaena Res. Rep. 3:93-94.

CHAPTER IX

FACTORS INFLUENCING THE BIOAVAILABILITY OF NUTRIENTS OF TROPICAL FORAGES IN RABBITS[1]

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CHAPTER IX

FACTORS INFLUENCING THE BIOAVAILABILITY OF NUTRIENTS OF TROPICAL FORAGES IN RABBITS

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SUMMARY

The effect of fiber on the voluntary intake and the digestibility of nutrients of a number of tropical forages were studied. Increasing fiber levels in the forages depressed voluntary dry matter intake, gross energy (GE) and crude protein (CP) contents and the digestibility of dry matter (DM), GE, CP, acid and neutral detergent fiber (ADF and NDF), ash, calcium (Ca) and phosphorus (P). Among forages, woody legumes had the highest digestibility values, while grasses were the lowest. Significant and negative relationships were observed between indigestible ADF content and the digestibility of nutrients. The magnitude of the ADF effect was dependent on the species or groups of forages and on the nutrient content within species. The depression of nutrient bioavailability was greatest with the woody legumes per unit increase of indigestible ADF, except for CP, Ca and P. Grasses had the greatest CP depression per unit increase of indigestible ADF, which might be associated with their low CP content. Comparing tropical and temperate forages, the digestibility values of the legumes are comparable. For grasses, the tropical species consistently show lower digestibility values than observed for temperate grasses. Inherent characteristics of the photosynthetic pathway between tropical (C-4) and temperate (C-3) grasses were suggested to be the factor responsible for this difference.

INTRODUCTION

In the forage-feeding system for animals, the presence of high dietary fiber intake is inevitable. Fiber is probably the most controversial dietary constituent in rabbit production. With a low fiber diet, the efficiency of nutrient utilization is high (Spreadbury, 1978; Lang, 1981; Pote et al, 1981), but physiological (Laplace, 1978; Cheeke and Patton, 1980; Borrielo and Carmann, 1983) and nutritional (Champe and Maurice, 1983; Patton et al, 1983) digestive disorders may occur. At high levels, fiber depresses nutrient digestibility (Fekete and Gippert, 1985; Raharjo et al, 1986), but stimulates the cecal-colonic motility (Colin et al, 1976; Ehrlein et al, 1983) and minimizes the occurence of enteritis (Cheeke and Patton, 1978; Cheeke, 1984). The role of fiber in rabbit nutrition and its relation with enteritis have been reviewed (Cheeke et al, 1986, 1987), but from the nutitional-enteritis point of view, more study is needed to elucidate this interaction as Morrisse et al (1985), in contrast to the general theory, argued that high fiber low starch diets may promote diarrhea.

Beside the amount, the type of fiber has also an effect on the animal growth. Sugarbeet and beet root pulp have high digestible fiber fractions (Maertens and deGroote, 1984), which increase the fiber digestibility, but cause diarrhea (Colin et al, 1975). On the other hand, grasses have a high level of indigestible fiber (Raharjo et al, 1986; 1987c), which cause no incidence of diarrhea, but produce poor growth due to inadequate nutrient intakes (Raharjo et al, 1987b)

The presence of secondary compounds such as tannins and other phenolics, enzyme inhibitors and metal-binding substances in the forages (Skerman, 1977; Crowder and Chedda, 1982; Cheeke and Shull, 1985) also depress the nutrient utilization of forages by the rabbits.

The objective of this paper was to evaluate the bioavailability of nutrients and the voluntary intake of tropical forages in relation to the forage fiber content and to the effects of plant secondary compounds. The data presented in this paper were gathered from the previous results (Raharjo et al, 1986, 1987a, 1987c). A comparison of the digestibility values of tropical and temperate forages was also given.

COMPOSITION AND CONSUMPTION

Irrespective of the types of forages, increasing levels of fiber decreased the contents of gross energy (GE) and crude protein (CP) (Table IX. 1). Significant and negative relationships between acid and neutral detergent fiber (ADF and NDF) with GE or CP content of forages have been reported (Raharjo et al, 1986). The decreases of GE and CP were more pronounced with increasing maturity and lignification (Minson, 1982b). Woody legumes had higher contents of GE and CP, suggesting less intake of these particular nutrient requirements than other type of forages. Forage consumption was highest in the woody legumes and lowest in the grasses (Figure IX.1a).Low CP and high fiber content of grasses might be largely responsible for their extremely low intake (average of 26 g/rabbit/day). Depression of forage intake due to increasing fiber levels was also shown in sheep (Thornton and Minson, 1973). A non significant relationship ($r=-0.18$; $n=25$) was observed between indigestible ADF content with the dry matter intake

Table IX. 1. Mean and standard error (SE) of chemical composition of woody legumes (WL, n=10), non-woody legumes (NON-WL, n=11), agricultural by-products (AGBP, n=6) and grasses (GRASS, n=10) used in the study of tropical forages for rabbit production.

Nutrient	Forage			
	WL	NON-WL	AGBP	GRASS
Gross energy, kcal/kg	4557 ± 302	4290 ± 726	4389 ± 260	3569 ± 488
Digestible energy, kcal/kg	2768 ± 685	1678 ± 250	1826 ± 364	895 ± 592
Crude protein, %	22.27 ± 5.28	17.43 ± 3.40	17.20 ± 4.87	8.14 ± 2.96
Acid detergent fiber, %	27.00 ± 6.46	36.30 ± 8.01	25.38 ± 6.13	42.49 ± 4.36
Neutral detergent fiber, %	38.16 ± 4.39	47.91 ± 8.56	46.23 ± 10.30	62.96 ± 6.71
Ash, %	6.96 ± 1.55	7.52 ± 2.45	11.48 ± 3.10	13.40 ± 1.34
Calcium, %	1.21 ± 0.46	1.03 ± 0.34	1.61 ± 1.06	0.43 ± 0.14
Phosphorus, %	0.25 ± 0.07	0.22 ± 0.06	0.30 ± 0.05	0.21 ± 0.07

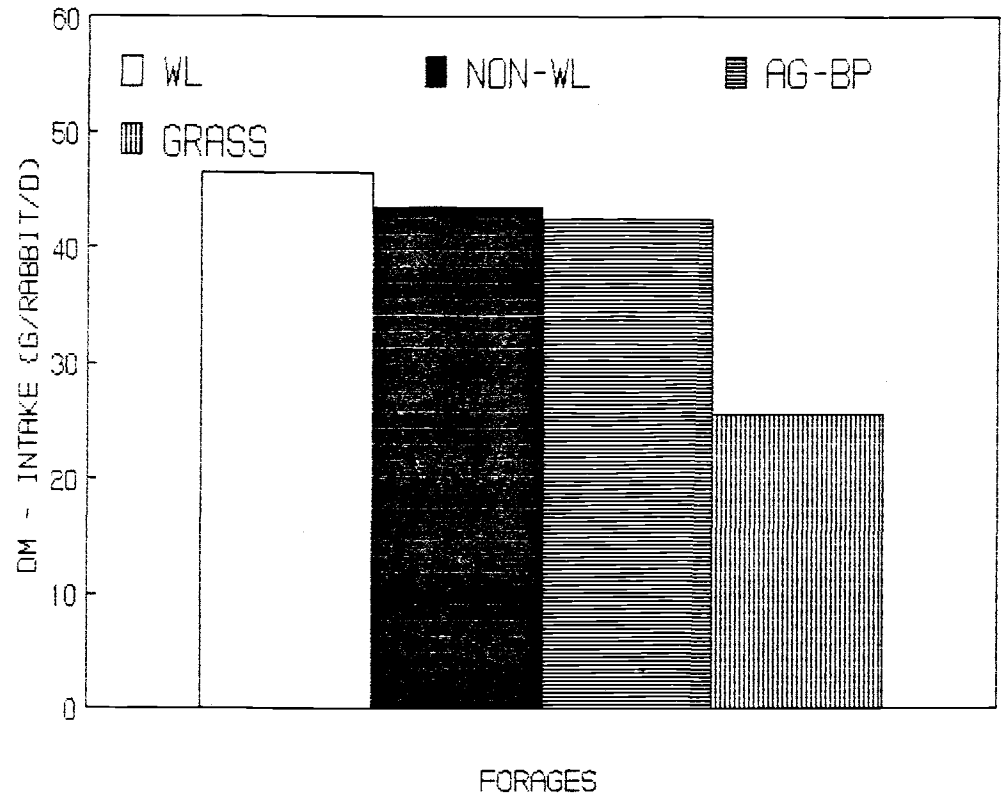


Figure IX. 1a. Mean dry matter intake of woody legumes (WL), non-woody legumes (NON-WL), agricultural by-products (AG-BP) and grasses (GRASS) by rabbits.

(DMI) of the forages (Figure IX. 1b). The poor relationship might be due to the large variations between individual forage species, which was also reported in sheep (Thornton and Minson, 1973). In addition, type of fiber may also affect the voluntary DMI. For instant, sweet potato leaves, which contain similar NDF content with Setaria sphacelata (49 %), were consumed at 67 g/ rabbit/day, whereas setaria consumption was only 10.7 g/rabbit/day (Raharjo et al, 1987c). Physically, sweet potato leaves and stems are softer than the setaria grass. Nevertheless, in a fewer number of observations (n=16), in which sweet potato leaves or other physically soft leaves such as papaya leaves were not included in the observations, Raharjo et al (1986) showed a significant relationship between ADF or NDF content with the DMI of forages in rabbits. Furthermore, fiber depressed DM and GE digestibility which has a significant effect on the DMI (Raharjo et al, 1987c).

In addition to the amount and the types of fiber, the secondary compounds and the physical structure of the leaves may also depress the voluntary DMI of the forages. High oxalate levels (Bogdan, 1977; Crowder and Chedda, 1982) and tannins, which have astringent properties and cause irritation to the epithelial linings of the mouth and esophagus (Jones and Mangan, 1977), in many tropical grasses (Cheeke and Shull, 1985) were reported to decrease forage intake. Sharp, hard and hairy leaves such as cotton grass (Imperata cilindrica) and brachiaria (Sitorus et al, 1982) and comfrey (Symphitum officinale) (Harris et al, 1983) are not palatable to rabbits. These results, along with those previously observed, suggested that DMI is more dependent on the species of forages, which have own physical and

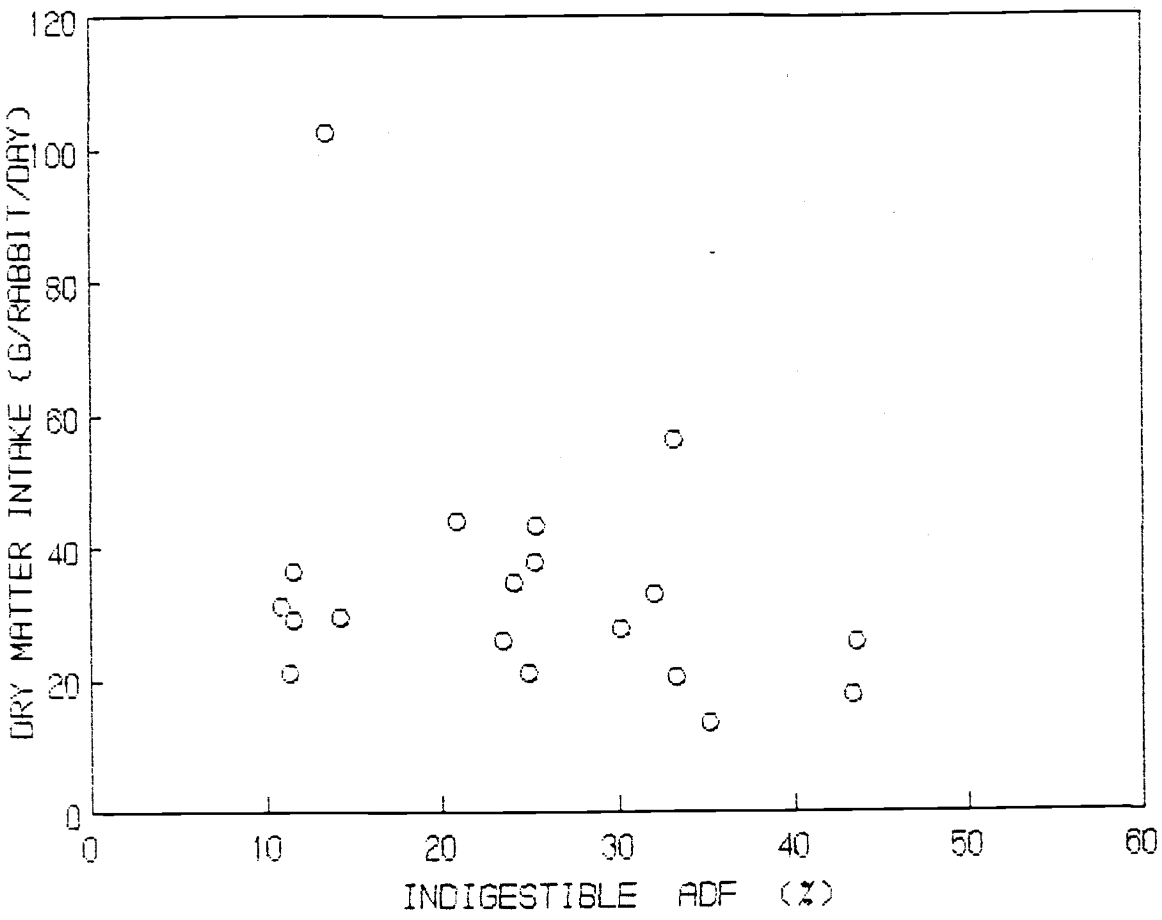


Figure IX. 1b. Relationship between indigestible ADF with the dry matter intake of tropical forages in rabbit (y = 48.1 - 0.36 x; r = -0.18).

textural characteristics, than on the content of total fiber or indigestible fiber.

DIGESTIBILITY

Increasing levels of fiber of the forages generally decrease nutrient bioavailability. The specific effects depend on the stage of growth and the forage species, and on the amount and type of fiber they contain. The more lignified forages usually have a lower digestibility values (Minson, 1982a). The general causes for the low digestibility values of forages containing high level of fiber are a faster rate of passage of the digesta, hence less time for nutrient absorption, and the interaction of fiber with particular nutrients, rendering them unavailable. Patterns of the mean nutrient digestibility values of woody legumes, non woody legumes, agricultural by-products and grasses are shown in Figure IX. 2. Regardless of the nutrients, woody legumes consistently showed highest, while grasses were lowest, digestibility values. In contrast to the results obtained with sheep, in which the dietary fiber content (particularly cellulose) was positively correlated with its digestibility values (Minson, 1982a), our results showed that lower fiber content forages, such as woody legumes, had higher ADF and NDF digestibility than grasses, which contain a higher fiber level. This contrast may be related to the comparative nature of their gastro intestinal tracts. Cellulose is extensively degraded in the rumen of the sheep, but not in the gut of rabbits. Fiber is rapidly excreted from the hind gut of the rabbit (Cheeke, 1985), while in ruminants, fiber cannot exit the rumen until

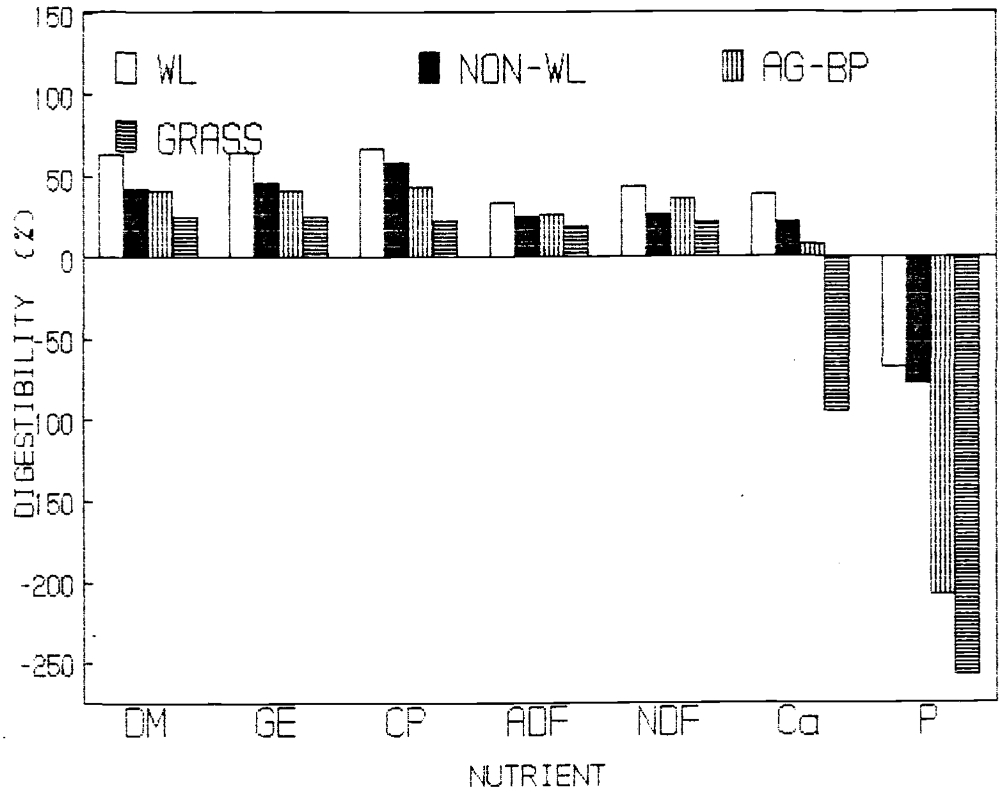


Figure IX. 2. Mean nutrient digestibility of woody legumes (WL), non-woody legumes (NON-WL), agricultural by-products (AG-BP) and grasses (GRASS) in rabbits.

degraded into small particles or digested. In addition, the anatomical structure of the leaves, which is related to the type of photosynthesis (C-3 for legumes and C-4 for grasses) contributes to the different physical and chemical degradation rates between legumes and grasses during digestion (Akin, 1979; Cheeke et al, 1985). Nonetheless, for calcium (Ca) in some forages and phosphorus (P) in all forages, the digestibility values were negative with grasses having the lowest values. Because of their low nutrient content and low voluntary DMI, tropical grasses give very poor results as feeds for rabbits, unless a high quality supplement is provided. Grasses, thus serve primarily as a source of undigestible fiber. Some tropical grasses, such as elephant grass, paspalum and Rhodes grass, which gave moderately good digestibility values compared with other grasses, at immature stages may be useful for rabbit feeding.

DIGESTIBILITY OF DRY MATTER, GROSS ENERGY AND CRUDE PROTEIN

Significant relationships between indigestible ADF with DM (r=-0.81), GE (r=-0.83) and CP (r=-0.72) are illustrated in Figure IX. 3. The digestibility of DM, GE, and CP decreased with increasing levels of indigestible ADF. A consistent and linear decrease of *in vitro* DM digestibility associated with the increase of fiber fractions in the forages was also reported by Minson (1982a) and Norton (1982). The increase of fiber content, beside decreasing the content of easily degraded materials (Minson, 1982b) also increases the rate of passsage in the non ruminant animals (Moran, 1983). In addition, fiber encrusts some soluble carbohydrates, lipids and proteins in the cell wall and

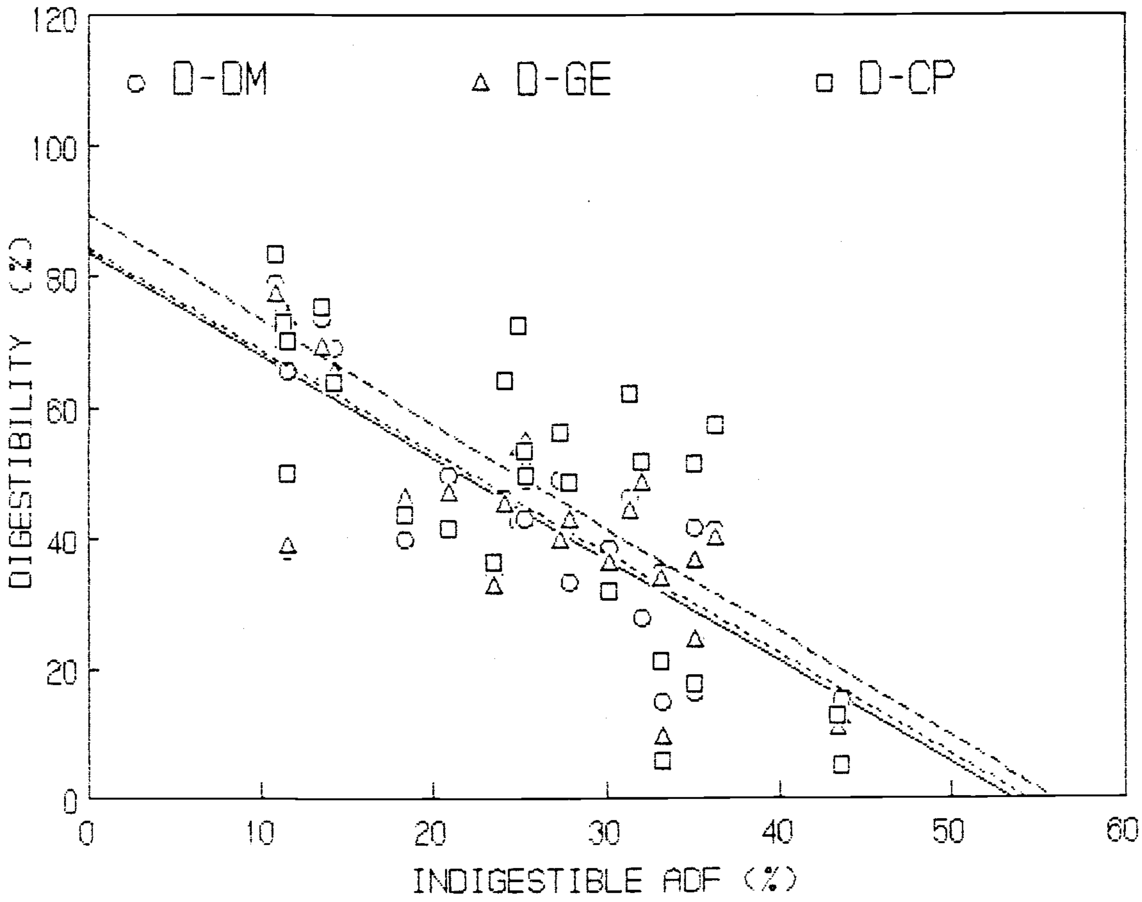


Figure IX. 3. Relationships between indigestible ADF with the digestibility of dry matter (D-DM; y=100.0-2.20x; r=-0.95), gross energy (D-GE; y= 93.2-1.74x; r=-0.98) and crude protein (D-CP; y=95.0-1.72x; r=-0.93) of the tropical forages.

reduces their digestibility. Jenkins *et al* (1977) reported that guar gum and pectin fed to human decreased blood glucose level significantly. Gel-forming properties of water soluble fiber fractions (Cummings, 1978) also depressed DM digestibility. Galactomannans, which have gel-forming properties (Telek, 1982) may be responsible for the low nutrient digestibility values of leucaena leaves, particularly when they are heated (Raharjo *et al*, 1986, 1987d). Methoxyl groups of lignin have also been suggested to interact with some organic constituents and reduce the DM and organic matter (OM) digestibility of the forages (Minson, 1982a).

Fiber has also been noted to alter lipid absorption. Cummings (1978) reported that dietary fiber (wheat bran) in the diet of humans resulted in increased fecal lipid and lowered digestibility of GE. Jenkins *et al* (1976) and Kay and Trusswell (1977) showed that fat excretion was doubled when pectin or guar gum was included in the diet. Furthermore, fiber can also bind bile salt (Moran, 1983), hence reduce lipid absorption.

The depression of CP digestibility in the presence of high fiber content is an indication of protein-fiber interaction, directly or indirectly, which may be triggered by a high content of lignin. The high content of lignin may encapsule soluble materials including proteins in the cells and cause them to be undigested (Cheeke and Myer, 1975). Fiber can also interfere with the digestive and absorptive pathways of proteins. Schennemann (cited by Cummings, 1978) showed that *in vitro* activity of trypsin and chymotrypsin is inhibited by high fiber content. In addition, higher levels of dietary fiber increases endogenous protein excretion (Raharjo and Farrell, 1984), hence decreasing the CP digestibility value.

Complexes of protein with polysaccharides other than fiber are also formed during drying or other pretreatment of feed, resulting in degradation, condensation and polymerization of amino acids and simple sugars (Meyer, 1978). The Maillard reaction is an example of these complexes and usually appears in the lignin analysis, and thus in the ADF and NDF fraction (Van Soest, 1964). Tannins and/or other phenolic compounds, which commonly occur in the legume species (Cheeke and Shull, 1985), can precipitate proteins (McLeod, 1975) and inhibit enzyme activities, such as trypsin (Goldstein and Swain, 1965; Barber and deBarber, 1980) and consequently reduce the protein digestion. Tannins also precipitate endogenous proteins (Mitjavilla et al, 1977) and thus contribute to the higher nitrogen-containing excreta.

Depressions of DM, lipid and CP digestibility obviously will reduce GE digestibility. The rate of depression of each nutrient in relation to the indigestible ADF, however, depends on the type of forages. For DM and GE digestibility (Figure IX. 4a and b) the rate of depression was greatest on woody legumes as shown by their slopes, 2.20 and -1.74, respectively. Corresponding values for grasses were -1.67 and -1.68, and for non woody legumes were -0.45 and -1.17, respectively. For CP (Figure IX. 4c), on the other hand, rate of depression was greatest with grasses (-2.40) suggesting that for every unit of the increase of indigestible ADF, the CP digestibility of grasses was depressed to a greater extent than for the other forages. This might be associated with the low content of CP in grasses. Minson (1982a) showed a linear relationship of CP content with the in vitro digestibility of grasses. Poor relationships occurred between indigestible ADF with DM, GE or CP of non woody legumes or

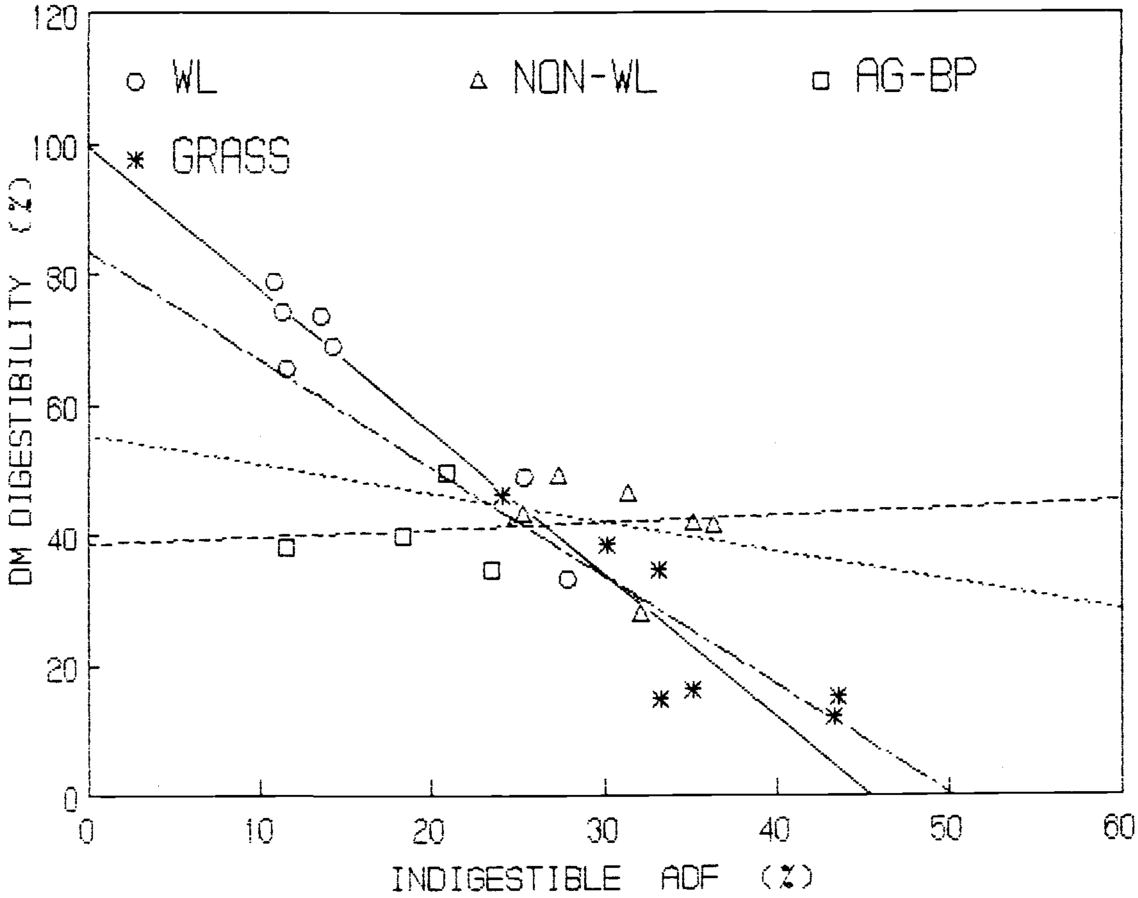


Figure IX. 4a. Relationship between indigestible ADF with the digestibility of dry matter of woody legumes (WL), non-woody legumes (NON-WL), agricultural by-products (AG-BP) and grasses (GRASS).

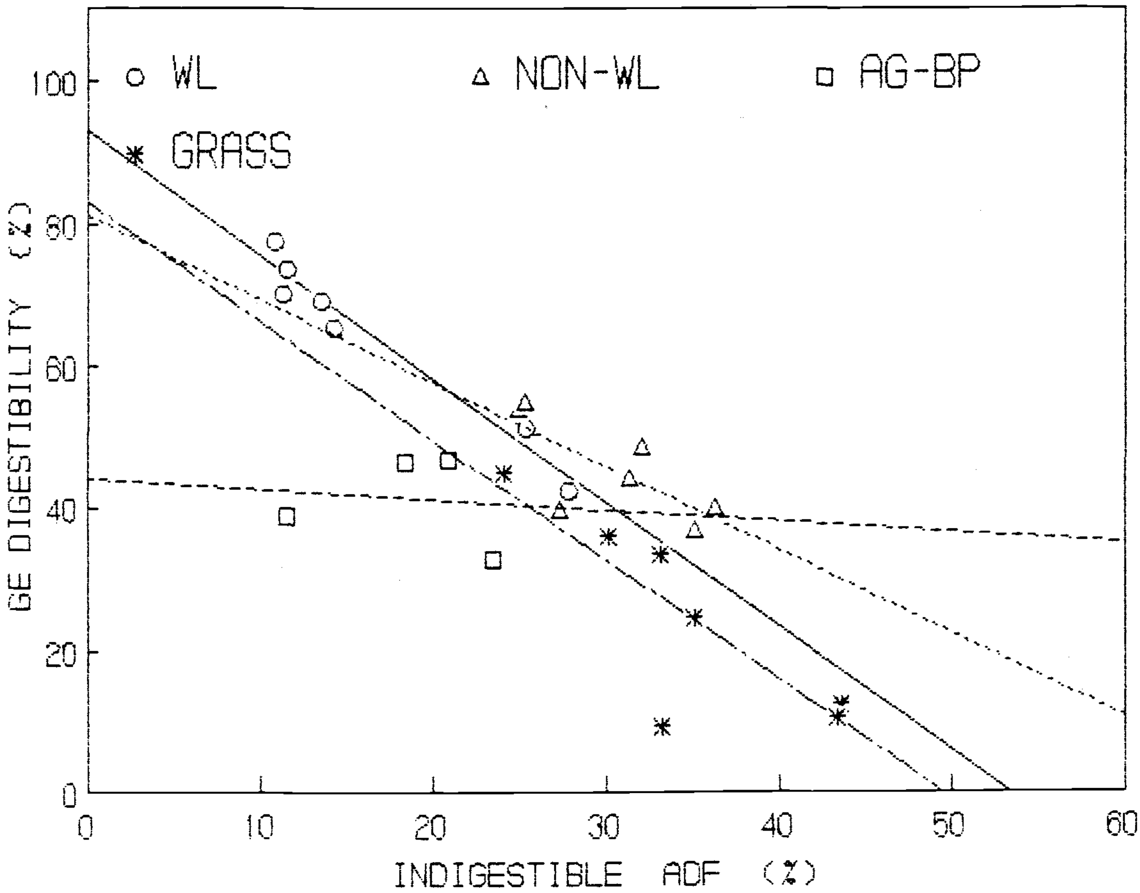


Figure IX. 4b. Relationship between indigestible ADF with the digestibility of gross energy of woody legumes (WL), non-woody legumes (NON-WL), agricultural by-products (AG-BP) and grasses (GRASS).

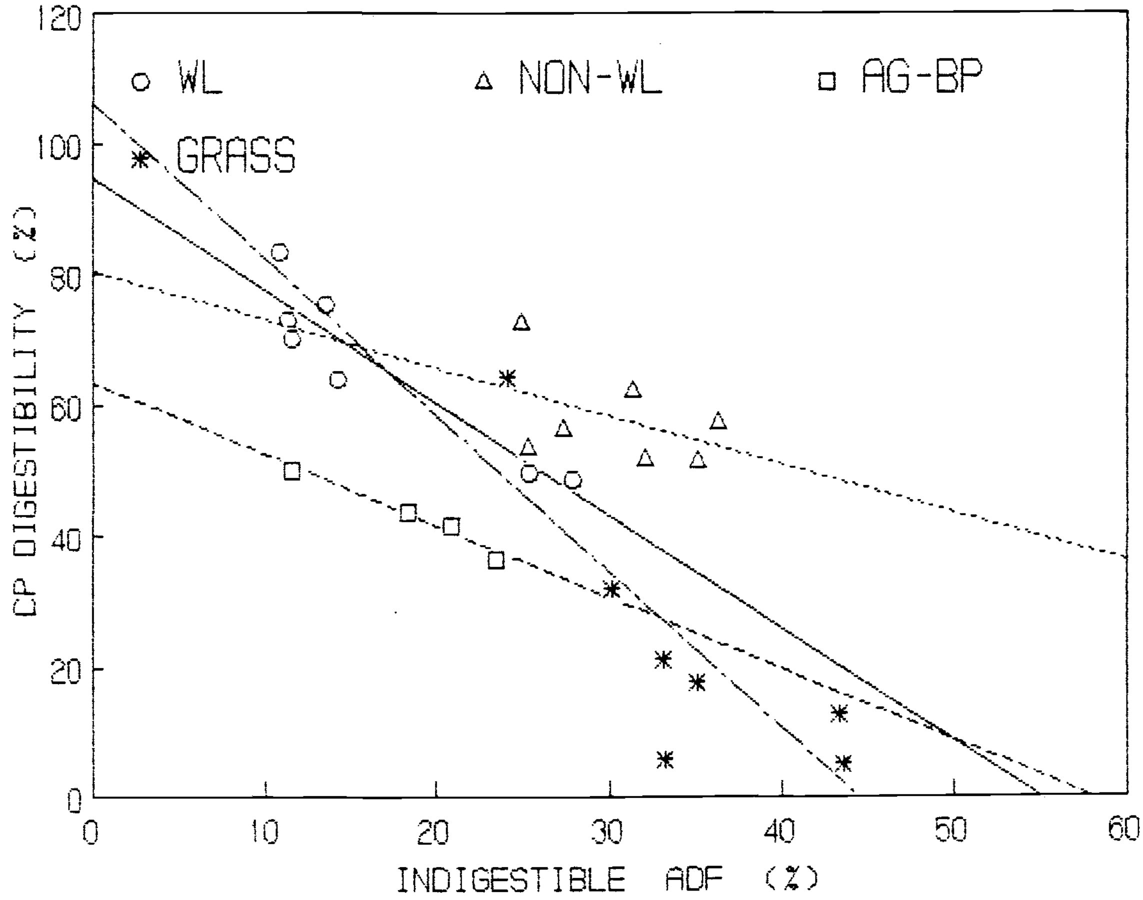


Figure IX. 4c. Relationship between indigestible ADF with the digestibility of crude protein of woody legumes (WL), non-woody legumes (NON-WL), agricultural by-products (AG-BP) and grasses (GRASS).

agricultural by-products. The reason for this is unclear, except due to the high variations between individual species of forages. The inconsistent softness of the leaves and stems, as perhaps an indicative of more soluble fiber fractions, might contribute to these variations.

DIGESTIBILITY OF ASH, CALCIUM AND PHOSPHORUS

It has long been known that fiber has a negative effect on the mineral utilization (Fleming, 1973). Feeding high proportion of bran to human was reported to cause negative calcium balance (Cummings, 1978). The development of osteomalacia (Berkynne et al, 1973) and rickets (Ford, 1972) due to the feeding of whole bran was reported. Although Ca-malabsorption is traditionally ascribed to the content of oxalate (Norton, 1982) and phytic acid (Wise, 1983), fiber may also have a significant role in the inhibition of Ca absorption. In forages, negative relationships were observed between indigestible fiber and the digestibility of Ca and P (Figure IX. 5). For ash, although the digestibility values were depressed from 74.6 to as low as 11.5 % (Figure IX. 7), they are still in the positive side. On the other hand, for Ca and particularly P, most of the digestibility values were negative (Figure IX. 6a and b, respectively). Jones (1978) reported that impairment of Ca absorption was due to the formation of Ca-pectin complexes in the cell wall, in which Ca-pectate acts as a cementing agent. Furthermore, carboxyl and hydroxyl groups of lignin (Molloy and Richards, 1971) and carboxyl groups of the uronides from pectin (Jones, 1978) have high cation exchange capacity (Allen et al, 1985) and are involved in metal-binding and poor Ca absorption.

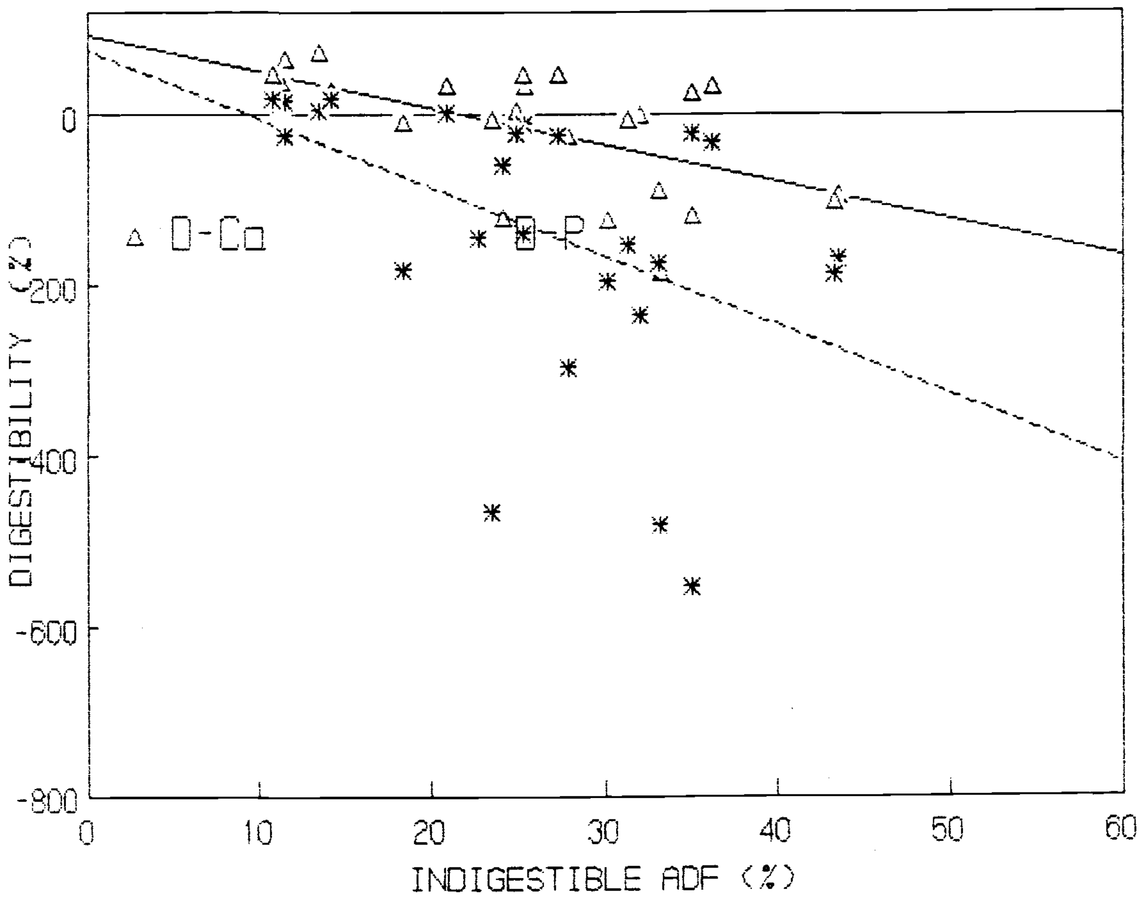


Figure IX. 5. Relationships between indigestible ADF with the digestibility of calcium (D-Ca) and phosphorus (D-P) of the tropical forages.

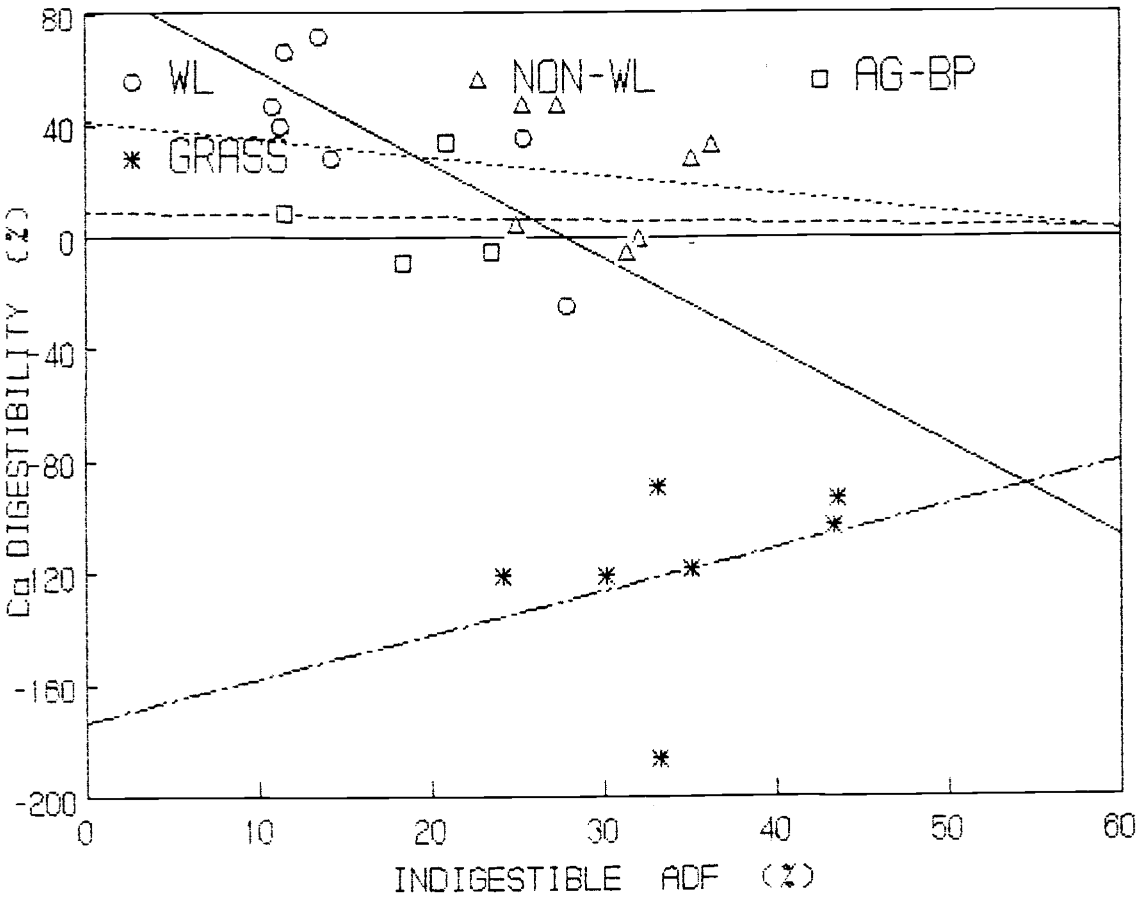


Figure IX. 6a. Relationship between indigestible ADF with the digestibility of calcium of woody legumes (WL), non-woody legumes (NON-WL), agricultural by-products (AG-BP) and grasses (GRASS).

Phosphorus absorption was markedly depressed by high levels of indigestible fiber. A digestibility value of almost - 600 % was observed with some grasses. This extremely low P digestibility value, besides being due to the unavailable complexes such as phytate (Wise, 1983), might also be associated with the extensive sloughing off of the endogenous mucosa, whose secretion is triggered by high fiber diets (Raharjo and Farrell, 1984). In addition the P content of grasses is usually low (Norton, 1982) and therefore, a slight change of its quantity in the feces would have a marked effect on its digestibility.

Silica, which contributes to the ash content, may be contained up to 8 % in grasses (Wilson, 1982). Silica uptake in the plant is associated with active transpiration, which is extensive in the dry areas. Silica is deposited in the plant cell wall and acts structurally like lignin and it also reduces the digestibility of forage plants (Van Soest and Jones, 1968) and rice bran (Maust et al, 1972).

DIGESTIBILITY OF ACID AND NEUTRAL DETERGENT FIBER

In a consideration of the nutritional implications of dietary fiber, it is important to remember that fiber itself is digested and contributes DE. The capacity of fiber digestion varies widely depending on the species of forages (Skerman, 1977; Norton, 1982), stage of maturity, which relates to the degree of lignification (Minson, 1982b), geographical areas, such as tropical vs temperate (Wilson and Ford, 1980), environmental, e.g. dry vs humid (Wilson, 1982), etc. Digestibility values ranging from -18.9 to 62.3 % for ADF and from

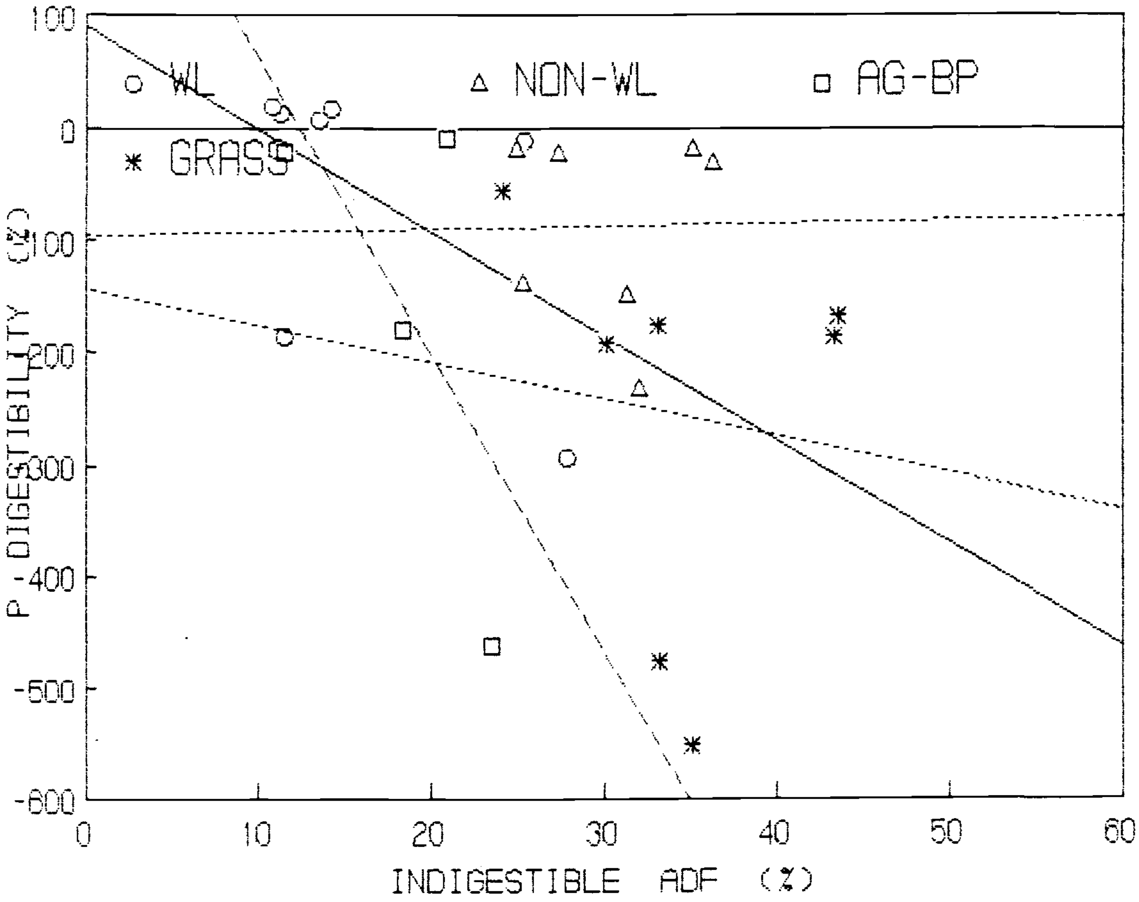


Figure IX. 6b. Relationship between indigestible ADF with the digestibility of phosphorus of woody legumes (WL), non-woody legumes (NON-WL), agricultural by-products (AG-BP) and grasses (GRASS).

2.28 to 63.1 for NDF are shown in figure IX. 7. Significant and negative relationships were observed between the indigestible ADF with the digestibility of ADF (r=-0.95) or NDF (r=-0.96). In contrast to these results, Minson (1982a) showed a linear and positive relationship between the dietary cellulose levels and the cellulose digestion in sheep. This difference, however, is understandable as cellulose is digested by the rumen bacteria in sheep.

Digestibility values for ADF and NDF varied between the type of forages (Figure IX. 8). Legumes, particularly the woody species, had the highest fiber digestibility and were folowed by agricultural by-products, non woody legumes and then grasses. The low fiber digestibility of grasses might be associated with the anatomical structures of the legume leaf compared with the grass blade. Cheeke et al (1985) using the electron microscope technique showed that legumes contain a greater proportion of digestible fractions, such as phloem, mesophylls, epidermis and parenchyma bundle sheaths than do grasses. Rigid and hard structure and a high proportion of indigestible fractions in grasses might be related to the C-4 system of photosynthesis in tropical grasses (Minson and Wilson, 1980), in which fast growth and rapid maturation occur. Legumes, on the other hand, have the C-3 photosynthesis pathways, in which the vegetative stage is maintained for a longer period (Norton, 1982); hence, legumes take a longer time to reach maturity. The nature of these photosynthetic pathways will be discussed in the following section.

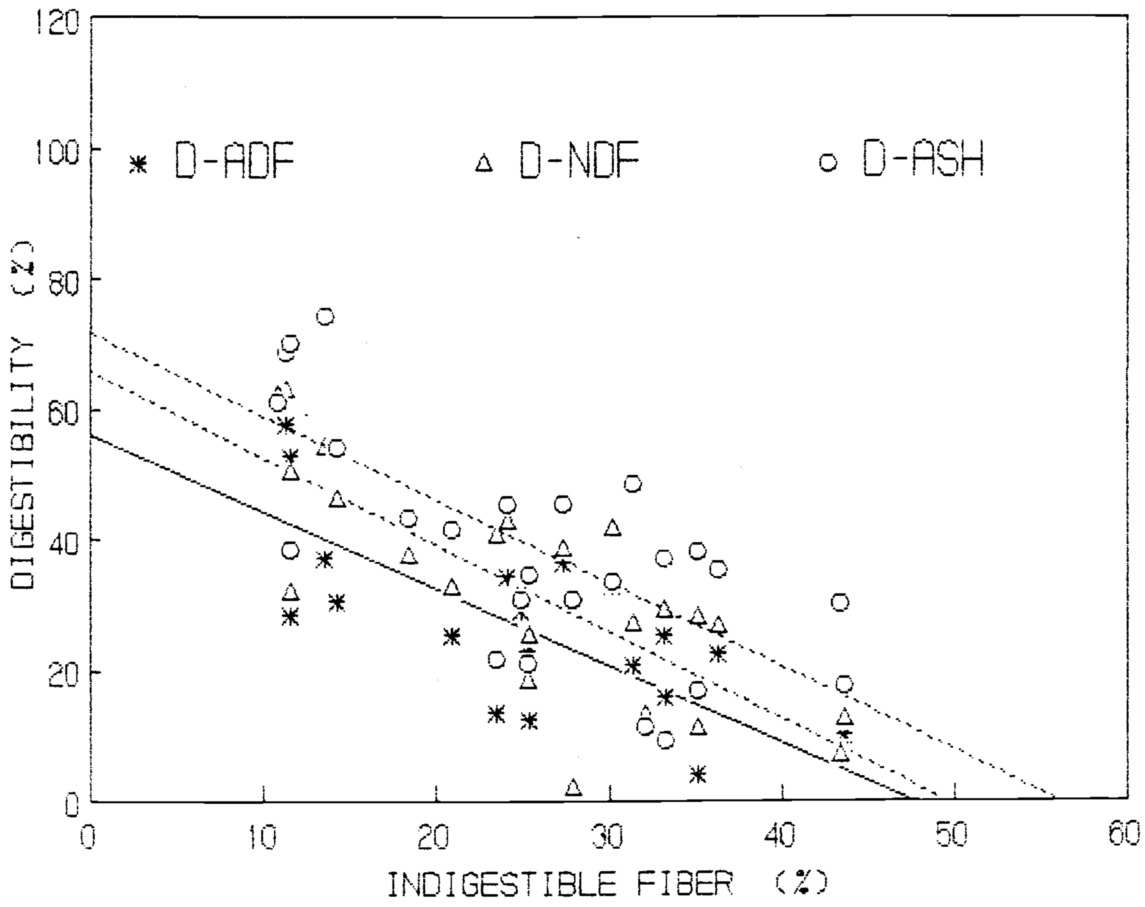
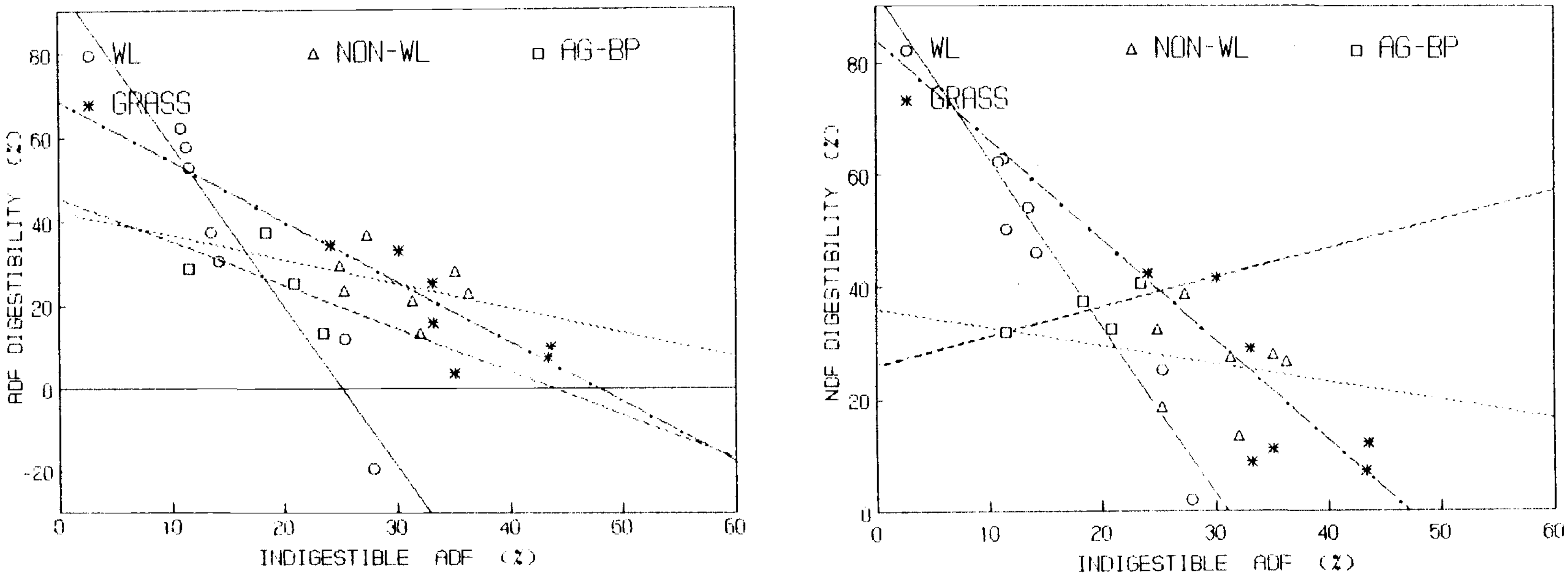


Figure IX. 7. Relationships between indigestible ADF with the digestibility of ADF (y=56.3-1.18x; r=-0.66), NDF (y=66.0-1.33x; r=-0.78) and ash of the tropical forages.



(a) (b)

Figure IX. 8. Relationships between indigestible ADF with the digestibility of ADF (a) and NDF (b) of woody legumes (WL), non-woody legumes (NON-WL), agricultural by-products (AG-BP) and grasses (GRASS).

TROPICAL AND TEMPERATE GRASSES

It has been known for sometime that tropical and temperate grasses differ markedly in their ability to satisfy the nutrient rquirements of animals. The main difference is attributed to the low efficiency of nutrient utilization of tropical grasses compared with those from temperate regions (Wilson and Ford, 1980). Low efficiency of nutrient utilization in the tropical grasses is due to the fact that they contain high fiber and lignin contents, lower CP and P contents, and are of low digestibility, even of their nitrogen- free extract fractions (Laksesvella and Said, 1978).

A comparison of the nutrient digestibility of tropical vs temperate forages by rabbits is presented in Table IX. 2. Such a comparison is thought to be of interest since most information on the ability of forage to meet the requirements of animals comes from the temperate environments. Digestibility values of the legumes were comparable between the two regions. This might be due to the fact that legumes, either tropical or temperate, follow the C-3 system of photosynthesis. Surprisingly high nutrient digestibility values were obtained in the agricultural by-products from the temperate region. Their average digestibility values were 90 %. Cabbage, in particular, had DM and GE digestibility of 101 and 102 % respectively. It is possible that Voris et al (1940) used the true, instead of apparent, digestibility value.

Digestibility values of the tropical grasses were consistently lower than for the temperate grasses. For fiber, however, some tropical grasses, such as elephant grass and Rhodes grass , had higher

Table IX. 2. Nutrient digestibility of some tropical and temperate forages in rabbits.

Forage	Digestibility (%)				
	DM	GE	CP	CF/ADF	Ash
Temperate*					
Alfalfa hay (California)	67.5	61.6	80.7	27.3	60.7
Clover hay (Pennsylvania)	52.8	49.3	62.8	19.7	64.3
Kale (California)	76.0	69.3	81.1	59.5	74.1
Kudzu (Alabama)	38.0	34.4	62.5	16.1	59.0
Lespedeza (Alabama)	44.7	43.0	66.7	10.6	53.1
Darnel grass**	35.4	—	54.2	12.5	22.7
Blue grass (California)	45.2	45.4	74.4	12.6	45.7
Sudan grass (California)	53.8	52.3	68.1	26.6	44.9
Timothy grass (Pennsylvania)	36.5	34.6	46.6	10.7	45.3
Orchard grass**	47.6	—	76.0	15.2	68.5
Cabbage	101.3	100.3	98.6	88.2	94.1
Carrot	92.8	90.8	85.7	56.4	87.6
Celery	92.5	89.3	76.8	93.3	86.6
Sweet potato leaves	92.6	90.4	43.8	94.3	103.7
Turnip	97.7	96.7	90.6	82.1	86.2
Tropical+					
Albizia	74.7	70.3	73.4	58.0	69.2
Calliandra	49.5	51.4	49.8	12.3	34.9
Leucaena	74.2	69.5	75.9	37.7	74.6
Sesbania	79.3	77.5	83.9	62.3	61.6
Centrosema	43.0	54.2	72.9	29.3	31.2
Desmodium	28.1	48.7	52.1	13.4	11.5
Stylosanthes	43.3	55.1	53.9	23.3	21.6
Brachiaria grass	16.7	24.5	17.8	4.2	17.3
Rhodes grass	38.9	36.8	32.4	33.2	33.8
Pangola grass	15.7	12.6	5.6	10.3	17.9
Brownseed millet grass	35.0	33.7	21.2	25.7	37.5
Elephant grass	46.3	45.2	64.7	34.6	46.0
Setaria grass	15.0	9.4	6.2	16.1	9.5
Corn leaves++	40.4	46.7	44.0	37.9	—
Cassava tops++	37.8	43.1	25.9	12.5	—
Banana leaves++	35.1	33.0	36.5	13.9	—
Papaya leaves++	38.6	39.0	50.3	28.8	—

* Voris et al., 1940.
** Von Knieriem and Weiske, edited by Voris et al. (1940).
\+ Raharjo et al. (1986).
\++ Raharjo et al. (1987a).

digestibility values. The low digestibility values of tropical grasses might be associated with the anatomical structure. Akin (1979), using a scanning electron microscope, showed that leaf blades of warm-season grasses posses a higher proportion of epidermis and parenchyma bundle sheath (i.e. more slowly digested) than mesophyll and phloem, which are more rapidly digested, than do the cool-season grasses. Consequently, less digestion occurs with the warm-season grasses. The parenchyma bundle sheaths of the tropical grasses have more starch grains because of the higher efficiency of the C-4 photosynthesis pathway (Goodwin and Mercer, 1983), but they are not available for digestion by the animal unless the cell wall is ruptured (Akin and Burdick, 1977). Furthermore, Akin (1979) showed that irrespective of tropical or temperate plants, similar tissues in different forages or even in cultivars within species were degraded at different rates suggesting that inherent cell wall characteristics influence cell wall digestibility.

The high yield of tropical grasses, i.e. 35 - 85 ton/ha/year, compared with 25 - 27 ton/ha/year from temperate grasses, (Goodwin and Mercer, 1983) is associated with the high temperature at which they grow and the CO_2 fixation in their C-4 biochemical pathway (Brown, 1978). A simplified pathway of C-3 (temperate) and C-4 (tropical) photosynthesis is shown in Figure IX. 9 (Janick et al, 1974). In the C-4 pathway, CO_2 is first fixed by phosphoenolpyruvate carboxylase (PEP-Case) to form 4-C compounds such as malate, oxaloacetate and aspartate. After some rearrangements, these C-4 compounds enter the Calvin cycle, in which ribulose diphosphate carboxylase (RuDP-Case) acts as a key enzyme to carry out the synthesis of sugar from CO_2. In

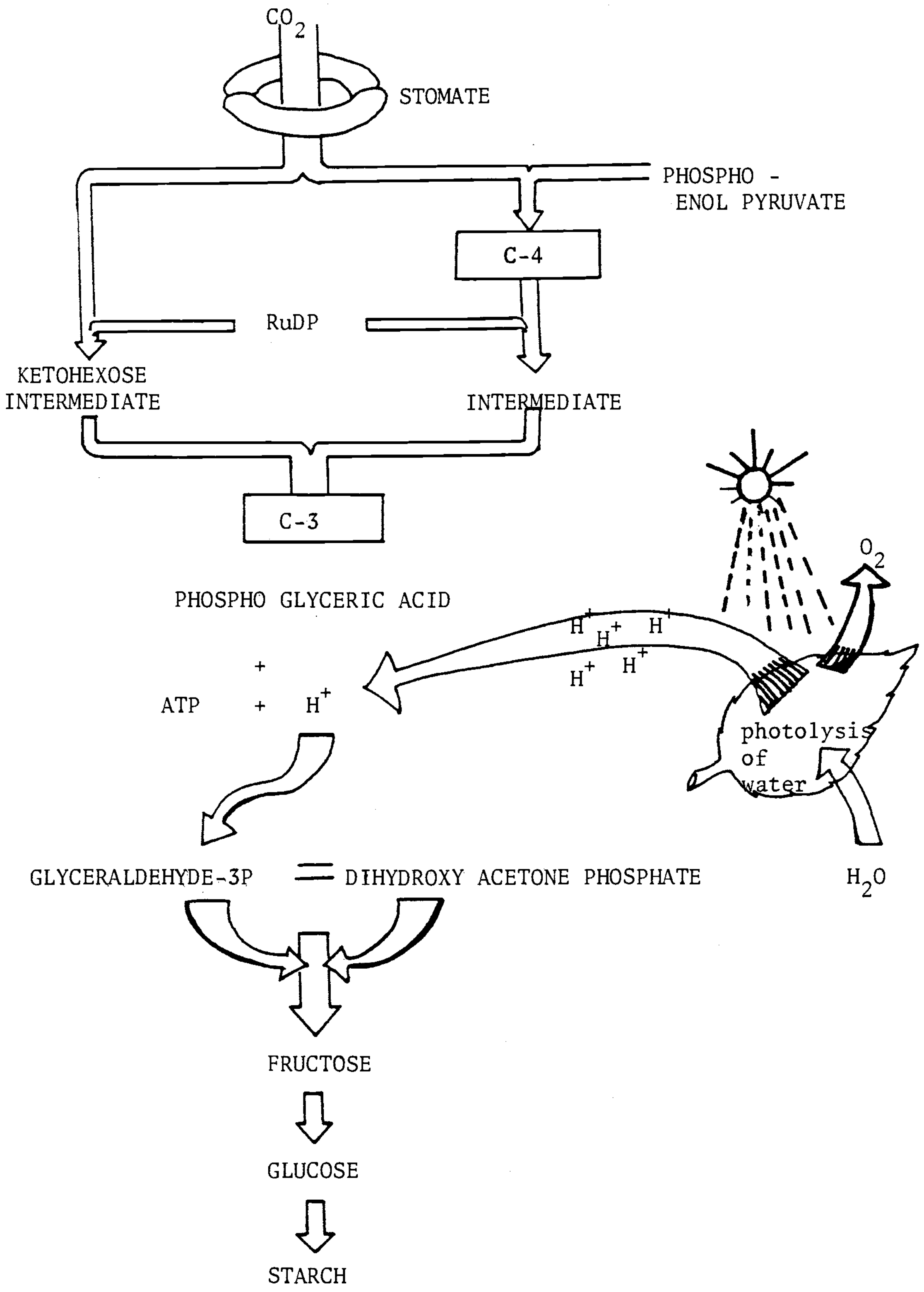


Figure IX. 9. Photosynthesis pathways. (Note C-3 and C-4 pathways). (Adapted from Janick <u>et al</u>, 1974).

the C-3 pathway, CO_2 is fixed directly into the Calvin cycle by RuDP-Case to produce phosphoglyceric acid (Goodwin and Mercer, 1983). RuDP-Case in the C-3 plants represents about 50 % of the soluble proteins in the mesophyll cells, but it has a low activity and thus limits the carbon fixation and carbohydrate production. On the other hand, 4-C compounds have the ability to increase intercellular CO_2 fixation through PEP-Case. PEP-Case is at low concentration in C-4 mesophyll cells, but its higher activity results in high rates of CO_2 fixation per unit of cellular protein when compared with C-3 plants (Norton, 1982). RuDP-Case in C-4 plants is restricted in the bundle sheath cells, in which the Calvin cycle takes place, at about 20 % of the total soluble protein. Better nitrogen (N) use efficiency by C-4 than by C-3 plants is also reported (Figure IX. 10). These results suggest that C-4 plants use nitrogen for dry matter accumulation, which is associated with lower tissue N content with at least twice the efficiency of C-3 plants, although the rate of efficiency or tissue N formation were similar. Furthermore, Colman and Lazenby, cited by Norton (1982) showed that the efficiency of N use by C-4 plants is higher, but the tissue N content is lower, at higher temperature. Norton (1982) concluded that the low CP content of tropical grasses is an inherent characteristics of C-4 metabolism. Low CP content, consequently, is a major limit to intensive forms of animal production. Moreover, mesophyll cells of the tropical grasses are more densely packed, to reduce the water loss due to the warm environment. The intercellular air space represents only 3 - 12 % of the leaf volume, compared with 10 - 35 % in C-3 plants. Although this results in less photorespiration, a process that uses energy for photosynthesis, and

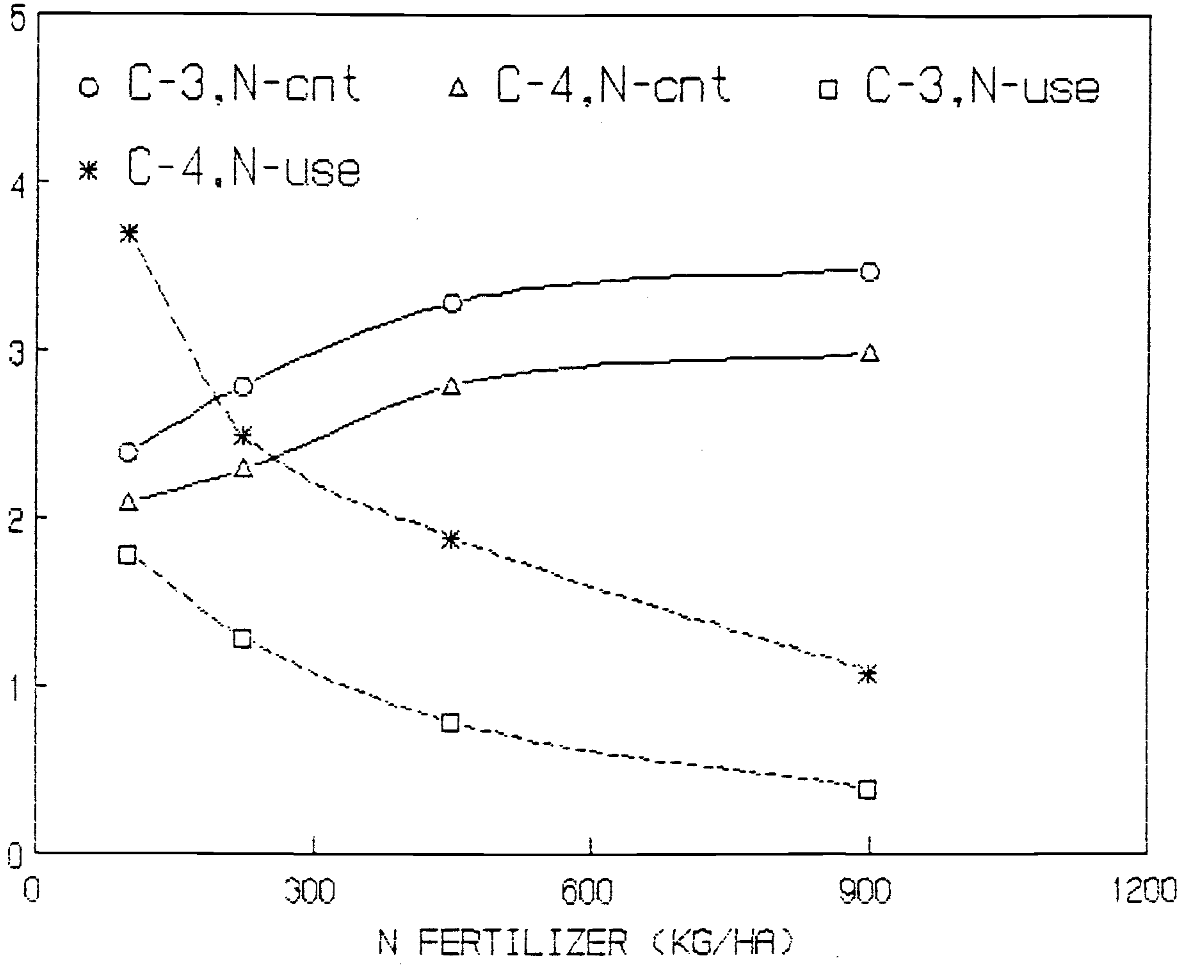


Figure IX. 10. The effects of N fertilizer on the efficiency of N-use (------) and tissue N contents (———) of C-3 (□,○) and C-4 (✱,Δ) plants. (Adapted from Norton, 1982).

thus increases the storage of photosynthetic products, the problem exists that there is less air space available so less uptake of CO_2. In addition, the higher growth rates and fewer environmental restraints (e.g. long or short day) to flowering cause the tropical grasses to mature rapidly, which implies higher rates of vascularization, hence higher cell wall contents, and thus the grass quality declines rapidly (Minson and Wilson, 1980).

CONCLUSIONS

In conclusion, indigestible fiber has detrimental effects on the bioavailability of nutrients of the forages. The rate of depression, however, depends on the plant species and the nutrient profile within species. While legumes and some non woody legumes and agricultural by-products show good potential, tropical grasses are of poor quality. This is associated with the inherent characteristics such as photosynthetic pathway of the plants grown in the warm climate areas. Attempts to improve their utilization should be moved away from what cannot be achieved with poor quality forages to what can be achieved with them through improved technical knowledge by, for example, supplementation or feed preparation.

REFERENCES

Allen, M.S., M.I.McBurney and P.J. Van Soest. 1985. Cation exchange capacity of plant cell walls at neutral pH. J. Sci. Food Agric. 36:1065-1072.

Akin, D.E. 1979. Microscopic evaluation of forage digestion by rumen microorganisms. A review. J. Anim. Sci. 48:701-710.

Akin, D.E. and D. Burdick. 1977. Rumen microbial degradation of starch-containing bundle sheaths cells in warm-season grasses. Crop Sci. 17:529-533.

Barber, S. and C.B deBarber. 1980. Rice bran : Chemistry and Technology. In 'Rice : Production and Utilization' (Luh, B.S., editor). pp. 790-862. AVI Publ. Co. Inc., Westport, Connecticut.

Berkyne, G.M., J.B. Ari, E. Nord and R. Shainkin. 1973. Bedouin osteomalacia due to calcium deprivation caused by high phytic acid content of unleavened bread. Am. J. Clin. Nutr. 26:910-911.

Bogdan, A.V. 1977. Tropical Pasture and Fodder Plants (Grasses and Legumes). Longman, London and New York.

Borrielo, S.P. and R J. Carman. 1983. Association of Iota-like toxin and Clostridium spiriforme with spontaneous and antibiotic-associated diarrhea and colitis in rabbits. J. Clin. Microbiol. 17:414-418.

Brown, R.H. 1978. A difference in N-use efficiency in C-3 and C-4 plants and its implications in adaptation and evolution. Crop Sci. 18: 93-98.

Champe, K.A. and D.V. Maurice. 1983. Response of early weaned rabbits to source and level of dietary fiber. J. Anim. Sci. 56:1105-1114.

Cheeke, P.R. 1983. The significane of fiber in rabbit nutrition. J. Appl. Rabbit Res. 6:103-106.

Cheeke, P.R. and R.O. Myer. 1975. Protein digestibility and lysine availability in alfalfa meal and alfalfa protein concentrate. Nutr. Rep. Int. 12:337-344.

Cheeke, P.R. and N.M. Patton. 1978. Effect of alfalfa and dietary fiber on the growth performance of weanling rabbits. Lab. Anim. Res. 28:167-172.

Cheeke, P.R. and N.M. Patton 1980. Carbohydrate overload of the hind gut - A probable cause of enteritis. J. Appl. Rabbit Res. 3(3):20-23.

Cheeke, P.R. and L.R. Shull. 1985. Tannins and polyphenolic compounds. In 'Natural Toxicants in Feeds and Poisonous Plants'. pp. 322-357. AVI Publ. Co., Inc., Westport, Connecticut.

Cheeke, P.R., D.E. Akin, K.L. Robinson and N.M. Patton. 1985. Fragmentation of forages during mastication and digestion by rabbits. J. Appl. Rabbit Res. 8:26-30.

Cheeke, P.R., M.A. Grobner and N.M. Patton. 1986. Fiber digestion and utilization. J. Appl. Rabbit Res. 9:25-30.

Cheeke, P.R., N. M. Patton, S.D. Lukefahr and J.I. McNitt. 1987. Rabbit production. The Interstate Printers and Publishers, Inc. Danville, Illinois.

Crowder, L.V. and H.R. Chedda. 1982. Tropical Grassland Husbandry. Longman, London and New York.

Colin, M., C.L. Maire, J. Vaissaire and L. Renault. 1976. Experimental study on replacement of crude fiber by mineral ballasts (sand and mica in rabbit diets. Rec. Med. Vet. 152:457-465.

Cummings, J.H. 1978. Nutritional implications of dietary fiber. Am. J. Clin. Nutr. 31:S21-S29.

Ehrlein, H.J., H. Reich and M. Schwinger. 1983. Colonic motility and transit of digesta during hard and soft feces formation in rabbits. J. Physiol. 33:75-86.

Fekete, S. and T. Gippert. 1985. Effect of crude fiber on protein utilization by rabbits. J. Appl. Rabbit Res. 8:31-38.

Fleming, G.A. 1973. Mineral composition of herbage. In 'Chemistry and Biochemistry of Herbage' (G.W. Butler and R.W. Bailey, editors). 1:529-566. Academic Press. London and New York.

Ford, J.A., E.M. Calhoun, W.B. McIntosh and M.G. Dunnigan. 1972. Biochemical response of late ricketts and osteomalacia to a chuppaty - free diet. Bri. Med. J. 3:446-447.

Goldstein, J.L. and T. Swain. 1965. The inhibition of enzymes by tannins. Phytochem. 4:185-192.

Goodwin, T.W. and E.I. Mercer. 1983. Introduction to Plant Biochemistry. Second edition. Pergammon Press. New York.

Harris, D.J., P.R. Cheeke and N.M. Patton. 1983. Feed preference studies with rabbits fed fourteen different fresh greens. J. Appl. Rabbit Res. 6:121-122.

Janick, J. R.W. Schery, F.W. Woods and V.W. Ruttan. 1974. Plant Science. Second edition. W.H. Freeman and Co. San Francisco.

Jenkins, D.J.A., M.J. Hill and J.H. Cumming. 1976. Effect of wheat fiber on blood lipids, fecal steroid excretion and serum iron. Am. J. Clin. Nutr. 28:1408-1416.

Jenkins, D.J.A., A.R. Leeds, H. Houston, L. Hinks, K.G.M.M. Alberti and J.H. Cummings. 1977. Carbohydrate tolerance on man after six weeks of pectin administration. Proc. Nutr. Soc. 36:624-628.

Jones, L.H.P. 1978. Mineral components of plant cell walls. Am. J. Clin. Nutr. 31:S94-S98.

Jones, W.T. and. J.L. Mangan. 1977. Complexes of condensed tannins of sainfoin (Onobrichis viciifolia Scop.) with fraction 1 leaf protein and with submaxillary mucoproteins and their reversal by polyethylene glycol and pH. J. Sci. Food Agric. 28:126-136.

Kay, R.M. and A.S. Truswell. 1977. The effect of wheat fiber on plasma lipids and fecal steroid excretion in man. Bri. J. Nutr. 37:227-235.

King, J.O.L. 1984. Crude fiber in rabbit diets. Comm. Rabbits 12 (4): 10-19.

Laksesvella, B. and A.N. Said. 1978. Tropical vs temperate grasses. Wrld. Rev. Anim. Prod. 14:49-57.

Lang, J. 1981. The nutrition of the commercial rabbit. 2. Feeding and general aspects of nutrition. Nutr. Abstr. Rev. 51(5): 287-299.

Laplace, J.P. 1978. Gastrointestinal transit in monogastric animals. III. Feeding behaviour (feed intake-cecotrophy), gastrointestinal motility and transit, and pathogeny of diarrhea in the rabbit. Ann. Zootech. 27:225-265.

Ledward, D.A. 1979. Protein-polysaccharides interactions. In 'Polysaccharides in Food' (J.M.V. Blanshard and J.R. Mitchell, eds.), pp. 205-217. Butterworth and Co., Ltd., Sydney-Wellington-Durban-Toronto.

Maertens, L. and G. deGroote. 1984. Digestibility and digestible energy content of a number of feedstuffs for rabbits. III Wrld. Rabbit Congress. 1:415-421. Rome, Italy.

McLeod, M.N. 1975. Plant tannins - their role in forage quality. Nutr. Abstr. Rev. 44:803-815.

Maust, L.E., W.G. Pond and M.L. Scott. 1972. Energy value of cassava-rice bran diet with or without zinc for growing swine. J. Anim. Sci. 35:953-957.

Meyer, L.H. 1978. Food Chemistry. AVI Publ. Co. Inc., Westport, Connecticut

Minson, D.J. 1982a. Effect of chemical composition on feed digestibility and metabolisable energy. Nutr. Abstr. Rev. 52:591-615.

Minson, D.J. 1982b. Effects of chemical and physical composition of herbage eaten upon intake. In 'Nutritional limits to animal production from pasture'. pp. 167-182. (J.B. Hacker, editor). Proc. Int. Symp., St. Lucia. Queensland. Australia. Aug. 24-28th. 1981.

Minson, D.J. and J.R. Wilson. 1980. Comparative digestibility of tropical and temperate forage - a contrast between grasses and legumes. J. Austr. Inst. Agric. Sci. 46:247-249.

Mitjavilla, S., C. Lacombe, G. Carrera and R. Derache. 1977. Tannic acid and oxidized tannic acid on the functional state of rat intestinal epithelium. J. Nutr. 107:2113-2121.

Molloy, L.F. and E.L. Richards. 1971. Complexing of calcium and magnesium by the organic constituents of Yorkshire fog (Holcus lanatus). II. Complexing of Ca^{++} and Mg^{++} by cell wall fractions and organic acids. J. Sci. Food Agric. 22:397-403.

Moran Jr., E.T. 1983. Comparative nutrition of fowl and swine : The Gastrointestinal systems. Ontario Agric. Coll. Univ. Guelph. Canada.

Morrisse, J.P., E. Boilletot and R. Maurice. 1985. Changes induced by feeding in intestinal environment of rabbits (VFA, NH_3, pH, flora). Rec. Med. Vet. 161:443-449.

Norton, B.W. 1982. Differences between species in forage quality. In 'Nutritional limits to animal production from pastures' (J.B. Hacker, editor). Proc. Int. Symp. pp.89-110. St. Lucia, Brisbane, Queensland, Australia. Aug. 24-28th, 1981.

Patton, N.M., H.T. Holmes and P.R. Cheeke. 1983. Hairballs and pregnancy toxemia. J. Appl. Rabbit Res. 6:99.

Pond, K.R., W.C. Ellis and D.E. Akin. 1984. Ingestive mastication and fragmentation of forages. J. Anim. Sci. 58:1567-1574.

Raharjo, Y.C. and D.J. Farrell. 1984. A new biological method for determining amino acid digestibility in poultry feedstuffs using a simple cannula, and the influence of dietary fiber on endogenous amino acid output. Anim. Feed Sci. Technol. 12:29-45.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1986. Evaluation of tropical forages and by-products feed for rabbit production. 1. Nutrient digestibility and effect of heat treatment. J. Appl. Rabbit Res. 9:56-66.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1987a. Evaluation of tropical forages and by-product feeds for rabbit production. 2. Composition, consumption and digestibility in growing rabbits.

Raharjo, Y.C., P.R. Cheeke and N.M Patton. 1987b. Evaluation of tropical forages and by-product feeds for rabbit production. 3. Growth performance of rabbits fed different forages and agricultural by-products.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton, S. Yuhaeni and M.E. Siregar. 1987c. Evaluation of tropical forages and by-product feeds for rabbit production. 6. Feed preference study.

Sitorus, P., S. Sastrodiharjo, Y.C. Raharjo, I.G. Putu, Santoso, B. Sudaryanto and A. Nurhadi. 1982. Report of the survey on the rabbit raising in Java. Central Research Institute for Animal Science, Box 123, Bogor, Indonesia.

Skerman, P.J. 1977. Tropical Forage Legume. FAO Plant Production and Protection Series. No. 2. FAO of the U.N. Rome, Italy.

Spreadbury, D. and J. Davidson. 1978. A study on the need for fiber by the growing New Zealand White rabbit. J. Sci. Food Agric. 29:640-648.

Telek, L. 1982. Preparation of leaf protein concentrate from _Leucaena leucocephala_. Leucaena Res. Rep. 3:93-94.

Thornton, R.F. and D.J. Minson. 1973. The relationship between apparent retention time in the rumen, voluntary intake and apparent digestibility of legume and grass diets in sheep. Aust. J. Agric. Res. 24:889-898.

VanSoest, P.J. 1964. Symposium on nutrition and forage and pasture : new chemical procedure for evaluating forages. J. Anim. Sci. 23:838- 845.

VanSoest, P. J. and L.H.P. Jones. 1968. Effect of silica in forages upon digestibility. J. Dairy Sci. 51:1644-1648.

Voris, L.R., L.F. Marcy, E.J. Tracker and W.W. Wainio. 1940. Digestible nutrients of feedingstuffs for the domestic rabbits. J. Agric. Res. 61:673-683.

Wilson, J.R. 1982. Environmental and nutritional factors affecting herbage quality. In 'Nutritional limits to animal production from pasture' (J.B. Hacker, editor). Proc. Int. Symp. pp. 111-131. St. Lucia, Brisbane, Queensland, Australia. Aug. 24-28th. 1981.

Wilson, J.R. and C.W. Ford. 1973. Temperature influences on the _in vitro_ digestibility and soluble carbohydrate accumulation of tropical and temperate grasses. Aust. J. Agric. Res. 24:187-198.

Wise, A. 1983. Dietary factors determining the biological activities of phytates. Nutr. Abstr. Rev. 53:791-8Ø6.

CHAPTER X

EVALUATION OF TROPICAL FORAGES AND BY-PRODUCT FEEDS FOR RABBIT PRODUCTION

9. GROWTH AND REPRODUCTIVE PERFORMANCE OF RABBITS ON A MODERATELY LOW CRUDE PROTEIN DIET WITH OR WITHOUT METHIONINE OR UREA SUPPLEMENTATION[1]

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SUMMARY

The reproductive and growth performances of New Zealand White rabbits on four dietary treatments were compared. The treatments were a 21.5% crude protein (CP) diet (control), a 16% CP diet (LP), LP + 0.3% DL-methionine (LP + met) and LP + 2.1% urea (LP + urea). The CP in the LP diet was derived entirely from alfalfa meal and wheat mill run, with no protein supplement used. Data were collected over 5 parities. Preweaning and postweaning growth rates, reproductive performance as assessed by litter size, conception rate and litter interval were comparable for the four treatments. Average daily postweaning growth rates and reproductive performance, as assessed by litter size, conception rate and litter interval, were comparable for the four treatments. Average daily postweaning gain was about 40 g per day. Litter size at weaning was 7 kits per litter. This study indicates that a simple diet of forage and a grain-milling by-product, with no cereal grain or protein supplement, can support normal growth and reproduction of commercial meat rabbits.

INTRODUCTION

Most reports on the crude protein (CP) requirements of rabbits have been from observations of growing animals (Romney and Johnston, 1978; Spreadbury, 1978; Ouhayoun and Cheriet, 1983; Hassan, 1984). Less information is available regarding breeding rabbits (Omole, 1982; Adams, 1983; Partridge and Allan, 1982, 1983), especially with regard to intensive postpartum breeding (Harris et al., 1982; Sanchez et al., 1985). The recommended CP level for lactating does varies from as low as 13.5% (Adams, 1983) to 21.5% (Harris et al., 1981a). Adams (1983) noted that the 13.5% CP may be satisfactory only for a limited period, while Harris et al. (1981) suggested that the level of 21.5% CP is probably higher than necessary. Omole (1982), with a 42 d or 49 d postpartum rebreeding schedule, suggested CP levels ranging from 18 to 22%, while Sanchez et al. (1985), with a 14 d postpartum breeding schedule, recommended 19% CP.

Reduction of the dietary CP level will likely decrease the dietary essential amino acids (AA) and this may lead to AA deficiencies. Methionine is most likely to be first limiting (Portsmouth, 1977; Spreadbury, 1978; Sanchez et al., 1985). Growth improvement (Colin, 1978a,b; Berchiche and Lebas, 1984) as well as improved nitrogen balance and retention (Balogun et al., 1982) have been reported when rabbits were fed diets supplemented with methionine.

Replacement of cereal grains commonly used in conventional rabbit feed with forages or by-product feeds may reduce feed costs. An alfalfa-wheat mill run-based diet containing 16% CP with no cereal grain gave performance of young rabbits equal to that of diets with

21% soybean meal containing a 21% dietary CP level (Sanchez et al., 1984). Reproductive performance with the 16% CP diet was examined in the present study.

The presence of active urease (Knutson et al., 1977; Crociani et al., 1984) in the digestive tract together with the practice of coprophagy offers a potential utilization of urea as a source of nitrogen in rabbit diets and, hence, suggests a less expensive alternative to conventionally used protein sources. Results on urea inclusion in rabbit diets were reported to be either discouraging (King, 1971; Fonolla et al., 1977; Niedzwiadek et al., 1978), no effect (Lebas and Colin, 1973, Hoover and Heitmann, 1975; Cheeke, 1978) or better performance (Salse and Raynaud, 1977; Semertzakis, 1978). In the adult rabbit, in which the cecum is more developed, Houpt (1963) showed significant nitrogen metabolism from the utilization of orally ingested urea, while Lang (1981a) noted considerable protein synthesis from the in vitro incubation of urea in the cecal contents of rabbit.

The present experiment was undertaken to determine if, under an intensive rebreeding schedule, a diet with no soybean meal or corn, with or without a supplementation of methionine or urea, met the requirements for lactation and preweaning growth of rabbits.

MATERIALS AND METHODS

Procedures were similar to those described by Sanchez et al. (1985) with slight modifications. The study was carried out over a 9 mo period (January-September 1984) at the Rabbit Research Center, Oregon State University.

Diets. The dietary treatments consisted of three alfalfa-wheat meal run based diets containing 16% CP. Diets differed in being with or without methionine or urea supplementation. The diet with 2.1% urea brought the total "CP" (N x 6.25) to 21%. A diet with 54% alfalfa meal and 21% soybean meal and containing 21% CP was used as the control diet. All diets were pelleted (4.7 mm in diameter). Dietary composition and chemical analysis are presented in Table X. 1. Diets were designated control, LP (16% CP), LP + met, and LP + urea.

Chemical analyses. Two samples, each pooled from three subsamples, of each of three batches of feed used were analyzed for dry matter (DM), CP and acid detergent fiber (ADF). A forced air oven technique (AOAC, 1980), a micro Kjehldahl (AOAC, 1980) and a microdigestion (Waldern, 1971) method were used to analyze DM, CP and ADF, respectively. Values for digestible energy (DE), calcium, phosphorus, lysine and methionine were calculated from the NRC (1977) data.

Housing. Rabbits were housed individually in all-wire quonset style hanging cages (Harris, 1983) measuring 76 x 76 x 46 cm or 76 x 61 x 46 cm. Each cage was equipped with a subterranean nest box (Harris, 1982). Cages were suspended with wire about 122 cm above the ground on two sides of a concrete walkway. A J-shaped screened metal feeder (25.4 x 7.7 x 15.0 cm) and automated waterer were provided at the front of each cage. All cages were located in an open sided, A-frame building (Harris et al., 1983).

Animals and management. The study was started with 28 multiparous and 16 nulliparous New Zealand White does. Rabbits in each group were allocated randomly to 4 dietary treatments. Animals were raised on the control diet and were introduced to dietary treatments

Table X. 1. Composition of experimental diets containing 21% and 16% crude protein with or without methionine or urea supplementation.

Ingredient, %	Dietary Protein, %			
	21.0 OSU # 7	16.0 OSU # 14	16.0 OSU # 15	16.0 OSU # 16
	Supplement			
	—	—	0.3% methionine	2.1% urea
Alfalfa meal (IFN 1-00-023)	54.0	54.0	54.0	54.0
Soybean meal (IFN 5-04-604)	21.0	—	—	—
Wheat mill run (IFN 4-05-190)	20.0	41.0	41.0	39.0
Trace mineral salt[a]	0.5	0.5	0.5	0.5
Dicalcium phosphate (IFN 6-01-080)	0.25	0.25	0.25	0.25
Molasses (IFN 4-04-696)	3.0	3.0	3.0	3.0
Tallow	1.25	1.25	1.25	1.25
DL-methionine	—	—	0.3	—
Urea	—	—	—	2.1
Bentonite	2.0	2.0	2.0	2.0
Copper sulfate (IFN 6-01-719) $CuSO_4 5H_2O$	0.1	0.1	0.1	0.1
Chemical analysis[b]				
Dry matter	91.07 ± 1.21	89.88 ± 1.35	89.67 ± 1.60	90.47 ± 0.90
Crude protein	21.13 ± 1.02	16.37 ± 0.22	15.88 ± 0.66	21.22 ± 2.71
Acid detergent fiber	20.87 ± 2.94	21.59 ± 1.44	22.32 ± 1.25	21.64 ± 0.87
DE, kcal/kg[c]	2683	2439	2439	2387
Calcium[c]	0.79	0.76	0.76	0.75
Phosphorus[c]	0.51	0.65	0.65	0.62
Lysine[c]	1.22	0.72	0.72	0.71
Sulfur amino acid[c]	0.63	0.45	0.75	0.44

[a] Mortons Farm and Ranch; OFIXT T-M salt. Provides NaCl and the following elemental levels of mg/kg of complete diet: Zn, 17.5; Mn, 14; Fe, 8.75; Cu, 1.75; I, 0.35; Co, 0.35.

[b] Unless otherwise specified, all values are reported in percent air dry basis.

[c] Calculated values using NRC (1977) data.

at least two weeks prior to first mating. The full capacity of the rabbitry (66 does) was achieved in late April and maintained at that number for the rest of the experiment. Animals that died or were removed for poor performance were replaced with nulliparous does about 18-20 weeks old. Rabbits for replacement were maintained on the same dietary treatments on which they were to be assigned, starting at 16 wk of age. A strict replacement of non-productive does was practiced using the criteria of Sanchez et al. (1985).

All multiparous does had been first bred at approximately 154 d of age, while the nulliparous were 18-20 wk old. Does were rebred 7 d postpartum. Each doe was serviced by a buck randomly selected from a group of six. Does were allowed to have two or more matings within 15 minutes from the same buck. Ten days after mating does were palpated to detect pregnancy and does that failed to conceive were rebred. Does that failed to accept service were mated to a different buck on the same day and each day thereafter until the service was observed. A four-sided wooden nest box lined at the bottom with a wire mesh was provided on d 28 of gestation. Laboratory grade wood shavings were added. On d 21 of lactation the nest box was removed and litters were weaned at d 28.

Does were fed ad libitum from kindling, but whenever the doe was without a litter, including the period of gestation, only 180-240 g feed were fed daily.

Variables used to measure the doe and preweaning litter performances were conception rate, gestation period, litter interval, total number of kits born, number of kits born alive and dead, doe and litter weight at birth, d 21 and d 28, doe and litter gain at d 21 and d

28, doe and litter feed consumption (FC) and feed conversion ratio (FCR = FC/gain) at d 21 and d 28, and mortality rate (%) at d 21 and d 28. Mean individual body weight of stillborn kits was also recorded.

Postweaning performance was assessed in two experiments. In experiment 1, ten litters from each treatment, from second parity does, were maintained on the respective treatment diets. Each litter consisted of 6 to 11 weanling rabbits, with an average of 8.3 ± 1.49, 8.3 ± 2.0, 8.5 ± 1.35 and 8.4 ± 1.65 for the control, LP, LP + met and LP + urea diets, respectively. In experiment 2, 240 weaned rabbits from third parity does were used, with litters from each of the four treatments. The rabbits were pooled and divided into two groups, weaning weights of 301-500 g and 501-700 g, without regard to pre-weaning dietary treatment. The animals were assigned to each of the 4 diets, with 6 replicates of 5 rabbits each. Three replicates were males and the other 3 were females. The allocation of weaned rabbits into dietary treatments are illustrated in Figure X. 1. For both experiments, performance traits were measured over the postweaning period of 28 to 56 days of age.

Statistical procedure. Only does with at least two live litters were included in the analysis. Numbers of litters born alive used in the analysis for does and pre-weaning litter traits are shown in Table X. 2. Data were subjected to analysis of variance. Litters were treated as the experimental unit; diet, parity number and interactions were used as potential sources of variation in the data set of 307 litter records. Only litters born alive (n = 284, Table X. 2) were used in doe and litter birth traits. A paired t-test to analyze dietary effects on the parities was used. Parity x diet interaction

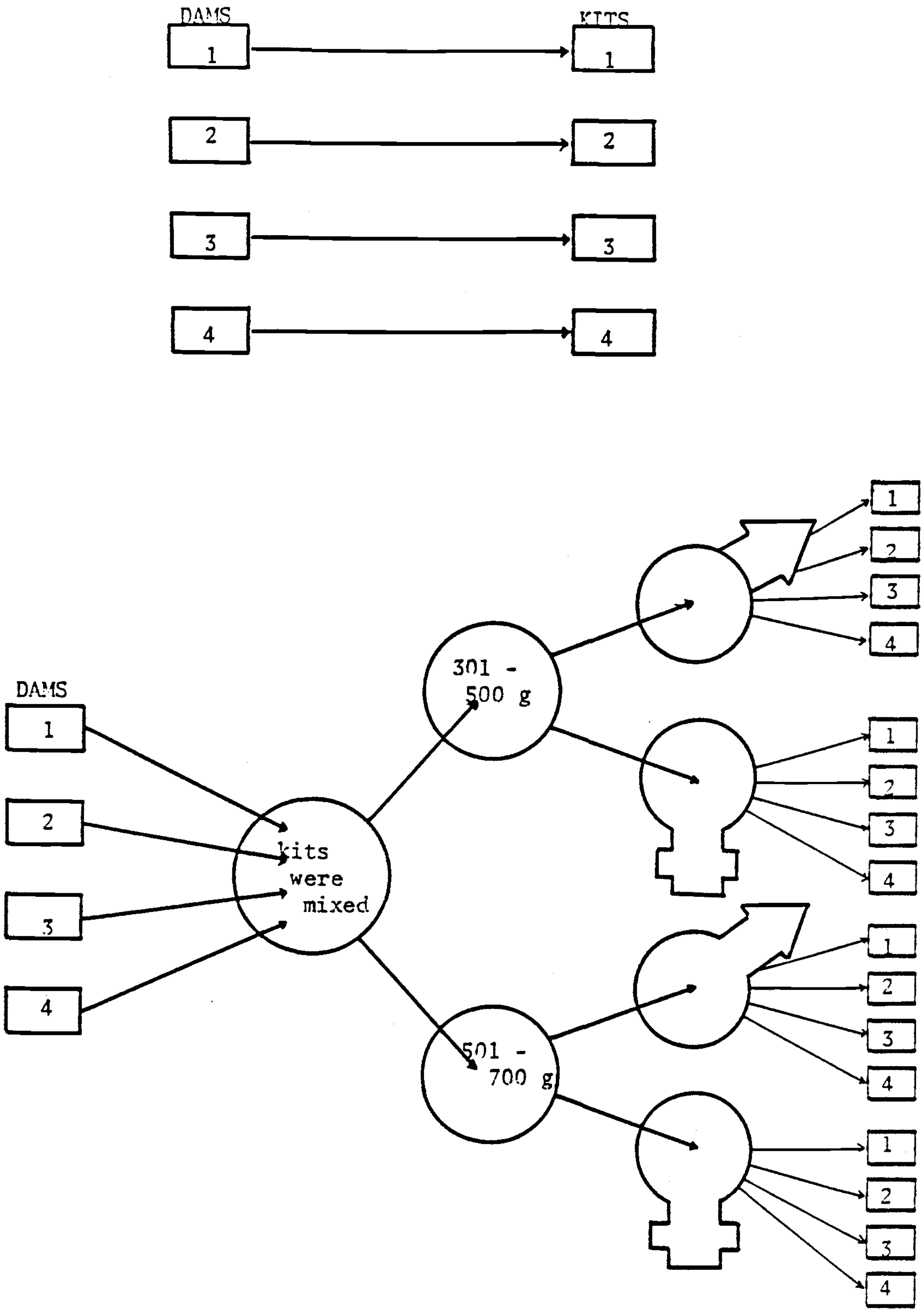

Figure X. 1. Allocation of weaned rabbits into dietary treatments (1=21% CP; 2=16% CP; 3=16% CP with 0.3% methionine; 4=16% CP with 2.1% urea) in the first (top) and second (bottom) experiment.

Table X. 2. Numbers of litters born alive used in the analysis for doe and pre-weaning litter traits.

Parity	Crude Protein, %			
	21.Ø	16.Ø	16.Ø	16.Ø
	Supplement			
	—	—	Methionine	Urea
1	21	18	17	18
2	21	18	17	18
3	14	18	15	14
4	11	15	12	9
5	9	7	6	6
TOTAL	76	76	67	65

effects were analyzed using factorial analysis. When significant differences were detected, comparisons of mean differences were tested using the Least Significant Difference test (Steel and Torie, 1980).

RESULTS AND DISCUSSION

Results are grouped into doe and preweaning litter performance traits and postweaning performance. Measurements were separated into 1 to 21 d, 21 to 28 d, 1 to 28 d and 28 to 56 d postpartum records. The first 21 d reflect milk production as the litter is still dependent upon the dam's milk (Lebas, 1972; Lang, 1981b; Lukefahr et al., 1981). The period of 21 to 28 d reflects the adaptation of the litter to solid feed and decreased dependence on the doe's milk, while the period 1 to 28 d reflects overall performance from birth to weaning. The 28 to 56 d period provides postweaning performance.

Parity effect. Parity effect is important to measure carryover or cumulative effects of dietary treatments on the performance of animals over a long time period. Within each dietary treatment, with over 34 variables observed, results from the first to fifth parity fluctuated but, in general, did not show significant differences ($P > 0.05$). Regardless of dietary treatments, mean doe body weight at birth, 21 and 28 d of lactation decreased ($P > 0.05$) from first to third parity and then leveled out to the fifth parity (Figure X. 2). Sanchez et al. (1985) reported a 500 g/doe weight loss from first to fifth lactation, particularly from the second to the third, between which the loss was 400 g. Thereafter Sanchez et al. (1985) observed an increased doe weight up to eighth parity. The increase was sug-

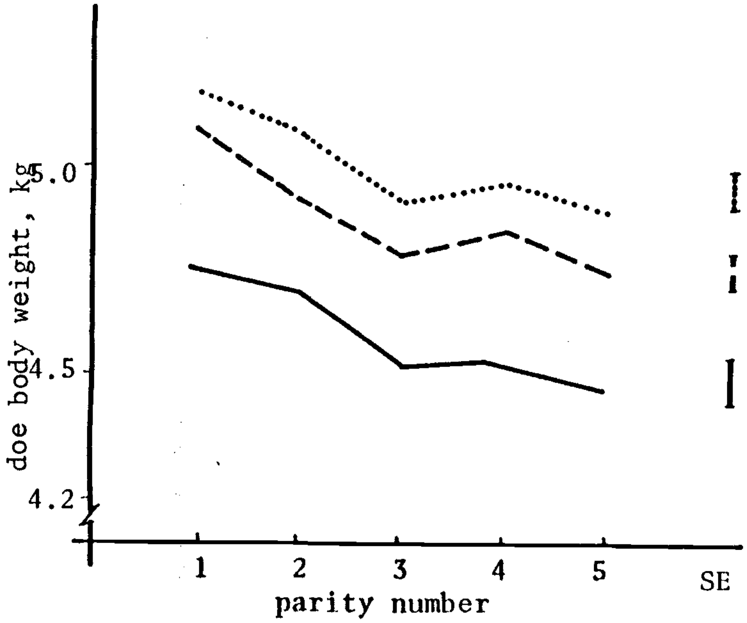

Figure X. 2. Mean and standard error (SE) of doe bodyweight at birth (———), 21 d (.....) and 28 d (-----) in 5 parities.

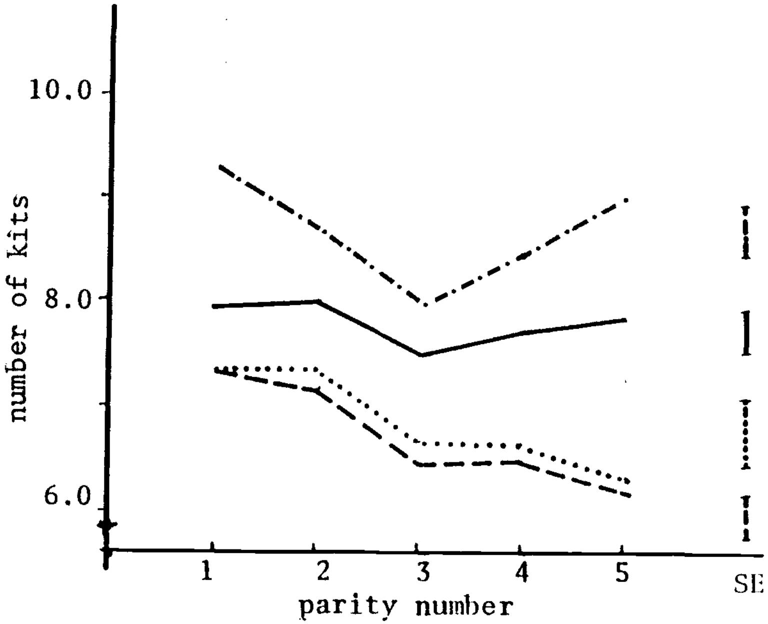

Figure X. 3. Mean and standard error (SE) of number of kits born (-.-.-.-), kits born alive (———), litter size at 21 d (.....) and 28 d (------) in 5 parities.

gested as a reflection of possible genetic superiority in animals that had reached the sixth lactation. In the present study, doe body weight increased to the fourth lactation, then decreased slightly in the fifth lactation.

Number of kits born, kits born alive, and number of kits at 21 and 28 d were not influenced by parity number (Figure X. 3). Lukefahr et al. (1981) also reported similar results over 3 successive lactations. On the other hand, Sanchez et al. (1985) reported a lower number of kits born alive at first parity with a steady increase thereafter. It is unclear why the number of kits born decreased (13.79%) in the third parity and then increased to the level similar to the first parity. The decrease was contributed mainly from the three dietary treatments with 16% CP. The number of kits at 21 and 28 d showed a downward trend, although they did not differ statistically with the increasing parity number. Likewise, these results followed the significant increase of mortality ($P < .05$) from first to fifth parity as shown in Table X. 3.

Figure X. 4. shows mean litter weight at birth, 21 and 28 d and mean litter gain at 21 and 28 d. Decreasing body weight and weight gain of litters at 21 and 28 d were observed as the numbers of parity increased. The decrease was significant only in litter weight at 21 d between the first and second parity versus the fifth parity (Table X. 3). In contrast, Lukefahr et al. (1981) found that litter weight, litter gain and milk production were higher in the second than in the first parity. Kalinowski and Rudolph (1975) also reported lower milk production by New Zealand White rabbits in the first lactation and, consequently, less litter gain. Reduced litter gain with increasing

Table X. 3. Mean and standard error (SEM) of variables measured in rabbits regardless of diets fed.

Variable	Parity 1	2	3	4	5	SEM
Total litter weight						
at 21 d, kg	2.57^{bc}	2.68^{c}	2.41^{abc}	2.32^{ab}	2.24^{a}	0.098
Mortality, %						
at 21 d	7.04^{a}	8.71^{a}	11.83^{ab}	15.54^{ab}	18.42^{b}	3.101
at 28 d	7.77^{a}	10.45^{ab}	13.41^{ab}	16.17^{ab}	19.98^{b}	3.150

^{a,b,c} Row means bearing different superscripts are significantly different ($P < 0.05$).

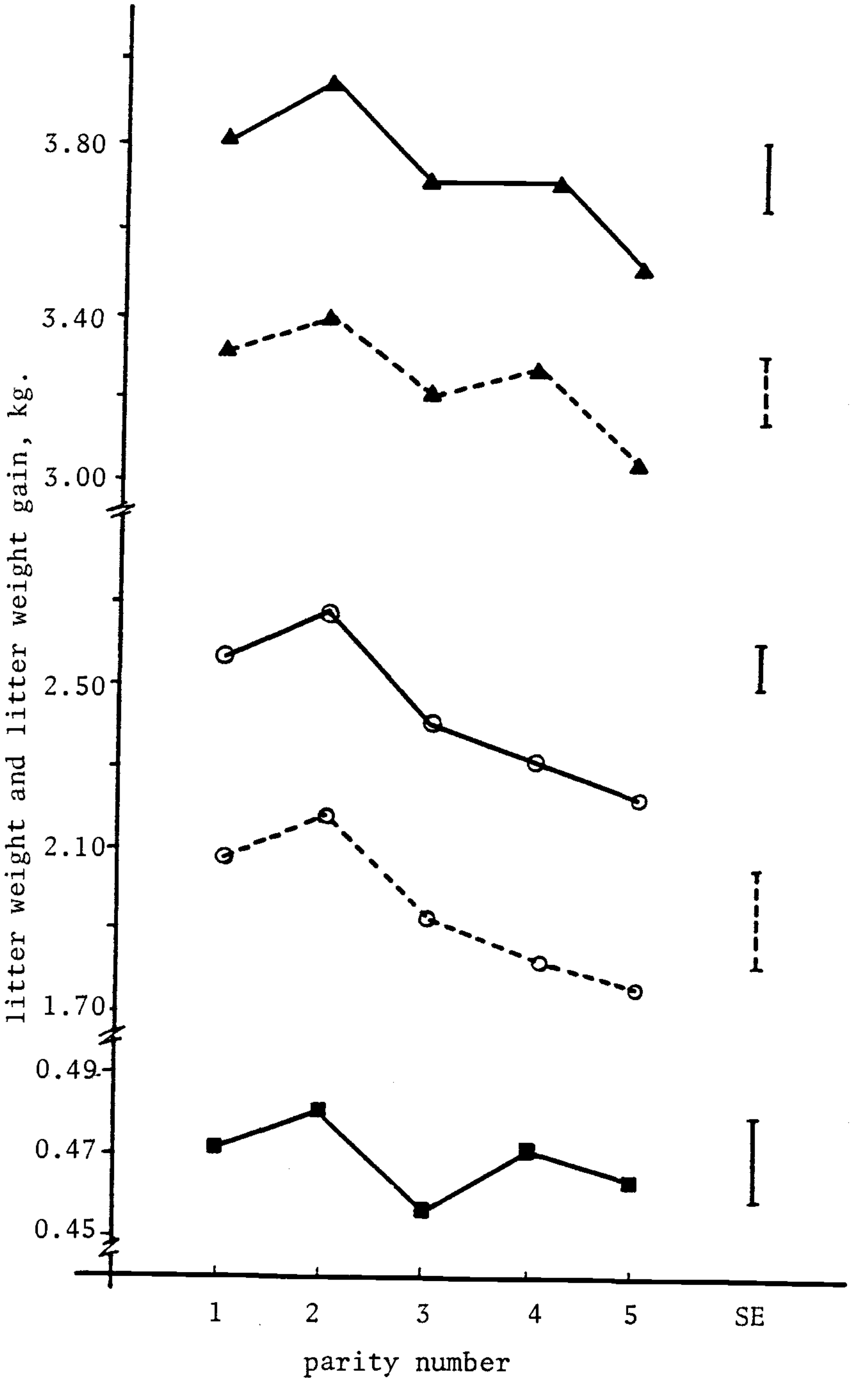

Figure X. 4. Mean and standard error (SE) of litter weight (———) and litter weight gain (------) at birth (□), 21 d (O) and 28 d (Δ) of rabbits in 5 parities.

parity in the present study might be due to the decrease in feed consumption (Figure X. 5), reducing the milk yield. Reduction of feed consumption might be related to the environmental temperature, because lactation periods for parities 4 and 5 occurred between June and September, when the maximum temperature ranged from 29 to 40° C. Stephen (1980) also reported a marked drop of feed consumption that subsequently reduced growth performance of rabbits when temperature was raised from 25 to 30° C. In addition, less milk production in the subsequent lactations might partly be due to the rapid reproductive cycle (7 d postpartum breedback), which may require more intake of nutrients. No differences were observed among parities for FCR both at 21 or 28 d postpartum (Figure X. 6).

Doe performance. Reproductive performance traits of does are presented in Table X. 4. There were no significant differences ($P > 0.05$) detected among dietary treatments except for mean doe weight at kindling.

It is interesting to note that the low CP group without supplement had a higher number of successful matings than other treatments. Adams (1983) reported similar observations in that does on a 14% CP diet had higher receptivity (76%) than does on an 18% CP diet (69%). The reasons for this higher receptivity under the lower CP diet are not known. In this study, however, the total number of does presented for mating was not recorded. Conception rate, which reflects fertility, was lowest on the diet supplemented with methionine. The overall value was 86.7%. Using the same breeding management except that 14 d postpartum breed back was practiced, Sanchez et al (1985) reported values ranging from 89.2 to 91.0%. On the other hand, Harris et al

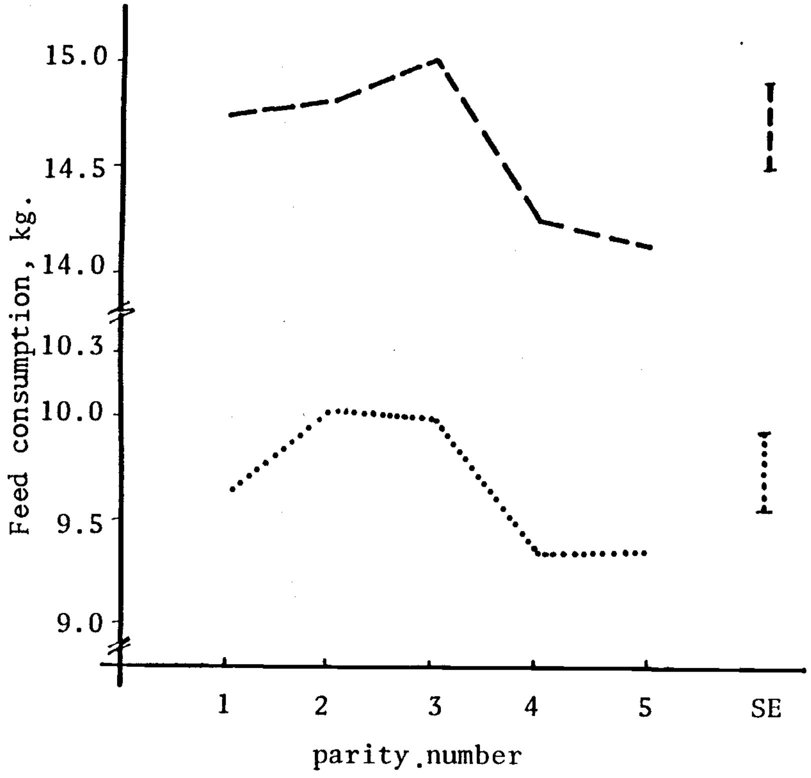

Figure X. 5. Mean and standard error (SE) of feed consumption of rabbits (doe + litter) at 21 d (·····) and 28 d (-----) in 5 parities.

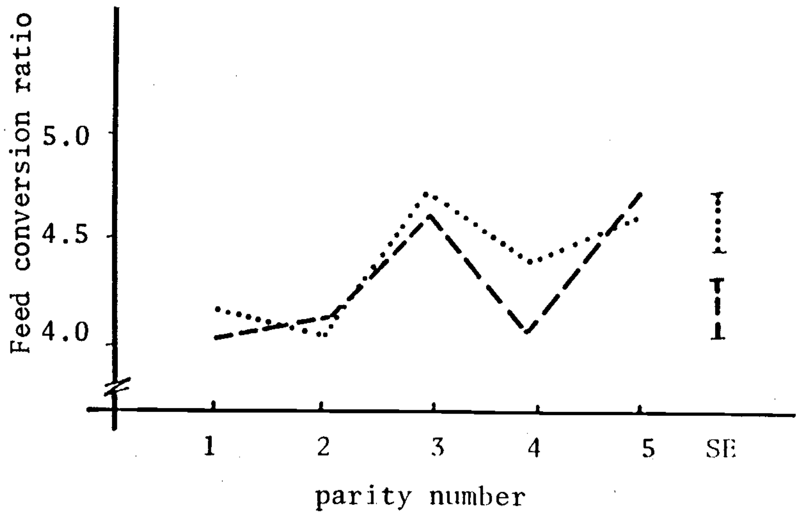

Figure X. 6. Mean and standard error (SE) of feed conversion ratio of rabbits (doe+litter) at 21 d (·····) and 28 d (-----) in 5 parities.

Table X. 4. Mean and standard errors (SEM) of reproductive traits of does fed diets containing 21 and 16% crude protein with or without DL-methionine or urea supplementation.

Variable	Crude Protein, %				SEM
	21.0	16.0	16.0	16.0	
	Supplement				
	--	--	Methionine	Urea	
Successful mating*	89	95	88	82	--
Conception rate, %**	89.89	87.37	82.95	86.58	--
Gestation period, d	31.6	31.6	32.1	31.6	0.17
Litter interval, d	37.8	40.3	45.6	42.4	7.95
Doe weight at kindling, g	4518[a]	4497[a]	4827[b]	4495[a]	100.4
Doe gain, g					
at 21 d	413	363	439	399	32.6
at 28 d	324	236	322	293	42.5

[a,b] Row means bearing different superscripts are significantly different ($P < 0.05$).

* Number of successful breedings, determined by positive palpation.

** Number of kindling/number of successful mating.

(1982) and Lukefahr et al. (1983) reported much lower values, 68% and 64% respectively. The reason for the higher values in the present study and in that of Sanchez et al (1985) was that the non-fertile does, which were replaced either after 3 consecutive failures to conceive or after service but before parturition, were not used to calculate conception rate. In addition, multiple services provided more sperm and this practice has been reported to increase both receptivity and fertility in breeding does (Szendro et al., 1984).

Gestation period and litter interval did not differ among treatments. Regardless of nutrient supplementation, Omole (1982) found a similar result (31.2 d) for gestation period of does fed an 18% CP diet. Higher values, up to 33.7 d, however, were reported when dietary CP content was reduced to 10%. Litter interval is an important measure of the potential productivity of the animal over a period of time. High variations (19.23%) were observed among individual does. The control diet gave shorter and fewer variations among individual does than the other dietary treatments. Values of 34.5 to 45.3 d, 34.8 to 53.0 d, 36 to 78 d and 34.5 to 64.7 d were observed in does fed control diet, 16% CP diet without supplement and 16% CP diet with methionine or urea supplementation, respectively. Harris et al. (1982) reported values of 39.3 d and 50.9 d when the rebreeding schedule was 1 and 14 d postpartum, respectively. These results suggested that, irrespective of the dietary treatments, nine litters could be obtained from the same dam in one year without affecting the performance of the rabbit.

Doe weight at birth was significantly higher ($P < 0.05$) in the rabbits fed 16% CP diet with methionine supplementation. Similar patterns were observed at 21 d and 28 d postpartum (Table X. 4), but weight gain was not different among treatments (P > Ø.Ø5). The growth improvement by methionine supplementation has been discussed elsewhere (Colin, 1978a,b; Spreadbury et al., 1978; Sanchez et al., 1984). In this study, however, the significantly heavier weights of does (P < Ø.Ø5) on the diet with methionine were likely due to heavier initial weights at random allocation to treatment rather than to the effect of supplemental methionine itself. Heavier does under this treatment had already been observed in the first litter. Doe weight gradually decreased as parity number increased. In addition, the non-significantly different weight gains among treatments indicated that the addition of methionine did not exert beneficial effects.

Doe weights increased following the lactation period, but it was observed that, regardless of dietary treatment, doe weights at 21 d were heavier than at 28 d (Table X. 4). This decrease in doe weight was also indicated by negative doe gains from 21-28 d (Table X. 4). Similar results were observed by Butcher et al. (1983) irrespective of dietary energy levels and by Sanchez et al. (1985) in does fed diets containing 19 and 2Ø.5% CP. It seems surprising that doe wieghts at 21 d, following the period of peak lactation, were heavier than after kindling. This is likely an artifact, resulting from the cessation of feed intake before kindling and dehydration. Partridge et al. (1983) noted that body weight changes are a poor indicator of body tissue mobilization in the lactating doe, because of factors such as gut fill and body tissue hydration. These workers noted that although there was no loss of body weight of does during lactation, mobilization of body tissue begins at about 11 d following parturition, and continues for the remainder of lactation. Milk production rapidly decreases after 21 d of lactation (Lebas, 1972; Partridge and Allan, 1981, 1983) and feed intake is also lower at d 28 (Partridge and Allan, 1982, 1983; Partridge et al., 1983), probably explaining the decrease in doe weight at 28 d. In particular, in a heavy rebreeding schedule, decreasing milk produciton after 21 d might be accelerated by the competition for nutrients for embryo development (Lebas, 1972).

Causes for replacement of does (Table X. 5) were unlikely related to the dietary treatments, as the number of does replaced within treatments were too small or the causes were similar among treatments. Mastitis occurred more frequently than other causes. Heat stress occurred in pregnant does almost ready to kindle (d 28 - d 30 gestation). Temperature during that time (June 21-28) ranged from 36 to 40^{o} C. Enteritis was not detected with the lower protein diets. Whether the higher dietary fiber content, as the result of increasing level of wheat mill run in the diet, prevented this disease in the lower protein diets is unknown. There are, however, many reports showing the significance of fiber in preventing enteritis (Cheeke and Patton, 1980).

Preweaning litter performance. Preweaning litter performance traits are presented in Table X. 6. Results from other workers are presented in Table X. 7 for comparison.

Reduction of dietary protein level from 21% to 16% did not significantly decrease ($P < 0.05$) most of the performance traits of the preweaning litters. Numbers of total kits born did not differ ($P < 0.05$) among treatments and were similar to those reported by previous workers from the same institute (Harris et al., 1981, 1982; Lukefahr

Table X. 5. Number and percentage of breeding does replaced and/or culled on the 21.0 and 16.0% crude protein diet with or without methionine or urea supplementation.

	Crude Protein, %			
	21.0	16.0	16.0	16.0
	Supplement			
	--	--	Methionine	Urea
Poor production[a]	1	--	1	--
Respiratory problems[b]	--	1	--	--
Mastitis	2	1	2	2
Pododermatitis	--	1	1	--
Enteritis	2	--	--	--
Heat stress	--	2	--	2
Other	2	--	--	--

[a] Included severe weight loss and failure to conceive after 3 consecutive matings.

[b] Infection of Pasteurella multocida, excessive sneezing or pneumonia.

Table X. 6. Mean and standard error (SEM) of preweaning performance traits of rabbits fed diets containing 21.0 and 16.0% crude protein with or without methionine or urea supplementation.

Variable	Crude Protein, %				
	21.0	16.0	16.0	16.0	S.E.M.
	Supplement				
	--	--	Methionine	Urea	
Total kits born	9.11	8.67	8.01	8.96	0.434
Kits born alive	8.47^{b}	7.86^{ab}	6.82^{a}	8.17^{b}	0.362
Total live litter weight, g	519^{b}	461^{ab}	435^{a}	505^{b}	18.4
Individual live kit weight, g	61.3^{ab}	58.6^{a}	63.8^{b}	61.8^{ab}	1.58
Mortality, %	8.20	9.26	13.26	8.53	2.873
Individual dead kit weight, g	57.6	52.8	57.6	45.9	3.70
1-21 days					
Litter size	7.21	6.79	6.11	7.36	0.614
Total litter weight, kg	2.55	2.35	2.38	2.49	0.087
Total litter gain, kg	2.03	1.88	1.94	2.00	0.196
Individual kit gain, g	282^{a}	277^{a}	318^{b}	272^{a}	11.3
Feed intake, kg+	9.99	9.47	9.75	9.70	0.297
Feed Conversion Ratio+	4.28	4.65	4.36	4.28	0.164
Mortality, %	15.41	13.03	11.01	9.79	2.774
1-28 days					
Litter size	7.18	6.75	6.09	7.34	0.312
Total litter weight, kg	3.92	3.66	3.66	3.92	0.146
Total litter gain, kg	3.39	3.20	3.23	3.41	0.136
Individual kit gain, g	472	474	532	468	36.5
Feed intake, kg+	14.99	14.10	14.45	14.80	0.348
Feed Conversion Ratio+	4.25	4.68	4.19	4.19	0.159
Mortality, %	16.95	14.36	12.13	10.78	3.882
21-28 days					
Total litter gain, kg	1.39	1.31	1.27	1.43	0.142
Individual kit gain, g	194	196	208	197	11.8
Feed intake, kg+	4.99	4.62	4.73	5.06	0.154
Feed Conversion Ratio+	3.58	3.53	3.75	3.55	0.232
Mortality, %	1.81	1.71	1.35	1.13	0.419

a,b Row means bearing different superscripts are significantly different ($P < 0.05$).

+ Doe + litter.

et al., 1981, 1983; Sanchez et al., 1985). Sanchez et al. (1985) reported a slightly, but not significantly, lower value of total born when dietary protein level was reduced from 20.5 to 17.5%. Lower numbers of kits born, ranging from 4.3 to 7.9, from does fed various levels of dietary protein (Table X. 7) were also reported (Partridge et al., 1981; Omole, 1982).

Number of kits born alive and their total weight was poorest ($P < 0.05$), but individual kit weight was heaviest ($P < 0.05$), in low protein diet with 0.3% methionine supplementation. Heavier individual kit weight was a result of smaller litter size, as also reported by Lebas and Sandi (1969) and Lebas (1970). As the kits grew, differences in litter size and total weight among treatments were not significant ($P > 0.05$), as shown by the results at d 21 and at weaning (d 28). Less mortality and higher growth rate of kits, which were indicated by higher individual kit gain, on the low protein diet with methionine compensated for these initial differences. However, higher growth rate of kits on the low protein diet supplemented with methionine was more likely due to a lower number of kits per litter and, consequently, less competition for milk resulting in heavier individual kit weight, than to the response to methionine supplementation.

Highest litter size and total litter gain recorded at weaning were 7.34 and 3.41 kg, respectively, for the urea group. These results were not different statistically from other groups. Feed intake, feed conversion ratio and mortality also did not differ among treatments in the 1-21 d, 1-28 d and 21-28 d period. Results of this study were also comparable to those reported by various workers (Table X. 7).

Table X. 7. Performance of preweaning litter traits of New Zealand White rabbits as reported by several authors, regardless of rebreeding schedule.

Trait	Authors*							
	1	2	3	4	5	6	7	8
	Dietary Protein Level, %							
	19.0	21.6	21.6	—	21.7	18.0	20.5	22.8
	n							
	62	5	31	36	205	36	129	142
Total kits born	6.9	11.8	9.0	9.2	8.8	7.6	9.4	8.9
Kits born alive	5.8	11.3	8.5	—	7.3	7.1	7.4	7.6
Total live litter wt, g	—**	606	493	—	—	318	517	497
Individual live wt, g	—	52.1	61.0	—	—	44.8	69.8	65.4
Still birth, %	15.94	4.24	5.56	—	17.7	6.21	21.1	14.8
1-21 days								
Litter size	—	10.7	8.0	7.5	—	—	7.7	—
Total litter wt, kg	—	3.08	2.72	2.55	2.47	—	2.69	—
Total litter gain, kg	—	2.47	2.23	2.04	—	—	2.17	—
Individual litter gain, g	—	236	308	272	—	—	282	—
Feed intake, kg	—	9.73	—	—	—	—	10.24	—
FCR	—	3.94	—	—	—	—	4.72	—
Mortality, %	—	5.31	11.1	—	—	—	10.03	—
1-28 days								
Litter size	5.0	10.6	8.0	—	7.0	7.0	7.63	6.9
Total litter wt, kg	—	5.08	4.27	3.78	3.85	3.44	4.12	3.66
Total litter gain, kg	—	4.47	3.78	—	—	3.14	3.60	3.09
Individual kit gain, g	—	422	506	—	—	449	472	448
Feed intake, kg	—	15.7	15.5	8.57	—	—	—	13.50
FCR	—	3.51	4.10	4.17	4.45	—	—	4.37
Mortality, %	13.5	6.19	11.10	—	18.20	4.37	11.66	17.40

* 1. Partridge et al. (1981), 2. Harris et al. (1981), 3. Harris et al. (1981), 4. Lukefahr et al. (1981), 5. Harris et al. (1982), 6. Omole (1982), 7. Sanchez et al. (1985), 8. Lukefahr et al. (1983).

** Data are not available.

n = number of observations.

The postweaning performance (Tables X. 8 and 9) show no differences in any of the parameters measured.

A diet with 16% crude protein (air dry basis) did not appear to be deficient for rabbits under an intensive rebreeding schedule, during gestation and lactation periods, although the performance of does and preweaning litters was slightly lower than those on a 21% CP diet. Inclusion of 0.3% methionine had no significant effect, although numerically the values were lowest with this treatment. Colin (1975) and Colin and Arkhurst (1975) also reported a slight depressive effect of the additional 0.3, but not 0.1%, methionine on the weight gain of growing rabbits. With 0.75% of total sulfur AA in the diet in this study, it was unlikely that this depressive effect was due to methionine toxicity or imbalance of AA. As high as 0.82% of methionine and lysine was fed without any depressive effect (Spreadbury, 1978), while AA balance was argued to be less critical in rabbits because of the practice of coprophagy (Portsmouth, 1977). However, Adamson and Fisher (1973), using a purified diet, pointed out that a slight excess of isoleucine, lysine, phenylalanine, methionine and threonine caused growth depression in young rabbits. Moreover, Berchiche and Lebas (1984) reported that above 0.67% in the diet methionine was inhibitory to rabbit growth.

Supplementation with urea slightly improved performance. These results suggest that rabbits, to some extent, can utilize urea as a source of nitrogen. Active bacterial urease (King, 1971; Knutson et al., 1977; Emaldi et al, 1979, Crociani et al., 1984) may aid in the conversion of some of the urea to nonessential AA in the liver, and to microbial protein (Houpt, 1967), which is ingested during coprophagy

Table X. 8. Mean and standard error (SEM) of daily feed consumption, body weight gain and feed conversion ratio of rabbits maintaned on diets varying in CP level with or without methionine or urea supplementation, from 4 to 8 weeks of age (Experiment 1).

Variable	Crude Protein				
	21	16	16	16	SEM
	Supplement				
	--	--	Methionine	Urea	
Feed consumption (g/rabbit)	107	111	111	118	4.4
Body weight gain (g/rabbit)	36.0	36.4	37.3	36.1	1.44
Feed Conversion ratio	2.98	3.05	2.98	3.27	.094

No statistical differences were detected between treatments.

Table X. 9. Mean and standard error (SEM) of feed consumption, weight gain and feed conversion ratio of male and female rabbits in two groups of different initial fed diets varying in CP level with or without methionine or urea supplementation, from 4 to 8 weeks of age (Experiment 2).

	Group (g)	Sex	Crude Protein, %: 21	16	16	16	Mean of Sex (SEM)	Mean of Weight Group (SEM)
			Supplement: --	--	Methionine	Urea		
Feed consumption (g/d/rabbit)	301-500	M	101	114	103	103	M: 117	109^{a}
		F	106	116	110	110		
	501-700	M	123	138	132	132	F: 120	128^{b}
		F	136	111	140	148	(2.0)	(2.0)
	Mean (SEM)		117	122	124	123	(4.0)	
Weight gain (g/d/rabbit)	301-500	M	40.1	38.0	36.8	35.3	M: 39.9	38.7^{a}
		F	39.2	40.9	39.0	40.0		
	501-700	M	42.7	44.4	42.2	39.4	F: 41.2	42.4^{b}
		F	43.5	41.1	45.9	39.9	(0.84)	(0.84)
	Mean (SEM)		41.4	41.1	41.0	38.7	(1.19)	
Feed conversion	301-500	M	2.52	2.99	2.81	2.93	M: 2.93	2.81
		F	2.70	2.83	2.82	2.86		
	501-700	M	3.88	3.10	3.12	3.10	F: 2.91	3.03
		F	3.12	2.71	3.06	3.36	(0.051)	(0.051)
	Mean (SEM)		3.07	2.94	2.96	3.08	(0.083)	

(McBee, 1971). Slight beneficial effects of urea inclusion into rabbit diets were also reported by Houpt (1963), Salse and Raynaud (1977) and Semertzakis (1978), although many other authors found no appreciable response (King, 1971; Lebas and Colin, 1975; Cheeke, 1978) or even depressive effects (Fonolla et al, 1977; Niedzwiadek et al., 1978). The depressive effect of urea might occur when the rate of urea break-down to ammonia is faster than the conversion of ammonia to protein (King, 1971).

Replacement of whole soybean meal with wheat mill run, besides reducing the dietary CP level, also decreased the dietary DE content from 2680 kcal/kg to about 2400 kcal/kg. DE content lower than that of the control diet, however, did not appear to depress performance. Lang (1981a) suggested that a high fiber level in the diet increased volatile fatty acid (VFA) concentrations through the degradation of some fiber fractions by microbes (Lebas and Laplace, 1977; Spreadbury and Davidson, 1978) and that these VFA concentrations contribute as high as 10-12% of the daily DE requirement of the rabbit (Hoover and Heitmann, 1972).

This study indicates that rabbits can be successfully raised on a diet of forage and grain miling by-product without the use of cereal grain per se and high quality protein supplements. The simple nutritional needs of rabbits, in addition to their rapid growth and high reproduction potential, are promising attributes for meat production in developing countries, where competition between humans and livestock for high quality feedstuffs is significant (Cheeke, 1986).

REFERENCES

Adams, C.E. 1983. Reproductive performance of rabbits on a low protein diet. Lab. Anim. 17:340-344.

Adamson, I. and H. Fisher. 1973. Amino acid requirement of the growing rabbit: An estimate of quantitative need. J. Nutr. 103:1306-1310.

AOAC. 1980. Official method of analysis. Thirteenth edition. Association of Official Analytical Chemists. Washington, D.C.

Balogun, O.O., E.A. Balogun and A.A. Adetunji. 1982. Effect of amino acid supplementation of a protein free diet on growth and nitrogen economy of rabbits. Nutr. Rep. Int. 26:1095-1103.

Berchiche, M. and F. Lebas. 1984. Effect of methionine supplementation of a horse-bean based diet on growth and carcass characteristics of fryer rabbits. Proc. Third World Rabbit Congress, Rome, Italy. p. 391-398.

Butcher, C., M.J. Byrant and E. Owen. 1983. The effect of dietary metabolizable energy concentration upon the pre- and post-weaning performance of growing rabbits. Anim. Prod. 36:229-236.

Cheeke, P.R. 1978. Use of urea and other NPN sources by the rabbit. J. Appl. Rabbit Res. 2:6-7.

Cheeke, P.R. and N.M. Patton. 1980. Carbohydrate overload of the hindgut - a probable cause of enteritis. J. Appl. Rabbit Res. 3:20-23.

Cheeke, P.R. 1986. Potentials of rabbit production in tropical and subtropical agricultural systems. J. Anim. Sci. 63:1581-1586.

Colin, M. 1975. Effect of lysine addition to sesame oil-meal diets in the rabbit. Ann. Zootech. 24:144 (Abstr.).

Colin, M. 1978. Effects of methionine or cystine supplementation of sulphur amino acid deficient diets on the growth of rabbits. (In French). Ann. Zootech. 27:9.

Colin, M. 1978. Effect of adding methionine to drinking water on growth of rabbits. Nutr. Rep. Inter. 17:397-402.

Colin, M. and G. Arkhurst. 1975. Effect of DL-methionine addition to a soybean oil meal diet on growth and nitrogen retention in the rabbit. Ann. Zootech. 24:145 (Abstr.).

Crociani, F., B. Biavati, P. Castagloni and D. Matteuzzi. 1984. Anaerobic ureolytic bacteria from cecal contents and soft feces of rabbits. J. Appl. Bacteriol. 57:83-88.

Emaldi, O., F. Crociani, D. Matteuzi and V. Proto. 1979. A note on the total viable counts and selective enumeration of anaerobic bacteria in the cecal content, soft and hard feces of rabbits. J. Appl. Bacteriol. 46:169-172.

Fonolla, J., R. Sanz and J. Aguilera. 1977. Urea in the nutrition of monogastrics. 1. Part of total replacement of soy by urea in a ration for rabbits. Nutr. Abstr. Rev. 47:234 (Abstract 1886).

Harris, D.J. 1982. Advantages of the subterranean nest box. J. Appl. Rabbit Res. 5:101.

Harris, D.J. 1983. Construction of quonset-style rabbit cages. J. Appl. Rabbit Res. 6:142-147.

Harris, D.J., P.R. Cheeke and M.M. Patton. 1981. Utilization of high alfalfa diets by rabbits. J. Appl. Rabbit Res. 4:30-34.

Harris, D.J., P.R. Cheeke and N.M. Patton. 1982. Effect of diet, light and breeding schedule on rabbit performance. J. Appl. Rabbit Res. 5:33-37.

Harris, D.J., P.R. Cheeke and N.M. Patton. 1983. Advantages of narrow, open-sided rabbit buildings. J. Appl. Rabbit Res. 6:101-102.

Hassan, T. 1984. Daily weight gain, feed conversion efficiency and digestibility coefficients as affected by protein levels and amino acid supplementation. Proc. Third World Rabbit Congress, Rome, Italy: 294-304.

Hoover, W.H. and R.N. Heittmann. 1972. Effects of dietary fiber levels on weight gain, cecal volume, and volatile fatty acid production in rabbits. J. Nutr. 102:375-385.

Hoover, W.H. and R.N. Heittmann. 1975. Cecal nitrogen metabolism and amino acid absorption in the rabbit. J. Nutr. 105:245-252.

Houpt, T.R. 1963. Urea utilization by rabbits fed a low protein ration. Amer. J. Physiol. 205:1144-1150.

Houpt, T.R. 1967. Urea metabolism in the rabbit. Fed. Proc. 20:349.

Kalinowski, T. and W. Rudolph. 1975. Studies on the lactation performance of New Zealand White rabbit does during four consecutive lactations. Wissenschaftliche Zeitschrift der Universitat Rostock. 24:291-294.

King, J.O.L. 1971. Urea as a protein supplement for growing rabbits. Brit. Vet. J. 127:523-525.

Knutson, R.S., R.S. Francis, J.L. Hall, B.H. Moore and J.F. Heisinger. 1977. Ammonia and urea distribution and urease activity in the gastrointestinal tract of rabbits (Oryctolagus and Sylvilagus). Comp. Biochem. Physiol. 58A:151-154.

Lang, J. 1981a. The nutrition of the commercial rabbit. Part 1. Physiology, digestibility and nutrient requirements. Nutr. Abstr. Rev. 51:197-225.

Lang, J. 1981b. The nutrition of the commercial rabbit. Part 2. Feeding and general aspects of nutrition. Nutr. Abstr. Rev. 51:287-299.

Lebas, F. 1970. Nutrition and growth of suckling baby rabbits. (In French). Recueil de Medecine Veterinaire 146:1065-1070.

Lebas, F. 1972. Effect of concurrent lactation and pregnancy on the milking performance of the rabbit. (In French). Ann. Zootech. 21:129-131.

Lebas, F. and M. Colin. 1973. Effect of adding urea to a low protein diet for growing rabbits. (In French). Ann. Zootech. 23:577-581.

Lebas, F. and J.P. Laplace. 1977. Digestive transit in the rabbit: Influence of source of fibre. (In French). Ann. Zootech. 26:575-584.

Lebas, F. and G. Sardi. 1969. Milk feeding and weight increase of rabbits before weaning. (In French). Ann. Zootech. 18:197-208.

Lukefahr, S.D., W.D. Hohenboken, P.R. Cheeke and N.M. Patton. 1981. Milk production and litter growth traits in straightbred and crossbred rabbits. J. Appl. Rabbit Res. 4:35-40.

Lukefahr, S.D., W.D. Hohenboken, P.R. Cheeke and N.M. Patton. 1983. Doe reproduction and preweaning litter performance of straightbred and crossbred rabbits. J. Anim. Sci. 57:1090-1099.

McBee, R.H. 1971. Significance of intestinal microflora in herbivora. Ann. Rev. Ecol. and Syst. 2:165-176.

Niedzwiadek, S., J. Kawinska and J. Tuczynska. 1978. Urea in feeds for rabbits. In Nutr. Abstr. Rev. Series B 48:297 (Abstract 2455).

NRC. 1977. Nutrient Requirement of Domestic Animals. No. 9. Nutrient Requirements of Rabbits. Second revised edition. National Academy of Sciences. National Research Council, Washington, D.C.

Omole, T.A. 1982. The effect of level of dietary protein on growth and reproductive performance in rabbits. J. Appl. Rabbit Res. 5:83-88.

Ouhayoun, J. and S. Cheriet. 1983. Comparative utilization of diets with different crude protein levels in rabbits selected on growth rate and in farm rabbits. 1. Growth performance and weight gain composition. (In French). Ann. Zootech. 32:257-276.

Partridge, G.G. and S.J. Allan. 1982. The effects of different intakes of crude protein on nitrogen utilization in the pregnant and lactating rabbits. Anim. Prod. 35:145-155.

Partridge, G.G. and S.J. Allan. 1983. The effects of dietary protein concentration on the lactational performance of the rabbit. Anim. Prod. 37:119-123.

Partridge, G.G., S. Foley and W. Corrigall. 1981. Reproductive performance in purebred and crossbred commercial rabbits. Anim. Prod. 32:325-331.

Partridge, G.G., M.F. Fuller and J.D. Pullar. 1983. Energy and nitrogen metabolism of lactating rabbits. Brit. J. Nutr. 49:507-515.

Portsmouth, J. 1977. The Nutrition of Rabbits. In: Nutrition and the Climatic Environment (Ed.: W. Haresign, H. Swan and D. Lewis). Butterworths, London.

Romney, C.P. and N.P. Johnston. 1978. Dietary protein levels and early weaning on rabbit performance. Proc. West. Sec. Amer. Soc.Anim. Sci. 29:201.

Salse, A., F. Crampes and P. Raynauds. 1977. Feeding value of urea perfused into the cecum of rabbits. (In French). Ann. Biol. Anim. Biochim. Biophys. 17:559-565.

Sanchez, W.K., P.R. Cheeke and N.M. Patton. 1984. Influence of dietary level of soybean meal, methionine and lysine on the performance of weanling rabbits fed high alfalfa diets. J. Appl. Rabbit Res. 7:109-116.

Sanchez, W.K., P.R. Cheeke and N.M. Patton. 1985. Effect of dietary crude protein level on the reproductive performance and growth of New Zealand White rabbits. J. Anim. Sci. 60:1029-1039.

Semertzakis, N. 1978. Utilization of non-protein nitrogen by adult female rabbits for maintenance and during pregnancy. Nutr. Abstr. Rev. Series B 48:198 (Abstract 1548).

Spreadbury, D. 1978. A study of the protein and amino acids requirements of the growing New Zealand White rabbits with emphasis on lysine and the sulphur containing amino acids. Brit. J. Nutr. 39:601-613.

Spreadbury, D. and J. Davidson. 1978. A study on the need for fibre by the growing New Zealand White rabbit. J. Sci. Fd. Agric. 29:640-648.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. A Biometrical Approach. Second edition. McGraw Hill Book Co., New York.

Stephan, E. 1980. The influence of environmental temperatures on meat rabbits of different breeds. Proc. Second World Rabbit Congress. Barcelona, Spain: 399-409.

Szendro, T., T.H. Tag-El-Den and B. Nemeth. 1984. Effect of double mating on conception rate and litter size in rabbits. Proc. Third World Rabbit Congress, 2:124-130.

Waldern, D.C. 1971. A rapid microdigestion procedure for neutral and acid detergent fibre. Can. J. Anim. Sci. 51:67-69.

CONCLUSIONS AND FURTHER RECOMMENDATIONS

Sufficient evidence is presented to suggest that although they have not been utilized efficiently, tropical forages and by-product feeds have nutritional importants in rabbit production. Forages are not only inexpensive but also available throughout the year. Nonetheless, owing to their great diversity in species and quality within species, more information is needed to evaluate the potential of each forage species, the availability of forages in the particular area and their physiological effects on the animals. Gathering this information is unlikely to prove easy as the essence of the forage utilization is influenced by a number of different factors including the plant secondary compounds and fiber, which vary greatly in the type and amount between forage species.

From the results of this study, some general conclusions and recommendations for further research can be made :

1. Legume species showed more potential, in terms of their palatability, composition and digestibility than other type of forages. Leucaena and sesbania, in particular, are the most promising. Grasses, although are of poor quality, can be useful as a source of indigestible fiber, which are essential in the rabbit production. Fast growing non-woody legumes and high availability of supply of agricultural by-products, together with their moderately good in quality, showed their potential for rabbit production. More research is needed to elucidate the presence and the role of plant secondary compounds and fiber, in terms of their amount and type, which usually hinder the quality of forages. More efficient

utilization of fiber, e.g. through forage preparations, chemical treatments, etc. may improve the performance of the animals, hence rabbit production.

2. Combinations of good and poor quality forages proved to improve the performance of rabbits fed poor quality forages alone. More research of forage combinations, including the differentratios, are needed as there are many poor quality foragaes, particularly of the grass species, available abundantly.
3. Rice bran can be included up to 60 % in a well-balanced diet for rabbits. Supplementation of micro and micronutrients is needed when rice bran is used as the only concentrate in the forage-feeding system. Improvement of rice bran quality through processing, including its preparation is an important area to be examined.
4. Drying, particularly sundrying, which is cheap and easy, is needed to preserve and to transport the good quality forages to be used for supplementation to poor quality forages. Drying, however, depressed the quality of forages. An optimum drying procedure, including the method, temperature used and period of drying is needed to be established for each forages, owing to their different responses to a certain set of drying procedure. Other forage conservation procedures such as preparation of silage should be evaluated.
5. Replacement of the whole soybean meal with wheat-mill run and decreasing dietary crude protein (CP) to 16 % proved to support good growth and reproduction of rabbits. Urea supplementation did not improve performance significantly. The use of slowly released non-protein nitrogen source, such as biuret, may be beneficial to

reduce the dietary CP content originating from feedstuffs.

6. Overall growth performance results indicated that lower dietary intake occurred in the rabbits raised in the tropical (Bogor, Indonesia) than temperate (Corvallis, Oregon) area. Research on the effect of environment on the performance of rabbits are needed as great environmental variations exist from area to the other.

BIBLIOGRAPHY

Abunain D. 1979. Nutritional intakes in Indonesia. Proc. Third Biennial Meeting of AESSEA, Kuala Lumpur, Nov. 23 - 30th.

Adams, C.E. 1983. Reproductive performance of rabbits on a low protein diet. Lab. Anim. 17:340-344.

Adamson, I. and H. Fisher. 1973. Amino acid requirement of the growing rabbit: An estimate of a quantitative need. J. Nutr. 103: 1306-1310.

Allen, M.S., M.I.McBurney and P.J. Van Soest. 1985. Cation exchange capacity of plant cell walls at neutral pH. J. Sci. Food Agric. 36:1065-1072.

Akin, D.E. 1979. Microscopic evaluation of forage digestion by rumen microorganisms. A review. J. Anim. Sci. 48:701-710.

Akin, D.E. and D. Burdick. 1977. Rumen microbial degradation of starch-containing bundle sheaths cells in warm-season grasses. Crop Sci. 17:529-533.

AOAC. 1980. Official Method of Analysis. Thirteenth edition. Association of Official Analytical Chemists. Washington, D.C.

Ashton, W.W., C. Evans and P.C. Williams. 1960. Phosphorus compunds of oats. II. The utilization of phytate phosphorus by growing chicks. J. Sci. Food Agric. 11:722-727.

Aw, T.L. and B.G. Swanson. 1985. Influence of tannins on Phaseolus vulgaris protein digestibility and quality. J. Food Sci. 50:67-71.

Ayoade, J.A., T.P.E. Makhambera and M. Kayange. 1985. Studies in the nutrition of rabbits in Malawi. A preliminary study on the chemical composition of some central Malawi plants eaten by rabbits. J. Appl. Rabbit Res. 8:81-82.

Balogun, O.O., E.A. Balogun and A.A. Adetunji. 1982. Effect of amino acid supplementation of a protein free diet on growth and nitrogen economy of rabbits. Nutr. Rep. Int. 26:1095-1103.

Barber, S. and C.B deBarber. 1980. Rice bran : Chemistry and Technology. In 'Rice : Production and Utilization' (Luh, B.S., editor). pp. 790-862. AVI Publ. Co. Inc., Westport, Connecticut.

Barber, S. , C.B. deBarber, M.J. Flores and J.J. Montes. 1978. Toxic constituents of rice bran. 1. Trypsin inhibitor activity of raw and heat treated bran. J. Agric. Chem. Food Technol. 18:80-88.

Berchiche, M. and F. Lebas. 1984. Effect of methionine supplementation of a horse-bean based diet on growth and carcass characteristics of fryer rabbits. Proc. III Wrld Rabbit Congress. pp. 392-398. Rome, Italy.

Berkyne, G.M., J.B. Ari, E. Nord and R. Shainkin. 1973. Bedouin osteomalacia due to calcium deprivation caused by high phytic acid content of unleavened bread. Am. J. Clin. Nutr. 26:910-911.

Blaxter, K.L., F.W. Wainman and R.S. Wilson. 1961. The regulation of food intake by shep. Anim. Prod. 3:51-61.

Bogdan, A.V. 1977. Tropical Pasture and Fodder Plants (Grasses and Legumes). Longman, London and New York.

Borrielo, S.P. and R J. Carman. 1983. Association of Iota-like toxin and Clostridium spiriforme with spontaneous and antibiotic-associated diarrhea and colitis in rabbits. J. Clin. Microbiol. 17:414-418.

Brooks, C.C. 1972. Molasses, sugar, corn, tallow, soybean oil and mixed fat as sources of energy for growing swine. J. Anim. Sci. 34:217-224.

Brooks, C.C. and I.G. Lumanta Jr. 1975a. Rice bran composition and digestibility by the pigs. Proc. West. Sec. Am. Soc. Anim. Sci. 26:112-114.

Brooks, C.C. and I.G. Lumanta Jr. 1975b. Effect of rice bran on pig performance and carcass. Proc. West. Sec. Am. Soc. Anim. Sci. 26: 115-117.

Brown, R.H. 1978. A difference in N-use efficiency in C-3 and C-4 plants and its implications in adaptation and evolution. Crop Sci. 18: 93-98.

Buchanan, R.A. 1969. Effect of storage and lipid extraction on the properties of leaf protein. J. Sci. Food Agric. 20:359-364.

Burns, R.E. 1971. Methods for estimation of tannins in grain sorghum. Agron. J. 63:511-512.

Butcher, C., M.J. Byrant and E. Owen. 1983. The effect of dietary metabolizable energy concentration upon the pre- and post-weaning performance of growing rabbits. Anim. Prod. 36:229-236.

Chadhokar, P.A. 1982. Gliricidia maculata, a promising legume fodder plant. Wrld. Anim. Rev. 44:36-43.

Champe, K.A. and D.V. Maurice. 1983. Response of early weaned rabbits to source and level of dietary fiber. J. Anim. Sci. 56:1105-1114.

Cheeke, P.R. 1978. Use of urea and other non-protein nitrogen by the rabbit. J. Appl. Rabbit Res. 2(1):6-7.

Cheeke, P.R. 1979. Comparisons of comfrey and alfalfa : Composition, protein distribution and digestibility. J. Appl. Rabbit Res. 2(2) 7-8.

Cheeke, P.R. 1983a. Rabbit production in Indonesia. J. Appl. Rabbit Res. 6:80-86.

Cheeke, P.R. 1983b. The significane of fiber in rabbit nutrition. J. Appl. Rabbit Res. 6:103-106.

Cheeke, P.R. 1985. Rabbit production and research in Brazil. J. Appl. Rabbit Res. 8:123-125.

Cheeke, P.R. 1986. Potentials of rabbit production in tropical and subtropical agricultural system. J. Anim. Sci. 63:1581-1586.

Cheeke, P.R. and R. Carlsson. 1978. Evaluation of several crops as sources of leaf meal : composition, effect of drying procedure and rate of growth response. Nutr. Rep. Int. 18:465-473.

Cheeke, P.R. and R.O. Myer. 1975. Protein digestibility and lysine availability in alfalfa meal and alfalfa protein concentrate. Nutr. Rep. Int. 12:337-344.

Cheeke, P.R. and N.M. Patton. 1978. Effect of alfalfa and dietary fiber on the growth performance of weanling rabbits. Lab. Anim. Res. 28:167-172.

Cheeke, P.R. and N.M Patton. 1979. Utilization of alfalfa by rabbits. In 'The Domestic Rabbits : Potentials, Problems and Current Research'. Proc. Symp. 71st. Ann. Meet. ASAS. U.A., Tucson, Arizona. pp. 25-28. Published by OSU-Rabbit Research Center.

Cheeke, P.R. and N.M. Patton 1980. Carbohydrate overload of the hind gut - A probable cause of enteritis. J. Appl. Rabbit Res. 3(3):20-23.

Cheeke, P.R. and L.R. Shull. 1985. Tannins and polyphenolic compounds. In 'Natural Toxicants in Feeds and Poisonous Plants'. pp. 322-357. AVI Publ. Co., Inc., Westport, Connecticut.

Cheeke, P.R., J.H. Kinzell and M.W. Pedersen. 1977. Influence of saponins on alfalfa utilization by rats, rabbits and swine. J. Anim. Sci. 45:476-481.

Cheeke, P.R., D.E. Akin, K.L. Robinson and N.M. Patton. 1985. Fragmentation of forages during mastication and digestion by rabbits. J. Appl. Rabbit Res. 8:26-30.

Cheeke, P.R., M.A. Grobner and N.M. Patton. 1986. Fiber digestion and utilization. J. Appl. Rabbit Res. 9:25-30.

Cheeke, P.R., N. M. Patton, S.D. Lukefahr and J.I. McNitt. 1987. Rabbit production. The Interstate Printers and Publishers, Inc. Danville, Illinois.

Cheeke, P.R., L. Telek, R. Carlsson and J.J. Evans. 1980. Nutritional evaluation of leaf protein concentrates prepared from selected tropical plants. Nutr. Rep. Int. 22:717-721.

Church, D.C. and W.G. Pond. 1978. Factors affecting food consumption. In 'Basic Animal Nutrition and Feeding'. pp. 203-214. O&B Books Publ. Co. Corvallis.

Colin, M. 1975. Effect of lysine addition to sesame oil-meal diets in the rabbit. Ann. Zootech. 24:144 (Abstr.).

Colin, M. 1978. Effects of methionine or cystine supplementation of sulphur amino acid deficient diets on the growth of rabbits. Ann. Zootech. 27:9 (Abstr.).

Colin, M. 1978. Effect of adding methionine to drinking water on growth of rabbits. Nutr. Rep. Int. 17:397-402.

Colin, M. and G. Arkhurst. 1975. Effect of DL-methionine addition to a soybean oil meal diet on growth and nitrogen retention in the rabbit. Ann. Zootech. 24:145 (Abstr.).

Colin, M., C. Maire, J. Vaissaire and L. Renault. 1976. Experimental study on replacement of crude fiber by mineral ballast (sand and mica) in rabbit diets. Rec. Med. Vet. 152:457-465.

Cordova, F.J., J.D. Wallace and R.D. Pieper. 1978. Forage intake by grazing species : A review. J. Range Mgmt. 31:430-438.

Corley, J.R., D.H. Baker and R.A. Easter. 1980. Biological availability of phosphorus in rice bran and wheat bran as affected by pelleting. J. Anim. Sci. 50:286-292.

Crociani, F., B. Biavati, P. Castagloni and D. Matteuzzi. 1984. Anaerobic ureolytic bacteria from cecal contents and soft feces of rabbits. J. Appl. Bacteriol. 57:83-88.

Crowder, L.V. and H.R. Chedda. 1982. Tropical Grassland Husbandry. Longman, London and New York.

Cummings, J.H. 1978. Nutritional implications of dietary fiber. Am. J. Clin. Nutr. 31:S21-S29.

DeBarber, C.B. and S. Barber. 1978. Toxic constituents of rice bran. II. Hemagglutinating activity of raw and heat-treated bran. J. Agric. Chem. Food Technol. 18:89-94.

DeBattista, J.R. 1985. Rabbit production in Malta. J. Appl. Rabbit Res. 8:83-84

Deolankar, R.P. and K.S. Singh. 1979. Trypsin inhibitor, mineral availability and performance of broiler chickens fed on diets based on rice bran. Anim. Feed Sci. Technol. 4:133-141.

Din, M.G., M.L. Sunde and H.R. Bird. 1979. Effect of feeding plant by-product diets on growth and egg production. Poult. Sci. 58:1274-1283.

DGLS. 1981. A Minor Livestock Development Plan for Low Income People. Directorate General for Livestock Services. Dept. of Agric. Jakarta. Indonesia.

Dukes, J.A. 1981. Handbook of Legumes of World Economic Importance. pp. 313-315. Plenum Press. New York and London.

Ehrlein, H.J., H. Reich and M. Schwinger. 1983. Colonic motility and transit of digesta during hard and soft feces formation in rabbits. J. Physiol. 33:75-86.

Elias, L.G., D.G. deFernandez and R. Bressani. 1979. Possible effects of seed coat polyphenolics on the nutritional quality of bean protein. J. Food Sci. 44:524-527.

Emaldi, O., F. Crociani, D. Mateuzzi and V. Proto. 1979. A note on the total viable counts and selective enumeration of anaerobic bacteria in the cecal content, soft and hard feces of rabbits. J. Appl. Bacteriol. 46:169-172.

Farrell, D.J. and Y.C. Raharjo. 1984. The potential for meat production from rabbits. Central Research Institute for Animal Science. Box 123, Bogor, Indonesia.

Fekete, S. 1985. Rabbit feeds and feeding with special regards to tropical conditions. J. Appl. Rabbit. Res. 8:167-173.

Fekete, S. and T. Gippert. 1985. Effect of crude fiber on protein utilization by rabbits. J. Appl. Rabbit Res. 8:31-38.

Fernandez, R., L.G. Elias, J. E. Braham and R. Bressani. 1982. Trypsin inhibitors and hemagglutinins in beans (Phaseolus vulgaris) and their relationship with the content of tannins and associated polyphenols. J. Agric. Food Chem. 30:734-739.

Festenstein, G.N. 1983. Carbohydrates in LPC and fractionated protein extracts. In 'Leaf Protein Concentrates' (L. Telek and H.D. Graham, editors). pp. 215-234. AVI Publ. Co. Inc., Westport, Connecticut.

Fleming, G.A. 1973. Mineral composition of herbage. In 'Chemistry and Biochemistry of Herbage' (G.W. Butler and R.W. Bailey, editors). 1:529-566. Academic Press. London and New York.

Fomunjam, R.T. 1984. Cabbage and banana plantain leaf in rabbit diets. III Wrld. Rabbit Congress. 1:244-251. Rome, Italy.

Fonolla, J., R. Sanz and J. Aguilera. 1977. Urea in the nutrition of monogastrics. 1. Part of total replacement of soy by urea in a ration for rabbits. Nutr. Abstr. Rev. 47:234 (1886).

Ford, J.A., E.M. Calhoun, W.B. McIntosh and M.G. Dunnigan. 1972. Biochemical response of late ricketts and osteomalacia to a chuppaty - free diet. Bri. Med. J. 3:446-447.

Goering, H.K. and P.J. VanSoest. 1970. Forage fiber analysis. Agric. Handbook No. 379. pp. 1-20. Agric. Res. Service, USDA.

Gohl, B. 1981. Tropical Feeds : Feed Information, Summaries and Nutritive value. FAO Animal Production and Health Series. No. 12, pp. 302-307. FAO of the UN., Rome, Italy.

Goldstein, J.L. and T. Swain. 1965. The inhibition of enzymes by tannins. Phytochem. 4:185-192.

Goodwin, T.W. and E.I. Mercer. 1983. Introduction to Plant Biochemistry. Second edition. Pergammon Press. New York.

Grobner, M.A., P.R. Cheeke and N.M. Patton. 1983. Diet switching and enteritis. J. Appl. Rabbit Res. 6:25-28.

Grobner, M.A., P.R. Cheeke and N.M. Patton. 1985. Effect of feeding comfrey on growth and tissue copper levels of rabbits. J. Appl. Rabbit Res. 6:97-98.

Hagerman, A.E. and L.G. Butler. 1978. Protein precipitation method for the quantitative determination of tannins. J. Sci. Food Chem. 26: 809-812.

Hagerman, A.E. and L.G. Butler. 1981. The specificity of anthocyanidin-protein interaction. J. Biol. Chem. 256:4494-4497.

Harris, D.J. 1982. Advantages of the subterranean nest box. J. Appl. Rabbit Res. 5:101.

Harris, D.J. 1983. Construction of quonset-style rabbit cages. J. Appl. Rabbit Res. 6:142-147.

Harris, D.J., P.R. Cheeke and N.M Patton. 1981a. Utilization of high alfalfa diets by rabbits. J. Appl. Rabbit Res. 4:30-34.

Harris, D.J., P.R. Cheeke, N.M. Patton and J.L. Brewbaker. 1981b. A note on the digestibility of leucaena leaf meal in rabbits. J. Appl. Rabbit Res. 4:99.

Harris, D.J., P.R. Cheeke, L. Telek and N.M. Patton. 1981c. Utilization of alfalfa meal and tropical forages by weanling rabbits. J. Appl. Rabbit Res. 4:4-9.

Harris, D.J., P.R. Cheeke and N.M. Patton. 1982. Effect of diet, light and breeding schedule on rabbit performance. J. Appl. Rabbit Res. 5:33-37.

Harris, D.J., P.R. Cheeke and N.M. Patton. 1983a. Advantages of narrow, open-sided rabbit buildings. J. Appl. Rabbit Res. 6:101-102.

Harris, D.J., P.R. Cheeke and N.M. Patton. 1983b. Feed preference studies with rabbits fed fourteen different fresh greens. J. Appl. Rabbit Res. 6:121-122.

Harris, D.J., P.R. Cheeke and N.M. Patton. 1984. Evaluation of Black Locust leaves for growing rabbits. J. Appl. Rabbit Res. 7:7-9.

Hassan, T. 1984. Daily weight gain, feed conversion efficiency and digestibility coefficients as affected by protein levels and amino acid supplementation. Proc. III Wrld. Rabbit Congres. pp. 294-304. Rome, Italy.

Hegarty, M.P., P.G. Schinckel and R.D. Court. 1964. Reaction of sheep to the consumption of Leucaena glauca and to its toxic principle mimosine. Aust. J. Agric. Res. 15:153-167.

Hegarty, M.P., C.P. Lee, G.S. Christie, R.D. Court and K.P. Haydock. 1979. The goitrogen 3-hydroxy 4(1H) pyridone, a ruminal metabolite from Leucaena leucocephala : Effect in mice and rats. Aust. J. Biol. Sci. 32:27-40.

Holmes, J.C. and R.W. Lange. 1963. Effects of fertilizer nitrogen and herbage dry matter content on herbage intake and digestibility in bullocks. Anim. Prod. 5:17-26.

Hoover, W.H. and R.N. Heittmann. 1972. Effects of dietary fiber levels on weight gain, cecal volume and volatile fatty acid production in rabbits. J. Nutr. 102: 375-385.

Hoover, W.H. and R.N. Heittmann. 1975. Cecal nitrogen metabolism and amino acid absorption in the rabbit. J. Nutr. 105:245-252.

Houpt, T.R. 1963. Urea utilization by rabbits fed a low protein ration. Am. J. Physiol. 205:1144-1150.

Houpt, T.R. 1967. Urea metabolism in the rabbit. Fed. Proc. 20:349.

Houston, D.F. and G.O. Kohler. 1970. Nutritional properties of rice. National Academy of Sciences. Washington, D.C.

Huck, D.W. and C.C. Brooks. 1972. Effect of methionine, pig weight, sex and diet on digestion. Proc. West. Sec. Am. Soc. Anim. Sci. 23: 118-121.

Hussein, A.S. and F.H. Kratzer. 1982. Effect of rancidity on the feeding value of rice bran for chickens. Poult. Sci. 61:2450-2455.

Ingals, L.R., J.W. Thomas, E.J. Benne and M. Tesar. 1965. Comparative response of wether lambs to several cuttings of alfalfa, birdsfoot trefoil, brome grass and reed canary grass. J. Anim. Sci. 24:1159-1164.

Janick, J. R.W. Schery, F.W. Woods and V.W. Ruttan. 1974. Plant Science. Second edition. W.H. Freeman and Co. San Francisco.

Jenkins, D.J.A., M.J. Hill and J.H. Cumming. 1976. Effect of wheat fiber on blood lipids, fecal steroid excretion and serum iron. Am. J. Clin. Nutr. 28:1408-1416.

Jenkins, D.J.A., A.R. Leeds, H. Houston, L. Hinks, K.G.M.M. Alberti and J.H. Cummings. 1977. Carbohydrate tolerance on man after six weeks of pectin administration. Proc. Nutr. Soc. 36:624-628.

Johnson, W.L., W.A. Hardison, A.L. Ordaveza and L.S. Castillo. 1968. Factors affecting voluntary intake by cattle and water buffalo. J. Agric. Sci. 71:67-71.

Jones, L.H.P. 1978. Mineral components of plant cell walls. Am. J. Clin. Nutr. 31:S94-S98.

Jones, R.J. 1984. Leucaena toxicity and ruminal degradation of mimosine. In 'Proceedings Australia-USA Poisonous Plant Symposium' (A.A. Seawright, M.P. Hegarty, L.F. James and R.F. Keeler, eds.). pp. 111-119. Brisbane, Australia.

Jones, W.T. and. J.L. Mangan. 1977. Complexes of condensed tannins of sainfoin (Onobrichis viciifolia Scop.) with fraction 1 leaf protein and with submaxillary mucoproteins and their reversal by polyethylene glycol and pH. J. Sci. Food Agric. 28:126-136.

Jones, R.J. and R.G. Megarrity. 1983. Comparative toxicity responses of goats fed leucaena in Australia and Hawaii. Aust. J. Agric. Res. 34:781-790.

Jones, W.T., R.B. Broadhurst and J.W. Lyttleton. 1976. The condensed tannins of pasture legume species. Phytochem. 15:1407-1409.

Kalinowski, T. and W. Rudolph. 1975. Studies on the lactation performance of New Zealand White rabbit does during four consecutive lactations. Wissenschaftliche Zeitschrift der Universitat Rostock. 24:291-294.

Karyadi, D. 1983. Role of Nutrition in National Development. Speech delivered during Professorial Promotion. Bogor Agric. Univ. July 23rd.

Kay, R.M. and A.S. Truswell. 1977. The effect of wheat fiber on plasma lipids and fecal steroid excretion in man. Bri. J. Nutr. 37:227-235.

Kennedy, P.M. 1985. Influences of cold exposure on digestion of organic matter, rate of passage of digesta in the gastrointestinal tract, and feeding and rumination behaviour in sheep given four forage diets in the chopped or ground and pelleted form. Bri. J. Nutr. 53:159-173.

King, J.O.L. 1971. Urea as a protein supplement for growing rabbits. Brit. Vet. J. 127:523-528.

King, J.O.L. 1984. Crude fiber in rabbit diets. Comm. Rabbits 12 (4): 10-19.

Knutson, R.S., R.S. Francis, J.L. Hall, B.H. Moore and J.F. Heisinger. 1977. Ammonia and urea distribution and urease activity in the gastrointestinal tract of rabbits (Oryctolagus and Sylvilagus). Comp. Biochem. Physiol. 58A:151-154.

Kratzer, F.H. and C.G. Payne. 1977. Effect of autoclaving, hot water treating, parboiling and addition of ethoxyquin on the value of rice bran as a dietary ingredients for chickens. Bri. Poult. Sci. 18:475-482.

Kratzer, F.H., L. Earl and C. Chiaravanont. 1974. Factors influencing feeding value of rice bran for chickens. Poult. Sci. 53:1795-1800.

Laksesvella, B. and A.N. Said. 1978. Tropical vs temperate grasses. Wrld. Rev. Anim. Prod. 14:49-57.

Lang, J. 1981a. The nutrition of the commercial rabbit. 1. Physiology, digestibility and nutrient requirements. Nutr. Abstr. Rev. 51:197-224.

Lang, J. 1981b. The nutrition of the commercial rabbit. 2. Feeding and general aspects of nutrition. Nutr. Abstr. Rev. 51(5): 287-299.

Laplace, J.P. 1978. Gastrointestinal transit in monogastric animals. III. Feeding behaviour (feed intake-cecotrophy), gastrointestinal motility and transit, and pathogeny of diarrhea in the rabbit. Ann. Zootech. 27:225-265.

Lebas, F. 1970. Nutrition and growth of suckling baby rabbits. Recueil de Medicine Veterinaire 146:1065-1070.

Lebas, F. 1972. Effect of concurrent lactation and pregnancy on the milking performance of the rabbit. Ann. Zootech. 21:129-131.

Lebas, F. 1973. Variations in apparent digestibility coefficients of dry matter, organic matter and nitrogen, according to age, breed and sex in the rabbit. Annal. Biol. Anim. Bioch. Biophys. 13:699-706.

Lebas, F. 1980. Researches on rabbit feeding and nutrition. Evaluation during the last 20 years and development in the future. Proc. II Wrld. Rabbit Congress. 2:1-16. Barcelona, Spain.

Lebas, F. 1983. Small scale rabbit production. Feeding and management system. Wrld. Anim. Rev. 46:11-17.

Lebas, F. and M. Colin. 1973. Effect of adding urea to a low protein diet for growing rabbits. Ann. Zootech. 23:557-581.

Lebas, F. and J.P. Laplace. 1977. Digestive transit in the rabbit: Influence of source of fiber. Ann. Zootech. 26:575-584.

Lebas, F. and G. Sardi. 1969. Milk feeding and weight increase of rabbits before weaning. Ann. Zootech. 18:197-208.

Lebas, F., J. Dolz and A. Espaignet. 1975. Effect of drying conditions of dehydrated lucerne on growth performances of rabbits receiving diets containing lucerne. Annal. Zootech. 24:144.

Ledward, D.A. 1979. Protein-polysaccharides interactions. In 'Polysaccharides in Food' (J.M.V. Blanshard and J.R. Mitchell, eds.), pp. 205-217. Butterworth and Co., Ltd., Sydney-Wellington-Durban-Toronto.

Lesniak, K. 1981. Biochemical purification of the galactomannan in the leucaena seeds. Leucaena Res. Rep. 2:75-76.

LIPI. 1968. Workshop on Food. Indonesian Institute of Sciences. Jakarta May 27th - June 1st.

Lukefahr, S.D. and M. Goldman. 1985. A technical assessment of production and economic aspects of small scale rabbit farming in Cameroon. J. Appl. Rabbit Res. 8:126-135.

Lukefahr, S.D., W.D. Hohenboken, P.R. Cheeke and N.M. Patton. 1981. Milk production and litter growth traits in straightbred and crossbred rabbits. J. Appl. Rabbit Res. 4:35-40.

Lukefahr, S.D., W.D. Hohenboken, P.R. Cheeke and N.M. Patton. 1983. Doe reproduction and preweaning litter performance of straightbred and crossbred rabbits. J. Anim. Sci. 57:1090-1099.

Maertens, L. and G. deGroote. 1984. Digestibility and digestible energy content of a number of feedstuffs for rabbits. III Wrld. Rabbit Congress. 1:415-421. Rome, Italy.

Martin, F.N., L. Telek and R. Ruberthe. 1977. Some tropical leaves as feasible sources of dietary protein. J. Agric. (Uni. Puerto Rico) 51:32-40.

Maust, L.E., W.G. Pond and M.L. Scott. 1972. Energy value of cassava-rice bran diet with or without zinc for growing swine. J. Anim. Sci. 35:953-957.

Mayun, G.K. and C.G. Payne. 1977. Autoclaved rice bran in layer diets. Bri. Poult Sci. 18:201-203.

McBee, R.H. 1971. Significance of intestinal microflora in herbivora. Ann. Rev. Ecol. and Syst. 2:165-176.

McLeod, M.N. 1975. Plant tannins - their role in forage quality. Nutr. Abstr. Rev. 44:803-815.

McQueen, R.E. and J.W.G. Nicholson. 1979. Modification of the neutral detergent fiber procedure for cereals and vegetable by using amylase. J.A.O.A.C. 62:676-680.

Meyer, L.H. 1978. Food Chemistry. AVI Publ. Co. Inc., Westport, Connecticut

Minson, D.J. 1971. The digestibility of voluntary intake of six varieties of Panicum. Aust. J. Exptl. Agric. Anim. Husb. 11:18-25.

Minson, D.J. 1972. The digestibility and voluntary intake by sheep of six tropical grasses. Aust. J. Exptl. Agric. Anim. Husb. 12:21-27.

Minson, D.J. 1973. Effect of fertilizer nitrogen on digestibility and voluntary intake of Chloris gayana, Digitaria decumbens and Pennisetum clandistenum. Aust. J. Exptl. Agric. Anim. Husb. 13: 153-157.

Minson, D.J. 1982a. Effect of chemical composition on feed digestibility and metabolisable energy. Nutr. Abstr. Rev. 52:591-615.

Minson, D.J. 1982b. Effects of chemical and physical composition of herbage eaten upon intake. In 'Nutritional limits to animal production from pasture'. pp. 167-182. (J.B. Hacker, editor). Proc. Int. Symp., St. Lucia. Queensland. Australia. Aug. 24-28th. 1981.

Minson, D.J. and M.N. McLeod. 1962. The in vitro technique : Its modification for estimating digestibility of large numbers of tropical pasture samples. Aust. CSIRO Div. Trop. Pastures. Tech. Paper. 8.

Minson, D.J. and M.A. Loredo. 1972. Influence of leafiness on voluntary intake of tropical grasses by sheep. Aust. Inst. Agric. Sci. J. 38:303-305.

Minson, D.J. and J.R. Wilson. 1980. Comparative digestibility of tropical and temperate forage - a contrast between grasses and legumes. J. Austr. Inst. Agric. Sci. 46:247-249.

Mitjavilla, S., C. Lacombe, G. Carrera and R. Derache. 1977. Tannic acid and oxidized tannic acid on the functional state of rat intestinal epithelium. J. Nutr. 107:2113-2121.

Molloy, L.F. and E.L. Richards. 1971. Complexing of calcium and magnesium by the organic constituents of Yorkshire fog (Holcus lanatus). II. Complexing of Ca^{++} and Mg^{++} by cell wall fractions and organic acids. J. Sci. Food Agric. 22:397-403.

Moore, J. A. 1985. Basic ventilation consideration for rabbit buildings. J. Appl. Rabbit Res. 8:54-56.

Moran Jr., E.T. 1983. Comparative nutrition of fowl and swine : The Gastrointestinal systems. Ontario Agric. Coll. Univ. Guelph. Canada.

Morrisse, J.P., E. Boilletot and R. Maurice. 1985. Changes induced by feeding in intestinal environment of rabbits (VFA, NH_3, pH, flora). Rec. Med. Vet. 161:443-449.

NAS. 1979. Tropical Legumes. Resources for the future. National Academy of Sciences. Washington, D.C.

Ngoupayou, J.D.N., P.M. Maiorino, W.A. Schurg and B.L. Reid. 1985. Jojoba meal in rabbit diets. Nutr. Rep. Int. 31:11-19.

Niedzwiadek, S., J. Kawinska and J. Tuczynska. 1978. Urea in feeds for rabbits. Nutr. Abstr. Rev. (B) 48:297 (2455).

Norton, B.W. 1982. Differences between species in forage quality. In 'Nutritional limits to animal production from pastures' (J.B. Hacker, editor). Proc. Int. Symp. pp.89-110. St. Lucia, Brisbane, Queensland, Australia. Aug. 24-28th, 1981.

NRC. 1977. Nutrient Requirement of Domestic Animals. No. 9. Nutrient Requirement of Rabbits. Second revised edition. NAS, NRC, Washington, D.C.

NRC. 1982. United States-Canadian tables of feed composition. National Academy Press. Washington, D.C.

Oanh, D.K. 1984. Utilization of by-products from rice processing in rabbit feed. Nutr. Abstr. Rev. 54:554(4308).

O'Dell, B.L., A.R. deBoland and S. Koirtyohan. 1972. Distribution of phytate and nutritionally important elements among the morphological components of cereal grain. J. Agric. Sci. Food Chem. 20:718-720.

Oh, H.I., J.E. Hoff, G.S. Amstromg and L.A. Haff. 1980. Hydrophobic interaction in tannin-protein complexes. J. Agric. Food Chem. 28: 394-398.

Omole, T.A. 1982. The effect of level of dietary protein on growth and reproductive performance in rabbits. J. Appl. Rabbit Res. 5:83-88.

Ouhayoun, J. and S. Cheriet. 1983. Comparative utilization of diets with different crude protein levels in rabbits selected on growth rate and in farm rabbits. 1. Growth performance and weight gain composition. Ann. Zootech. 32:257-276.

Owen, J.E. 1976. Rabbit production in tropical developing countries. Trop. Sci. 18:203-210.

Owen, J.E. 1981. Rabbit meat for the developing countries. Wrld. Anim. Rev. 39:2-11.

Ozanne, P.G., M.D. Purser, E.M.W. Howes and I. Southay. 1976. Influence of phosphorus content on feed intake and weight gain in sheep. Aust. J. Exptl. Agric. Anim. Husb. 16:353-360.

Palipane, K.B. and C.D.P. Swarnasiri. 1985. Composition of raw and parboiled rice bran from common Sri Lankan varieties and from different type of rice mills. J. Agric. Food Chem. 33:732-734.

Parigi-Bini, R., M. Cinetto and N. Carotta. 1984. Digestibility and nutritive value of Leucaena leucocephala in rabbit diets. III Wrld. Rabbit Congress. 1:399-407. Rome, Italy.

Partridge, G.G. and S.J. Allan. 1982. The effects of different intakes of crude protein on nitrogen utilization in the pregnant and lactating rabbits. Anim. Prod. 35:145-155.

Partridge, G.G. and S.J. Allan. 1983. The effects of dietary protein concentration on the lactational performance of the rabbit. Anim. Prod. 37:119-123.

Partridge, G.G., S. Foley and W. Corrigall. 1981. Reproductive performance in purebred and crossbred commercial rabbits. Anim. Prod. 32:325-331.

Partridge, G.G., M.F. Fuller and J.D. Pullar. 1983. Energy and nitrogen metabolism of lactating rabbits. Bri. J. Nutr. 49:507-515.

Patton, N.M., H.T. Holmes and P.R. Cheeke. 1983. Hairballs and pregnancy toxemia. J. Appl. Rabbit Res. 6:99.

Pierpoint, W.S. 1983. Reaction of phenolic compounds with protein and their relevance to the production of leaf protein. In 'Leaf Protein Concentrates' (L. Telek and H.D. Graham, editors). pp.235-237. AVI Publ. Co. Inc., Westport, Connecticut.

Piliang, W.G., H.R. Bird and M.L. Sunde. 1982. Rice bran as a major energy source for laying hens. Poult. Sci. 61:357-363.

Pirie, N.W. 1966. Leaf protein as a human food. Science 152:1701-1705.

Pond, K.R., W.C. Ellis and D.E. Akin. 1984. Ingestive mastication and fragmentation of forages. J. Anim. Sci. 58:1567-1574.

Portsmouth, J. 1977. The Nutrition of Rabbits. In 'Nutrition and the Climatic Environment' (W. Haresign, H. Swan and D. Lewis, eds.). pp. 93-111. Butterworths, London.

Prawirodigdo, S. 1985. Green feeds for rabbit in West and Central Java. J. Appl. Rabbit Res. 8:181-182.

Price, M.L. and L.G. Butler. 1977. Rapid visual estimation and spectrophotometric determination of tannin content of sorghum grain. J. Agric. Food Chem. 25:1268-1274.

Price, M.L., S. VanScoyoc and L.G. Butler. 1978. A critical evaluation of the vanillin reaction as an assay for tannin in sorghum grain. J. Agric. Food Chem. 26:1214-1218.

Pusztai, A. 1985. Constraint on the nutritional utilization of plant proteins. Nutr. Abstr. Rev. 55(7):363-369.

Raharjo, Y.C. and P.R. Cheeke. 1985. Palatability of tropical tree legume forage to rabbits. Nitr. Fixing Tree Res. Rep. 3:31-32.

Raharjo, Y.C. and D.J. Farrell. 1984. A new biological method for determining amino acid digestibility in poultry feedstuffs using a simple cannula, and the influence of dietary fiber on endogenous amino acid output. Anim. Feed Sci. Technol. 12:29-45.

Raharjo, Y.C., P.R. Cheeke and N.M. Patton. 1986. Growth and reproductive performance of rabbits on a moderately low crude protein diet with or without methionine or urea supplementation. J. Anim. Sci. 63:795-803.

Raharjo, Y.C., P.R. Cheeke and K. Supriyati. 1985. The nutritive value of leucaena leaf for rabbits. Leucaena Res. Rep. 6:92-94.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1986. Evaluation of tropical forages and by-products feed for rabbit production. 1. Nutrient digestibility and effect of heat treatment. J. Appl. Rabbit Res. 9:56-66.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton and K. Supriyati. 1987a. Evaluation of tropical forages and by-product feeds for rabbit production. 2. Composition, consumption and digestibility in growing rabbits.

Raharjo, Y.C., P.R. Cheeke and N.M Patton. 1987b. Evaluation of tropical forages and by-product feeds for rabbit production. 3. Growth performance of rabbits fed different forages and agricultural by-products.

Raharjo, Y.C., P.R. Cheeke, N.M. Patton, S. Yuhaeni and M.E. Siregar. 1987c. Evaluation of tropical forages and by-product feeds for rabbit production. 6. Feed preference study.

Raharjo, Y.C., J. Diment, A.J. Evans and D. Muslih. 1984. Effect of cultivars of paddy (rice) and rice hull dilutions on the nutrient composition and metabolisability of rice bran in Alabio and Tegal ducks. Res. Report. 10 pp. Balai Penelitian Ternak. Box 123, Bogor, Indonesia.

Reid, R.L., G.A. Jung and S.J. Murray. 1966. Nitrogen fertilization in relation to the palatability and nutritive value of orchard grass. J. Anim. Sci. 25:636-645.

Robinson, K.L., P.R. Cheeke and N.M. Patton. 1985. Effect of prevention of coprophagy on the digestibility of high forage and high concentrate diets by rabbits. J. Appl. Rabbit Res. 8:57-59.

Robinson, K.L., P.R. Cheeke, N.M. Patton and I.W. Mathius. 1986. Effect of age and cecotrophy and urea utilization by rabbits. J. Appl. Rabbit Res. 9:76-79.

Robles, A. and R.C. Ewans. 1980. Utilization of energy of rice and rice bran by young pigs. J. Anim. Sci. 55:572-577.

Rollos, H. and D. Tuwo. 1982. Feed yourself by rabbit raising. Tool Foundation. Amsterdam.

Romney, C.P. and N.P. Johnston. 1978. Dietary protein levels and early weaning on rabbit performance. Proc. West. Sec. Am. Soc. Anim. Sci. 29:201-202.

Salse, A., F. Crampes and P. Raynauds. 1977. Feeding value of urea perfused into the cecum of rabbits. Ann. Biol. Anim. Biochim. Biophys. 17:559-565.

Sanchez, W.K., P.R. Cheeke and N.M. Patton. 1983. Evaluation of raw and extruded soybeans and extruded soy flour as protein sources for weanling New Zealand White rabbits. J. Appl. Rabbit Res. 7:101-105.

Sanchez, W.K., P.R. Cheeke and N.M. Patton. 1984. Influence of dietary level of soybean meal, methionine and lysine on the performance of weanling rabbits fed high alfalfa diets. J. Appl. Rabbit Res. 7: 109-116.

Sanchez, W.K., P.R. Cheeke and N.M. Patton. 1985. Effect of dietary crude protein level on the reproductive performance and growth of New Zealand White rabbits. J. Anim. Sci. 60:1029-1039.

Semertzakis, N. 1978. Utilization of non-protein nitrogen by adult female rabbits for maintenance during pregnancy. Nutr. Abstr. Rev. (B) 48:198(1548).

Singh, B. and S.S. Negi. 1986. Effect on wool production of supplementing Black Locust (Robinia pseudoacacia) and biul (Grewia optiva) leaves ad libitum to a concentrate diet of Angora rabbits. J. Appl. Rabbit Res. 9:159-163.

Sitorus, P., S. Sastrodiharjo, Y.C. Raharjo, I.G. Putu, Santoso, B. Sudaryanto and A. Nurhadi. 1982. Report of the survey on the rabbit raising in Java. Central Research Institute for Animal Science, Box 123, Bogor, Indonesia.

Skerman, P.J. 1977. Tropical Forage Legume. FAO Plant Production and Protection Series. No. 2. FAO of the U.N. Rome, Italy.

Slade, L.M. and H.F. Hintz. 1969. Comparisons of digestion in horses, ponies, rabbits and guinea pigs. J. Anim. Sci. 28:842-843.

Smith, C.A. 1962. The utilization of hyperrhenia for the nutrition of cattle in the dry season. III. Studies on the digestibility of the produce of mature veld and veld hay and the effect of feeding supplementary protein and urea. J. Agric. Sci. 53:173-178.

Spreadbury, D. 1978. A study of the protein and amino acid requirements of the growing New Zealand White rabbits with emphasis on lysine and the sulphur-containing amino acids. Bri. J. Nutr. 39:601-613.

Spreadbury, D. and J. Davidson. 1978. A study on the need for fiber by the growing New Zealand White rabbit. J. Sci. Food Agric. 29:640-648.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. A Biometrical Approach. Second edition. Mc.Graw Hill Book Co., New York.

Stephan, E. 1980. The influence of environmental temperatures on meat rabbits of different breeds. Proc. II Wrld. Rabbit Congress. pp. 399-409. Barcelona, Spain.

Sudaryanto, B., Y.C. Raharjo and M. Rangkuti. 1984. Effects of greens on the performance of weanling rabbits raised in the village. Ilmu dan Peternakan. 1:259-263. CRIAS, BOX 123, Bogor, Indonesia.

Sugandi, D., H.R. Bird, Y. Wahyu and R. Anggorodi. 1978. Poultry feed formulas based on ingredients indigenous to the tropics. Poult. Sci. 57:740-746.

Szendro, T., T.H. Tag-El-Den and B. Nemeth. 1984. Effect of double mating on conception rate and litter size in rabbits. Proc. III Wrld. Rabbit Congress. 2:124-130. Rome, Italy.

Szyszka, M., U. ter-Meulen, B. Cheva-Isarakul, S. Posri and N. Potikanond. 1984. Results of research on leucaena as an animal feed in West Germany. Leucaena Res. Rep. 5:5-11.

Tangendjaja, B., Y.C. Raharjo and J.B. Lowry. 1985. Evaluation of Leucaena leaf meal and its toxicity to rabbits. Res. report. Research Institute for Animal Production. Box 123, Bogor, Indonesia.

Telek, L. 1982. Preparation of leaf protein concentrate from Leucaena leucocephala. Leucaena Res. Rep. 3:93-94.

Telek, L. and F.W. Martin. 1983. Tropical plant for leaf protein concentrates. In 'Leaf Protein Concentrates' (L. Telek and H.D. Graham, editors). pp. 81-116. AVI Publ. Co. Inc., Westport, Connecticut.

Tempo. 1985. We and Rice. Tempo magazine (Indonesia) 38:12-18.

Thornton, R.F. and D.J. Minson. 1973. The relationship between apparent retention time in the rumen, voluntary intake and apparent digestibility of legume and grass diets in sheep. Aust. J. Agric. Res. 24:889-898.

Tuah, A.K. and S.H. Boateng. 1983. The effect of rice mill feed ('rice bran') in the finishing diet on the growth performance and carcass quality of pigs fed basal maize diet. Nutr. Abstr. Rev. 53:72 (415).

VanEys, J.E., I.W. Mathius, H. Pulungan and W.L. Johnson. 1984. Utilization of fresh and ensiled Pennisetum purpureum, Panicum maximum and Brachiaria brizantha by growing sheep. Proc. Sci. Meeting on Small Ruminant Research, pp. 50-54. Bogor, Indonesia.

VanSoest, P.J. 1964. Symposium on nutrition and forage and pasture : new chemical procedure for evaluating forages. J. Anim. Sci. 23:838- 845.

VanSoest, P. J. and L.H.P. Jones. 1968. Effect of silica in forages upon digestibility. J. Dairy Sci. 51:1644-1648.

Voris, L.R., L.F. Marcy, E.J. Tracker and W.W. Wainio. 1940. Digestible nutrients of feedingstuffs for the domestic rabbits. J. Agric. Res. 61:673-683.

Waldern, D.C. 1971. A rapid microdigestion procedure for neutral and acid detergent fiber. Can. J. Anim. Sci. 51:67-69.

Wilson, J.R. 1982. Environmental and nutritional factors affecting herbage quality. In 'Nutritional limits to animal production from pasture' (J.B. Hacker, editor). Proc. Int. Symp. pp. 111-131. St. Lucia, Brisbane, Queensland, Australia. Aug. 24-28th. 1981.

Wilson, J.R. and C.W. Ford. 1973. Temperature influences on the in vitro digestibility and soluble carbohydrate accumulation of tropical and temperate grasses. Aust. J. Agric. Res. 24:187-198.

Wise, A. 1983. Dietary factors determining the biological activities of phytates. Nutr. Abstr. Rev. 53:791-806.

Woodham, A.A. 1983. The nutritional evaluation of leaf protein concentrates. In 'Leaf Protein Concentrates' (L. Telek and H.D. Graham, editors). pp. 415-484. AVI Publ. Co. , Inc. Westport, Connecticut.

Zombade, S.S. and J.S. Ichhponani. 1983. Nutritive value of raw, parboiled, stabilized and deoiled rice bran for growing chicks. J. Sci. Food Agric. Chem. 34:783-788.

APPENDICES

Some of the forages used in
the experiment

Calliandra calothyrsus

Leucaena leucocephala

Sesbania grandiflora plantation
(note the cassava plants at the
bottom of the picture)

Sesbania formosa

Centrosema pubescens

Desmodium intortum
(note banana plants at the
left hand side background).

Lablab purpureus

<u>Neonotonia</u> <u>wightii</u>

<u>Stylosanthes</u> <u>guianensis</u>