SELECTION AND EVALUATION OF FEEDSTUFFS FOR URBAN AND PERI-URBAN SMALL RUMINANT PRODUCTION IN GHANA - A SYSTEMS APPROACH

by

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ABSTRACT

The objective of this research was to develop a feed package for small ruminants in the urban centres of Ghana. A survey of 120 households indicated that cassava peels were the most abundant feedstuff. However, the level of nitrogen (1.02%) was inadequate to support optimum rumen function.

The degradation of cassava peels and leaves of ficus, terminalia and chaya in the rumen was determined using the *in sacco* technique (Experiment 1). The respective rates of degradation of nitrogen fractions were 0.087, 0.052 and 0.133% h^{-1} ($P<0.05$). The ratios of nitrogen released from terminalia, ficus and chaya leaves to organic matter fermented from cassava peels during the first 12 h of incubation were; 1:60, 1:30 and 1:15.5, respectively.

In Experiment 2, six wethers fitted with permanent rumen cannulae were fed cassava peels supplemented with either 0, 50, 100, 150, 200, or 250 g d^{-1} of ficus leaves. Supplementation increased ($P<0.05$) the potentially degradable fraction (55.9 to 68.2%) of dry matter (DM) in cassava peels. The corresponding value for ficus was 72.5 to 78.7%.

In Experiment three, 48 individually housed wethers and ewe lambs, were fed cassava peels *ad libitum* and randomly allocated to one of six dietary supplements used in Experiment 2. Daily DM intake increased ($P<0.05$) from 44.0 g kg^{-1} $LW^{0.75}$ (no supplement) to 81.2 g kg^{-1} $LW^{0.75}$ (250 g d^{-1} of ficus leaves). Supplementation depressed apparent DM digestibility coefficients (78.1 to 73.9%, $P<0.05$). Animals which received 250 g d^{-1} of ficus leaves had the fastest growth rate (53.6 g d^{-1}, $P<0.05$).

Scanning electron microscopy was combined with electron dispersive x-ray analysis (EDXA) in Experiment 4 to study rumen microbial digestion of cassava peels and ficus leaves. The outer layer of cassava peels and epidermis of ficus leaves, except damaged regions were, resistant to microbial colonization and digestion. In digestible tissues, 4 h was close to initiation of digestion. EDXA of ficus leaf surfaces indicated that the entire epidermis was covered with silica.

It was concluded from the series of studies that a successful small ruminant feeding system could be based on feeding cassava peels *ad libitum* and 200-250 g d^{-1} of ficus leaves.

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CHAPTER 1 CONCEPTUAL FRAMEWORK

A. Introduction

This research is a component of a joint project between the International Development and Research Centre (IDRC), Ottawa, and the University of Science and Technology (UST), Kumasi, Ghana. The University of British Columbia (UBC), Vancouver, Canada. The Laboratory of Dr. K-J. Cheng (Agriculture Canada Research Station, Lethbridge, Alberta), also provided technical and material support. The general objective of the IDRC/UST project is to improve small ruminant production in Ghana through the development of feed packages based on crop residues and agricultural by-products for animals in the villages and the urban centres of Ghana. The main objective of this component of the project was to develop a nutritionally balanced and economically viable feed package, based on available feed resources, which could be recommended for small ruminant feeding systems in the urban centres of Ghana.

Livestock have traditionally been an important component in the economy of Ghana but little progress has been made towards either using available resources more efficiently or improving productivity. The livestock sector in Ghana contributed about 9 percent of agricultural GDP between 1990 and 1993. Meat was the predominant livestock product, amounting to about 67,000 mt in 1990 of which 22,000 mt was beef, 14,000 mt was pork, 16,000 mt was from poultry, and 14,000 mt was from mutton and goat meat (FAO, 1992). The West African Shorthorn is the predominant cattle breed in Ghana, and together with its crosses, and the Sanys, accounts for about 80% percent of the national cattle herd. Three quarters of all cattle are in the Upper East, Upper West and Northern regions. Sheep and goats are more evenly distributed throughout the country, being the main source of domestic meat supply for the rural farming community and increasingly assuming prominence in the urban-meat supply. They are kept mostly in small units of fewer than ten animals. Most sheep and goats are of the West African dwarf breeds with no more than ten percent being crosses with the Sahelian types (Sarris and Shams, 1991). Sheep and goats generally serve as a minor, but critical component of balanced

agricultural production systems. Their main roles in most parts of the country are to produce meat and generate income, usually to the direct benefit of some of the poorest people. Despite their importance, small ruminants and their producers have received relatively little attention from government and development agencies in terms of research, financial assistance and infrastructural support.

The human population of Ghana presently stands at 15 million and is increasing at the rate of about 3 percent per annum. At this rate the population has been projected to double between 1990 and the year 2020 (WHO, 1986). It has been estimated that livestock inventories would also have to double by the end of the century to meet total consumption requirements if there is no change in per capita consumption level. The current intake of animal protein is abysmally low, below 10 g per person per day, compared to 25 g recommended by WHO (1986). Increased levels of consumption can be met primarily by productivity increases since lack of foreign exchange limits extensive importations. A major potential for the livestock industry therefore lies in the rapid increase in population which assures a sustained demand for years to come.

In 1988 the Government of Ghana launched its Medium Term Agricultural Development Program (Medium-Term Agricultural Development Program, Working Paper No. 4, 1988). In this program it was envisaged that the sheep population would be increased from 2 million to 6 million by the year 2000. The goat population was expected to increase from about 2.5 million to 9 million during the same period. Although modest progress has been made, much more needs to be done if these targets are to be achieved.

It cannot be emphasised enough that the success of the program depends on proper identification of the constraints and opportunities of existing production systems, and, in the light of these, formulate appropriate policies which would be most effective in developing the animal industries.

B. Small Ruminant Production in the Urban Communities in Ghana

Of the 4.5 million small ruminants in Ghana (FAO, 1992), it has been estimated that about 25 percent are raised by people living in and around cities and towns. In recent times, these urban and peri-urban livestock producers have emerged as an important distinct sector of the livestock industry. The contribution of these farmers towards the provision of animal protein to the urban community is substantial; not to mention the tremendous economic return and improvement in the standard of living of these farmers as a result of livestock activities.

The production of small ruminants in these communities, though a minor agricultural enterprise, is also complementary to the other agricultural activities e.g. food processing industries. This often adds value to agricultural by-products by conversion to preferred animal products. The animals also play important social and cultural roles in the lives of some of these urban and peri-urban households. In spite of all these contributions, only rarely are these producers mentioned in descriptions of farming systems in the country. It is therefore not surprising that there has been no systematic attempt by the government or development agencies to understand the small ruminant production system in the urban and peri-urban areas with the ultimate aim of helping these farmers to increase their productivity. It is envisaged that by identifying and analysing some of the production constraints, appropriate recommendations could be made which would lead to optimum exploitation of this under-utilised agricultural resource.

Most of the animals in the urban centres are confined within households or in pens erected behind houses because of restrictions imposed on their movement by local authorities. Even in the peri-urban areas, traditional husbandry systems are being modified by high human population density and increasing pressure on agricultural land. In these areas, free-roaming animals also pose an increasingly important threat to growing crops and ornamental plants on private properties. Therefore, sheep and goats have to be either tethered or kept in pens. As a result, the backyard production of small ruminants has assumed a greater degree of "sophistication". It has evolved from a minor low-input household enterprise into a more

intensive, specialised enterprise demanding greater management input and demand for high quality feed.

C. Feed Resources for Small Ruminants

A major constraint within the production system is the provision of adequate feed throughout the year for the animals. Presently, the main sources of feed are from household agricultural wastes such as cassava peels, plantain/banana peels, yam/cocoyam peels, and by-products from the brewery and milling industries. Many producers purchase some of these agricultural wastes from other households not engaged in livestock rearing activities or from the agro-processing industries. In some situations these agricultural wastes are used as supplements while in others they are the only source of feed. Animals raised in the peri-urban areas also subsist on agricultural by-products such as cassava peels and plantain peels in addition to the few forage plants along roadsides and on abandoned farms or undeveloped plots of land. These sources of feed, though often abundant, are not being utilised efficiently because of certain problems associated with their use. Some of the problems associated with the utilisation of these agricultural by-products include collection, transportation, processing and storage and perhaps most importantly, their poor nutritive value.

The nutritive value of these feedstuffs depend upon the crop species, seasonal growing conditions and post harvest treatment or processing conditions. In addition a common characteristic of most of them is that they are deficient in nitrogen and essential minerals; notably, sodium, calcium, phosphorus and sulphur. The feedstuffs are also very fibrous. The consequences of such a profile for ruminants are a low intake and, a low digestibility both of which are reflected in poor levels of animal performance (Smith, 1993).

Low intakes and digestibilities are often the result of high lignin content in the feedstuff and the chemical bonding between the lignin and potentially nutritious cell wall fractions such as cellulose and hemicellulose (Welch, 1982; Van Soest, *et al.*, 1991). Therefore, most strategies developed to promote the efficient utilisation of such feed resources first aim at maximising

rumen function through the maximisation of the rate of degradation of the cell wall carbohydrates. However, a second approach, the supply of a suitable supplement which would provide the animal with otherwise deficient nutrients, is also called for in most cases.

Appropriate strategies for supplementation of feedstuffs require an understanding of the digestion and associated constraints with the use of those feedstuffs by the animals involved.

D. Structure and Degradation of Feed Particles in the Rumen

The plant materials that comprise the bulk of ruminant feed are composed of a vast array of nitrogenous compounds and polysaccharides. Among the nitrogenous compounds, protein is the most abundant, but nucleic acids always occur in association with the proteins, and substantial amounts of nitrate and ammonia may be present depending on the diet. On the other hand, most polysaccharides entering the rumen can be divided into two general groups; plant storage polysaccharides such as starch and the fructosans, or the structural polysaccharides which compose the greater part of the plant cell walls and which are loosely considered to form the fibrous component of animal feedstuffs. The polysaccharides that may be extracted from intact cell walls are considered conventionally to belong to one of three groups: cellulose, hemicellulose and the pectic substances.

Cellulose has unique properties conferred by its secondary, rather than its primary, structure. The linear chains of β 1-4 linked glucose units aggregate to form microscopically visible fibrils in which the individual glucan chains are extensively cross-linked by hydrogen bonding. The degree of order found within and between fibrils varies from regions in which the glucan chains are held firmly in parallel (and where x-ray diffraction studies have indicated a high degree of crystallinity), to regions in which this order is somewhat reduced (amorphous regions) (Chesson and Forsberg, 1988). Microfibrils are hydrophobic in nature, and show considerably more resistance to chemical or enzymatic hydrolysis than the glucan chains from which they are formed (Krassig, 1985). Resistance is directly related to the degree of order within the molecule,

with celluloses with a high crystallinity index showing the lowest rates of degradation when incubated in the rumen (Chesson, 1981).

Hemicellulose is the most complex of the plant polysaccharides. Its composition varies among plant parts and between species. Hemicellulose is a mixture of polysaccharides often with the common factor of β 1-4 linkage in the main xylan core polymer, although branching with a variety of other glucosidic linkages occurs. Hemicelluloses of leaf and stem and legumes seems to be largely arabinoxylan with associated linkages to glucuronic acid and probably lignin (Van Soest, 1982).

Pectic substances are a complex of polysaccharides which form the cementing substance in plant cell walls and are based on chains of α-1- linked galacturonic acid units in which the carboxylic acid groups are variably esterified with methanol and the uronic acid residues variably substituted at carbon-2 with acetyl groups. Rhamnose units are found throughout the chain, linked 1-2 to adjacent uronic acid residues (Stephen, 1983). Like starch, pectin is linked α 1-4 leading to non-linearity and coiling of the polygalacturonic acid chain. Pectin differs from starch, however, in the axial position of the linkage on carbon 4, and pectins are not attacked by amylases (Van Soest, 1982). Pectic substances are found in all plant feedstuffs but occur in far higher proportions in cell walls of dicotoledonous plants (Chesson and Forsberg, 1988).

Feed protein is usually hydrolysed rapidly in the rumen, although the precise rate and extent of breakdown depend on a number of factors, which ultimately determine its nutritive value. Apart from factors related to the nature of the protein itself (i.e. secondary and tertiary structure) and the number of disulphide bonds, the hydrolysis of non-protein polymers, such as polysaccharides may limit access of proteolytic organisms to their substrates (Siddon and Paradine, 1981; Wallace and Cotta, 1988).

The nature of the basal diet has a major influence on the proteolytic activity of the rumen contents. Fresh herbage promotes activity up to nine times higher than that found with dry rations (Nugent *et al.*, 1983). Cereal diets also yield higher activities than dry forage diets, probably because proteolytic rumen micro-organisms tend to be amylolytic rather than

cellulolytic (Siddon and Paradine, 1981). The nature of the protein substrate in a supplement also affects proteolytic activity. Hydrolysis of leaf Fraction I protein was stimulated, relative to casein, by fresh fodder (in which it would be abundant), more than in a diet consisting of hay and concentrates (Hazlewood *et al.*, 1983; Nugent *et al.*, 1983). In contrast, when albumin replaced casein as the protein supplement in a sheep diet, the rate of breakdown of albumin relative to casein was unchanged, despite a modified proteolytic flora (Wallace *et al.*, 1987). Furthermore, the proteolytic activity of rumen contents was hardly changed. The effect of different dietary proteins on ruminal proteolysis therefore appears to vary from protein to protein and with the other constituents of the diet.

Whatever the mechanism of digestion of feedstuffs at the molecular level, microbial attachment to the solid feed particles entering the rumen is an important prerequisite of digestion of the feedstuffs (Cheng *et al.*, 1984). Bacteria and protozoa are the predominant microbial forms in the rumen, but it has also been demonstrated that appreciable numbers of anaerobic fungi are associated with the feed particles and also contribute to the digestion of feedstuffs (Orpin, 1983).

E. Role of Rumen Microbes in the Digestion of Feedstuffs

Micro-organisms capable of degrading plant fibre (i.e., cell walls consisting of cellulose and hemicellulose) comprise an important part of the microbial population. Rumen bacteria are the most important degraders of the cellulosic materials that ruminants ingest as part of their diet (Bryant, 1973).

Some species of cellulolytic rumen bacteria are *Bacteroides succinogenes, Ruminococcus albus, R. flavefaciens, Clostridium longisporum, C. locheadii, Cillobacterium cellulosolvens, Cellulomonas fimi* and *Butyrivibrio fibrisolvens* (Hungate, 1966). The most important cellulolytic species, based on numbers and ability to degrade cellulose, are *B. succinogenes, R. albus*, and *R. flavefaciens* (Bryant, 1973). *Ruminococcus spp.* are hemicellulolytic as well as cellulolytic. Although *B. succinogenes* has been reported to degrade hemicellulose it cannot

utilize xylan, which comprises a large part of hemicellulose (Dehority and Scott, 1967). *B. fibrisolvens* and *Eubacterium* degrade hemicellulose.

A polymer not present in cell walls but important in many feeds, especially grains, roots and tubers is starch. The ability to utilize starch as a carbon source is widespread among strains of rumen bacteria, protozoa and fungi. Principal among the amylolytic rumen organisms are the bacteria *Bacteriodes amylophilus, Streptococcus bovis, Succinomonas amylolytica*, many strains of *Selemonas ruminantium, Butyrivibrio fibrisolvens* and *Eubacterium ruminantium*, and *Clostridium spp*. (Russell and Hespell, 1981; Marounek and Bartos, 1986), virtually all of the larger entodiniomorph protozoa, and the chytrid fungus *Neocallimastrix frontalis* (Orpin and Letcher, 1979; Pearce and Bauchop, 1985).

Even though amylolytic protozoa and fungi are not considered essential in starch digestion, it has been suggested that engulfing of starch granules by protozoa limits the amount of starch available for the rapid bacterial fermentation and so helps to prevent a detrimental lowering of rumen pH (Williams and Coleman, 1988; Dawson and Allison, 1988). The ability of the larger rumen ciliates to engulf and subsequently metabolize starch granules is well known. Among the holotrichs this ability is limited to *Isotricha*, but among the entodiniomorphs it is virtually universal.

F. Improvement of Low Quality Feedstuffs

Various methods have been developed based on knowledge of the structure of feedstuffs, the ecology of the rumen environment and the mode of action of the rumen micro-organisms to improve the utilization of feedstuffs. These include physical processing, and chemical and microbiological treatments of the feedstuffs. Physical processes such as grinding, chopping and compacting have been used to improve the intake of low quality feedstuffs by animals. The effect on intake is partly due to the reduction in the bulk of the feed and the chewing time required to reduce the particle size of the ingested feedstuffs to sizes that can pass through the reticulo-omasal orifice (Welch, 1982). It is, however, unlikely that many of the commonly used physical

processes like chopping and milling actually increase the digestibility of cellulose or hemicellulose by rumen micro-organisms. Only extreme milling treatments (such as ball milling) which disrupt fibre structures at the molecular level are capable of increasing the digestibility of cellulose and hemicellulose to any appreciable extent (Walker, 1984). Steam treatment of materials at high pressures have been shown to increase digestibility but this has lost its appeal due to its high energy demand. Compaction of roughages through cubing or pelleting has advantages such as increased density (reduction in dustiness), improvement in handling and, reduction in wastage. These treatments or processes subsequently lead to increased intake of the roughages by animals. However, the initial capital investments are high and is therefore of limited value to the Ghanaian situation.

Chemical treatment is considered to be the most effective method of improving the feeding value of low quality lignocellulosic agricultural by-products (Jackson, 1977). Sodium hydroxide is accepted as the most effective chemical for treatment of crop residues. The *in vivo* organic matter digestibilities of chemically treated materials are usually superior to those of untreated materials. The effect usually being more pronounced in highly lignified materials (Jayasuriya and Owen, 1975, Jackson, 1977). The increase in the extent of digestion is thought to be the result of breaking bonds between lignin and cellulose or hemicellulose (Van Soest, 1975).

The disruption of the bonds between lignin and cell wall carbohydrates makes the latter more accessible to hydrolysing enzymes (Theander and Aman, 1984; Lindberg *et al.*, 1984). Although sodium hydroxide treatment of crop residues can significantly improve intake and digestibility, it has several drawbacks which preclude its use in Ghana. Some of these drawbacks include; the high cost of the chemical, concerns about human safety due to its corrosive nature, contamination of the soils and water as well as concern regarding possible mineral imbalances in animals consuming sodium treated material.

Ensilage is the preferred microbiological method for preserving and utilizing wet agricultural by-products especially from the fruit and vegetable industry. However, when dry by-products are ensiled very little improvement in animal productivity is observed (Kiflewahid,

1982). Ensiling wet by-products could be of value to feedlot operators but not to the small scale farmer in view of expenses associated with processing the materials and maintenance of the silos.

Most of the above treatments often result in increased intake and/or digestibility of the treated materials. However, the materials treated are usually inherently deficient and/or unbalanced in most of the nutrients required for efficient rumen digestion and utilization of the fermentative products of digestion. Therefore, these increases are often not reflected in animal productivity.

Preston and Leng (1981) suggested that in order to optimize the utilization of fibrous agricultural by-products, animals must be provided with readily fermentable energy and protein; rumen by-pass protein and by-pass energy; and, micronutrients like sulphur, phosphorus and B vitamins. Urea, animal by-products, oilseed cakes and cereal milling by-products are the logical nitrogenous and energy supplements when available (Preston, 1986). The costs of protein and energy supplements, and the technical difficulties of using physical, chemical and microbiological treatment preclude their use in Ghana.

In Ghana the cheapest means by which requirements for essential nutrients could be provided would be through the strategic use of fodder trees and shrubs such as Acacia (*Acacia sp.*), ficus (*Ficus spp.*), gliricidia (*Gliricidia maculata*), terminalia (*Terminalia sp.*) and leucaena (*Leucaena leucocephala*) as supplements. These fodder trees are found in relative abundance in and around the urban areas. They constitute a valuable production resource which has not been exploited in any systematic manner as supplements (Smith,1992). The improvement in digestibility, intake and growth rate of ruminants through supplementation of diets based on agricultural by-products with fodder trees and shrubs have been demonstrated by Reed *et al.*, (1990), Kass, *et al.*, (1992), Smith and van Houtert (1987), Ndolvu and Buchanan-Smith, (1985).

G. General Research Methodology

The efficient utilization of production resources is an indication of the economic success of a production system. The magnitude of this success would largely be determined by the manner in which production resources are utilized. The scope for increasing the efficiency of feed utilization in innovative feeding systems in a situation like the one that exists in Ghana is enormous as demonstrated by Devendra (1979) with goats and by Soetanto (1986) with sheep in Asia. The components of such a strategy include the use of a wider selection of traditional and non-conventional feeds in dietary formulations and feeding systems that can sustain year-round feeding and intensive systems of production in proximity to the location of the feed sources. This strategy has long been recognized in Ghana and a considerable amount of research has been conducted in the country to ensure the efficient utilization of most of the agricultural by-products and fodder trees by livestock (Osei 1990; Tuah, 1989; Tuah *et al.* 1985; Okai and Opoku-Mensah, 1988; Okai *et al.*, 1985). Most of the research identified new non-conventional feedstuffs or developed methods to improve their utilization by livestock. However, very little, if any, of the findings have actually been adopted by livestock producers in the country.

The reason for this could be due to the fact that researchers have usually overlooked or ignored the systemic inter-linkages of biological and socio-economic conditions within farming households. As a consequence, significant relationships have been missed and envisioned improvements have not always materialized. To avoid a similar situation and to deal with these inter-linkages, a multi-disciplinary research approach and an overall systems perspective was adopted in this study.

H. Farming Systems Approach to Research

The approach to research, commonly called Farming Systems Research (FSR), is defined as applied, farmer-oriented, agro-biological research which is supported by the socio-economic sciences in a team effort to generate appropriate technology (Byerlee *et al.*, 1982). Farming

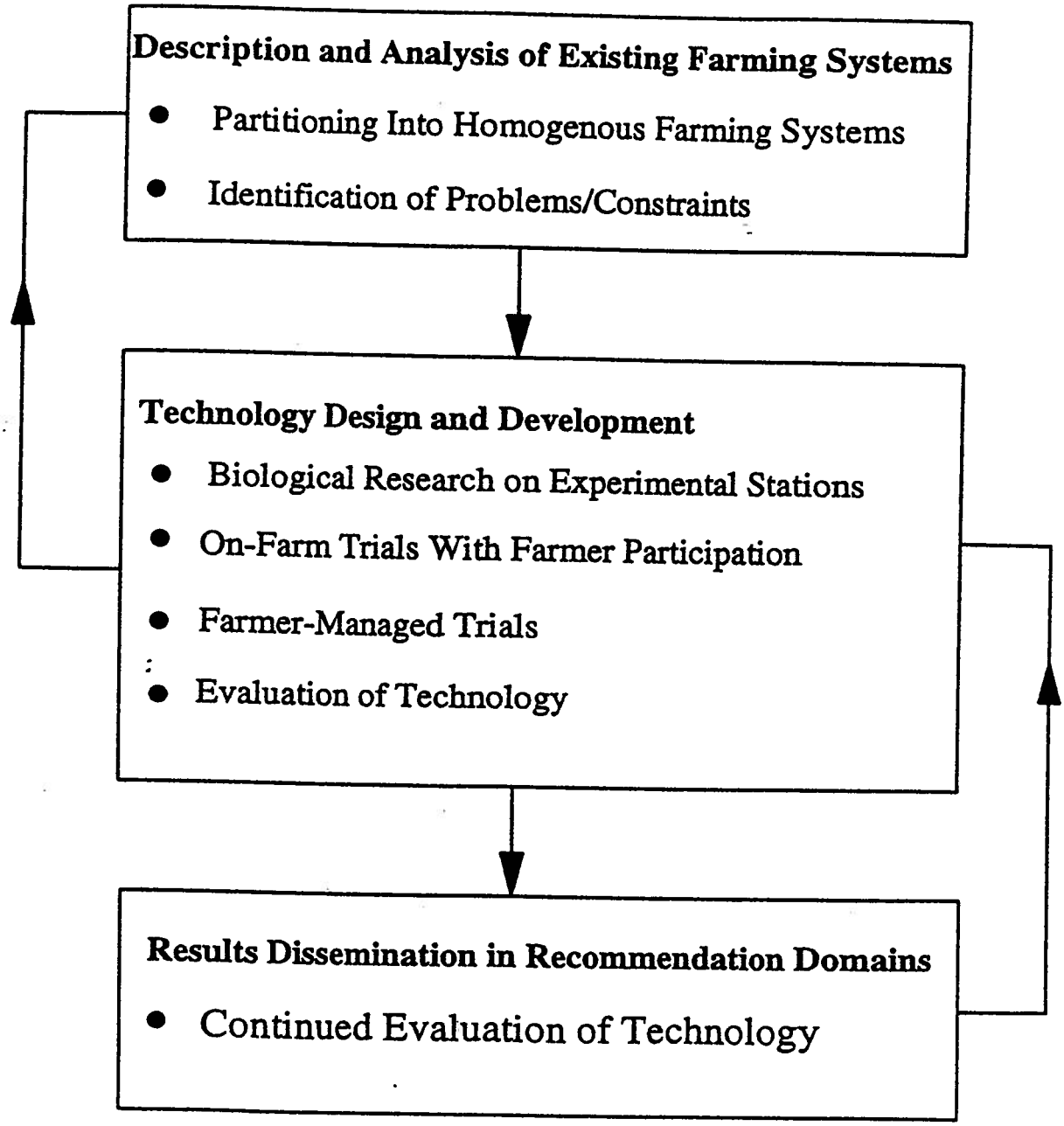


Figure 1.1. Schematic representation of Farming Systems Research (FSR).

Systems Research usually includes extension responsibilities. The principal product in FSR is technology and the primary clients are the farmers. Although FSR is flexible enough to fit the agricultural and institutional conditions found in different countries and under different cultural conditions, it usually involves three major steps (Norman and Baker, 1986). A typical schematic representation of FSR (adapted from Hildebrand and Waugh, 1986) is presented in Figure 1.1.

Hildebrand and Waugh (1986) have observed that in many ways this sequence parallels what farmers have always done. Farmers manage a complex set of biological processes which transform the resources at their disposal into useful products, either for home consumption or for sale. The choice of livestock enterprise and husbandry methods are determined not only by physical and biological constraints, but also by economic and socio-political factors, which make up the larger milieu within which the farmer operates.

I. Research Methods Adopted in this Study

Because of time constraints all the steps above were not completed in this study. The on-farm trials are to be conducted by Staff of the Animal Science Department of the University of Science and Technology and, the Ministry of Agriculture in Ghana. The sequence of steps taken to achieve the main objective of this component of the (IDRC/UST) project were:

1. Description and analysis of the existing farming systems through close consultation with farmers. The methods employed included diagnostic surveys (modified Rapid Rural Appraisal, RRA), and a formal survey with semi-structured interviewing. This facilitated the characterization and analyses of constraints and opportunities.
2. Identification and pre-screening of available feedstuffs which could form the basis of a feeding system. This involved chemical analyses; and dry matter and nitrogen degradability estimates. Selection of feedstuffs was based on socio-economic considerations and results of the pre-screening exercise.

3. Nutritional evaluation of selected feedstuffs under research station conditions. Among other things, this involved the measurement of intake, digestibility and growth rate of sheep and, microbial colonization and digestion of the feedstuffs.
4. Development of a set of recommendations for the development of the urban small ruminant industry.

As mentioned earlier small ruminant production in the urban communities is only one of a number of enterprises that contribute to the diversity of the larger household economy. Moreover, because of the intricate role of small ruminants in these households, the overall strategy adopted in the development of recommendations was based more on socio-economic considerations than technical achievement alone. This was to ensure that recommended technologies are compatible with the established production systems and other activities in the households. The advantages of matching feed resources with existing livestock systems in a manner that aims for economic and social optimization rather than biological maximization have been demonstrated in several instances by Preston (1982) and Preston and Leng (1987).

J. General Research Objectives

The overall objective of this thesis was therefore to identify and evaluate feedstuffs which could be recommended for use in the development of a nutritionally balanced and economically viable feed package for small ruminants in the urban centres of Ghana. The specific objectives were:

1. To describe the small ruminant production systems in the urban and peri-urban centres in Ghana, and to identify the major production constraints and recommend measures to overcome these constraints (Chapter 2).
2. To identify a basal and a supplementary feedstuff available in and around the urban areas of Ghana for small ruminant feeding (Chapter 3).

3. To assess the nutritional quality of the feedstuffs identified in (2) above (Chapters 4 and 5), and
4. To study the microbial digestion of the feedstuffs and the effect of the feedstuffs on the bacterial population in the rumen of sheep (Chapter 6).

CHAPTER 2 URBAN HOUSEHOLDS AND SMALL RUMINANT PRODUCTION

A. Introduction

Small ruminants have been an integral part of most urban and peri-urban households in Ghana for a long time. Moreover, it is unlikely that current production systems and the resources used to support them will change substantially in the foreseeable future. However, in most urban households their production is only one of a number of enterprises that contribute to the diversity of the larger household economy. It is therefore essential that any research or development strategy should take into account most of the socio-economic variables and other external factors that impinge on the household.

Any particular farming system is the result of a set of elements or components that are interrelated and interact among themselves toward the realization of the goals of individual farmers or the system as a whole. At the centre of this interaction is the farmer or household. Thus both farm production and household decisions of farmers are intimately linked and should be analyzed as such. A specific farming system arises from the decisions taken by the farmer or farming household with respect to allocating different quantities and qualities of land, labour, capital and management to crop, livestock and off-farm enterprises, in a manner which given the knowledge the household possesses, will maximize the attainment of the family goals (Jahnke, 1982). It is therefore essential to understand the existing production system in light of the socio-economic environment of the household within which farmers operate before any attempts are made to introduce any changes.

Therefore, the objectives of this component of the study were to describe the small ruminant production system within urban households; identify the opportunities and constraints of urban livestock development; and in the light of these, make recommendations to improve the system.

B. Methodology

As mentioned earlier, very little is known about the small ruminant production system in the urban and peri-urban areas; therefore, a diagnostic survey was conducted in Kumasi and Effiduasi. These two cities, in the Ashanti Region of Ghana, are in the humid forest zone of the central part of the country. The main objective of the diagnostic component of the study was to explore details of some key topics such as feed resources, management practices, constraints and opportunities (Appendix 2.1).This information was required to formulate a detailed questionnaire for a formal survey and also provide a better understanding of the small ruminant production systems in the urban communities.

The method used in the diagnostic survey was semi-structured interviews of producers and direct observation of their households. This technique was chosen because of its inherent flexibility in probing a largely unknown research topic (Lovelace *et al.*, 1990).

A total of 48 households in the two locations (24 in each of Kumasi and Effiduasi) were interviewed. Sampling of suburbs and households in the two towns was purposeful. Within each town only suburbs known to have a significant livestock population were sampled. While within each suburb only households engaged in small ruminant production were subsampled. The list of suburbs and households which fell into each group from each of the towns was obtained from the Ashanti Regional office of the Department of Animal Health and Production. A random sample of three households from each of eight suburbs in Kumasi and two households from each of 12 suburbs in Effiduasi were selected. In addition ten operators of "chop bars" (local restaurants), two workers at "gari" (fermented cassava product) processing factories and the Secretary of the Kumasi Small Ruminant Sellers Association were interviewed. Two officials of the Department of Animal Health and Production Division of the Ministry of Agriculture were also interviewed. The District Chief Executive of the Efigya-Sekyere District Council, of which Effiduasi is the capital, was also consulted.

The results of the diagnostic survey was used to formulate a detailed questionnaire which contained structured and open-ended questions (Appendix 2.2). The questionnaire consisted of

two schedules; household information (socio-economic questions) and, animal rearing activities (animal numbers, production resources and constraints).

The questionnaire was tested, refined and finally administered to 120 households. This was made up of 58 households from 12 suburbs in Effiduasi and at least six households from each of ten suburbs in Kumasi (62 households). The households were randomly selected from the list of households in the selected suburbs which was compiled during the diagnostic survey in the two towns. The questionnaires were administered with the help of two officials of the Department of Animal Health and Production Division of the Ministry of Agriculture, two teachers and one official of the Committee for the Defence of the Revolution (CDR).

Most of the data, except open-ended questions, were coded and analyzed with SPSS-x (1988) software package.

C. Results and Discussion

Apart from the types of small ruminants kept and the main feed resources, there were no significant differences between any of the variables measured between producers in Kumasi and Effiduasi. Producers in Effiduasi kept more goats than sheep and relied more on pastures and forages to feed their animals than producers in Kumasi. Therefore all the data except that of the type of animal and feed resources were pooled and analyzed as one. The main breed of sheep kept by urban producers was the Djallonke. Most of the goats were of the West African Dwarf types. They are both "indigenous" breeds and are trypanotolerant. There were, however, few crosses with the Sahelian type.

1. Reasons for keeping small ruminants

Respondents gave a number of reasons for keeping their animals. Irrespective of background, the majority of them (62% of goat owners and; 52% of sheep owners) cited financial considerations as the primary reason for keeping small ruminants (Table 2.1).

Table 2.1. Reasons for keeping small ruminants.[1]

Reason	Ruminant Type	
	Goats	Sheep
Financial only	28	25
Meat only	2	4
Religious and social only	4	5
Financial and others	34	27
Meat and others	25	14
Religious/social and others	7	25

[1]Values are percent of respondents

Number of respondents in each category: goats only = 95; sheep only = 80.

Table 2.2. Number of animals in the breeding herd.[1]

	Goats[2]		Sheep[3]	
	Males	Females	Males	Females
No. of animals	Percent		Percent	
1-3	80.5	56.5	83.7	43.8
4-6	14.6	21.7	16.3	29.7
7-9	0	10.9	0	7.8
10+	4.9	10.9	0	18.8

[1]Values are percent of respondents

[2]Number of respondents = 92

[3]Number of respondents = 64

Some of the financial reasons given were provision of cash for paying school fees of dependants and meeting both anticipated and unanticipated expenditures like hospital bills and emergencies. In earlier times, "prestige" was a term used, often in a derogatory manner, to describe the rationale behind keeping livestock by traditional livestock owners (Wilson, 1991). Traditional livestock owners were also described as conservative and not motivated by economic or profit considerations. While the studies of Ntifo-Siaw and Ghartey (1988) and Adebowale *et al.* (1993) appear to support this position, the present study does not. While the present study was based on urban and peri-urban populations, the earlier studies were done in rural communities. Economic and social demands made on these populations may be different and may probably account for the different production objectives observed. Both Ntifo-Siaw and Ghartey (1988) and Adebowale *et al.* (1993) reported that the majority of producers kept livestock for traditional and commercial reasons. Only 7% of producers in their studies kept livestock for purely commercial reasons as opposed to more than 25% reported in the present study. This study supports the view that the reasons why urban producers keep livestock are rarely irrational and that the reasons are related to their particular needs either in the long or short term.

This observation was further supported by the sex structure of flocks (Table 2.2). There was always a preponderance of females in larger flocks (>4). The emphasis here is that almost all animals in the flock are "productive", whether "production" consists of giving birth to young or simply undergoing the process of growth to a size at which another product (meat or reproduction) becomes the principal one. Similar flock structures in small ruminants kept by the Moors in Mauritania, the Fulani in Mali, and the "Arabs" in Chad have been reported by Wilson (1991).

The major management practice used to obtain stability in the flocks was culling and preferentially disposing of males not required for breeding (Table 2.3). Animals not required for breeding were sold. Table 2.2 indicates that the number of males in breeding herds was, strictly speaking, in excess of those required. However, as noted by Wilson (1991), this is a sort of insurance against sterile and temporary infertility in the males.

Dietary factors (provision of meat for the household) was an important consideration in the Islamic and the more affluent households where animals were slaughtered and consumed during religious festivals like "Id dir Kabir", Christmas and Easter holidays and social occasions like naming ceremonies and birthday celebrations. Only 7% of respondents kept goats for religious and social reasons while the corresponding figure for sheep was 25%. The higher figure for sheep could be a reflection on the role of this species in the religious activities of Moslems who invariably kept more sheep than goats. Among the Moslem community, sheep were preferred to goats because of their religious significance. During the celebrations of some Islamic festivals

Table 2.3. Preferred age, sex and time of disposal of small ruminants.

Category	Goats	Sheep
Preferred age (yr)		
1	33.7	18.3
2	10.9	11.5
3	27.7	20.2
>3	27.7	45.2
Preferred time		
Religious or social	27.4	35.2
Financial need	6.5	7.1
"When price is right"	66.1	57.4
Preferred sex		
Males	48.7	32.8
Females	29.7	26.2
Both	21.6	41.0

Number of respondents = 120

the slaughter of intact male rams is required by all families so each house tends to keep sheep with the aim of not having to buy a ram at the time of the celebrations, although those who could not afford sheep could slaughter intact goats.

2. Ownership patterns

Small ruminants were owned by individual men and women, rather than by domestic units. In this respect it may represent a unique resource in terms of empowerment of women and other disadvantaged groups such as the aged, illiterate and unemployed. The percent of women, aged (60 years and over), illiterate and unemployed who possessed small ruminants were 33, 27, 43, and 6% of respondents, respectively (Tables 2.4 and 2.5). Table 2.5 shows that small ruminant production in the urban centres is a secondary household activity. Only 20% of respondents were full-time farmers (i.e., total household income was derived from the sale of crops and/or animals only). The rest of the producers were engaged full-time in other activities. The implication of this for development is that any changes in the practices of farmers which would require substantially more "farm" work (when they are already burdened with off-farm work), or a substantially greater expenditure on inputs (when cash is very scarce), might involve sacrifices of opportunities for off-farm employment or of consumption that would make the changes seem impractical to such farmers. Another positive aspect of these observations is that the small ruminant rearing activity in these areas is not the predominant activity of one gender or the aged as found in other agricultural activities such as cocoa farming and food processing (Sarris and Shams, 1991). This ensures a broad base for the supply of labour.

The small ruminant foundation stock of most producers was acquired mainly through purchasing (72%). About 22% of respondents received their first animals as gifts while the rest (6%) were care-takers who used their share of the flock to build their own herds (Table 2.6). The acquisition of small ruminants was relatively easy and so even the "poor" (people with nothing they can call assets) can afford to raise them. This could be inferred from the assets of respondents (Table 2.6).

Table 2.4. Ownership patterns of small ruminants by age, sex and educational level of owners.

Category	Proportion of owners (%)
Age (yr)	
<29	15
30-39	22
40-49	21
50-59	16
60+	27
Educational Level	
No formal education	43
Up to High school	49
Above High school	8
Sex	
Males	67
Females	33

Number of respondents = 120

Table 2.5. Occupational distribution of small ruminant owners.

Type of Occupation	%
Farmers	20
Civil servants	2
Technicians/artisans	24
Traders	14
Pensioners	7
Others	27
Unemployed	6

Number of respondents = 120

Table 2.6: Mode of acquisition of small ruminants and assets of owners

Mode of Acquisition	%	Type of Asset	%
Purchase	72	Houses	58
Gift	22	Machines	6
Caretaker	6	Others	4
		None	32

Number of respondents in each category = 120

3. Flock types and sizes

Goat ownership was more widespread than sheep ownership in the two locations. About 31% of households owned only goats while 27% kept only sheep. Twenty one percent kept both goats and sheep and; 22% kept other types of livestock (e.g., cattle, rabbits, guinea pigs and poultry) in addition to goats and sheep (Table 2.7). Similar findings were reported by ILCA (1980) for countries in West Africa. In the humid zone of Nigeria it was reported that 37.4% and 8.3% of households kept goats and sheep, respectively. In Cote D'Ivoire 27.1% kept goats and 23.2% kept sheep. However, in terms of number of animals owned, producers kept more sheep than goats. About 41% of households kept between 6-10 sheep, 13% kept between 11-15 and 21% kept more than 15 sheep. The corresponding figures for goats were; 36%, 17% and 15% (Table 2.8).

There was a difference in the types of animals kept in the two locations (Table 2.7). Livestock owners in Effiduasi kept more goats than sheep compared to those in Kumasi. About 52% of producers in Effiduasi kept only goats while about 17.2% kept only sheep. The corresponding figures for producers in Kumasi were 11.3% and 35.5%. About equal numbers of owners (20.7% in Effiduasi and 21% in Kumasi) kept both sheep and goats. The proportion which kept both sheep and goats with other types of livestock was higher in Kumasi (32.2%), than in Effiduasi (10.4%). The main reason given by respondents for their preference for goats

was that goats are hardier and required less attention (i.e., they are better browsers than sheep and can therefore obtain their nutrient requirements from browsing or scavenging). The restriction on animal movement in Effiduasi was not as strict as that imposed by authorities in Kumasi, animals could, therefore, be left on their own for a considerable amount of time and respondents believed that goats were better at taking care of themselves.

Wilson (1991) also noted that livestock owners in tropical Africa keep a higher proportion of goats compared to sheep because goats are generally more prolific and capable of foraging more widely and on more feed types than sheep. This would make goats easier to manage for people with little experience with animals.

Table 2.7. Small ruminant distribution by location.

Class	Prevalence (%)		
	Kumasi	Effiduasi	Total
Goats only	11.3	51.7	30.8
Sheep only	35.5	17.2	26.7
Goats and Sheep	21.0	20.7	20.8
Goats, Sheep and Others	32.2	10.4	21.7
Number of respondents	62	58	120

Table 2.8. Herd/Flock sizes of small ruminants.

No. of animals	Goats (%)	Sheep (%)
1 - 5	32	25
6 - 10	36	41
11 - 15	17	13
>15	15	21

Number of respondents = 120

Table 2.9. Management decision making and allocation of labour within housholds.

Category	Frequency
Management decisions	
Producer	79.2
Household-head	10.0
Spouse	5.8
Consultations	5.0
Labour for feeding	
Producer only	55.0
Children/Family members only	31.7
Hired-hand only	1.0
Family members and Hired -hand	12.3
Labour for sanitation duties	
Producer only	38.3
Children/Family members only	25.8
Hired-hand only	6.7
Family members and Hired-hand	29.2

Number of respondents = 120

4. Labor

Labour requirements were dependent upon the production system and herd/flock size. Generally it was observed that the labour requirements for the daily activities was low. The main activities which required labour were feeding and sanitation. In most cases labour was supplied by members of the household (the producer, children and other family members). There seemed to be a pattern of allocation of tasks between family members (Table 2.9). In 55% of cases, producers themselves were responsible for feeding their animals. Children and other family members were responsible for feeding in about 32% of the cases. The use of hired-hands was

low. In sanitation related duties, children and hired-hands performed the bulk of the duties (55%) which included sweeping of pens and cleaning of feeding and drinking troughs. The sanitation related duties were regarded as menial and had to be performed by children or hired-hands.

Differences between level of confinement was a function of population density *vis a vis* availability of undeveloped lands or available pasture in the locality. The closer one gets to the centre of the cities, the more intensive the system and the greater the labour requirements for feeding and sanitation related duties. The low labour requirements and the limited skill required to maintain a small flock made it possible for the household to generate an economic return from family labour that has little or no opportunity cost.

5. Feed Resources

In a farming system context, ruminant production systems are particularly dependent on vegetation, and arable and perennial cropping for their feed base. The feed component is especially relevant as it is the primary link between crops and animals. The interaction between crops and animals provides for important socio-economic factors advantageous to the farm household and provides stability in farming systems.

The feed resources identified were permanent pastures and forages, and agro-industrial by-products from agricultural processing industries and households (Table 2.10). The permanent pastures were found along roadsides and undeveloped or partially developed plots of land. Only 3% of respondents used only pastures or browse to feed their animals. About 8% of respondents used only cereal (milling by-products and brewers spent grains) and root and tuber crop (cassava and yam) by-products. The majority of respondents (32%) used household garbage from food preparation (peels of cassava, plantain, cocoyam, yam, etc.). An equally large number of respondents used a combination of pasture/browse, cereal by-products and household garbage. The last group of respondents (25%) used a combination of pasture/browse and cereal by-products.

Table 2.10. Sources of feed and methods of feeding small ruminants.

Classification	%
Source of Feed	
Pasture/browse	3
Cereal and root by-products	8
Household garbage from food preparation	32
Pasture/browse + by-products	25
Pasture/browse + by-products + household garbage	32
Method of feeding	
Hand feeding/cut-and-carry	45
Free range - grazing/browsing/scavenging	3
Herding - on roadside/abandoned plots	7
Free range and hand feeding	33
Herding and hand feeding	12

Number of respondents = 120

These results show that agro-industrial by-products such as brewers spent grains and malt from the brewery industries, and cassava peels from household food preparation, "gari" and "chop bar" operations were the most important feed resources.

The agro-industrial feedstuffs were usually obtained in the "wet form" i.e. contained a high moisture content. About 85% of respondents processed these before feeding or storage (Table 2.11). Processing involved chopping and drying. Almost 53% of respondents had one form of feed storage facility or another. These consisted of stores (14%), baskets (25%), bags (18%). The duration of storage was, however, usually less than one month (97% of cases).

Overall, the fiscal cost of production was low (Table 2.12). The direct cost, transportation and storage of feed was negligible in most cases. The opportunity cost of labour involved in acquisition of feed by children was also said to be minimal. Less than 20% of

respondents spent more than 10,000 cedis per year to purchase feed for their animals. The amount was spent as occasional gifts to "chop-bar" operators for cassava peels. A few of them, however, usually purchased brewers spent grains from the breweries and cassava peels from the "gari" processing factories.

The predominant forage species in the pastures found in these areas were Guinea grass (*Panicum* sp.) and Elephant grass (*Penisetum purperum*). The main legume species was *Centrocema* sp. Producers had no control over this source of feed and had to share it with other members of the community. In some cases its availability throughout the year could not be guaranteed as the roadsides were weeded periodically by local government officials and undeveloped pieces of land were cleared for development.

Ficus sp. and *Terminalia* sp. were the major browse species fed to the animals by respondents. Occasionally, others fed leaves of the mango, banana, plantain and cassava plants. Ficus was the most widely used browse and according to respondents, the most preferred by the animals.

Table 2.11. Processing and storage of feed among small ruminant producers.

Category	Proportion of respondents[1] (%)
Processing	85.0 (120)
Storage	52.5 (120)
Processing before Storage	84.1 (64)
Duration of Storage (64)	
< 1 month	96.8
1 - 6 months	1.6
> 6 months	1.6

[1]Numbers in parentheses indicate the number of respondents

Grazing on roadsides and on communal (undeveloped) land was practised mainly by producers living near the fringes of the cities. In a few cases tethering of animals was done on roadsides and undeveloped plots. This was mostly the case when the location was close to the producer's house or where there was a lot of commercial activities going on so the danger of theft was reduced. In Effiduasi, free-roaming systems were predominant, probably because of

Table 2.12. Yearly expenditure on acquisition of feed (cost, transportation and storage).

Category	Cost in Ghanaian Cedis	% of respondents
Feed		
	Negligible	75.7
	<4,000	7.5
	4,000 - 10,000	1.0
	>10,000	15.8
Transportation		
	Negligible	67.5
	<4,000	28.2
	4,000 - 10,000	1.0
	>10,000	3.3
Storage		
	Negligible	61.2
	<4,000	8.3
	4,000 - 10,000	11.1
	>10,000	19.4

Number of respondents = 120

less pressure on land. Under such conditions animals do not make heavy demands on the time, cash or management resources of producers. Also because land used under these situations is communal, even the landless may engage in small ruminant production.

Some livestock owners practised what is called a cut-and-carry system. In this case, forage was brought in from outside the house and fed to the animals. In some situations this feed served a supplementary role, whereas in situations where herd/flock size was small it could be the only source of feed. This system, however, required a high investment in labour and also depended on the seasonal abundance or shortage of forage. Because the supply of feed was sporadic, and in most cases inadequate, animals raised under this system usually fair worse than under the free-roaming and other systems.

6. Management practices

Major management decisions (marketing, flock structure maintenance and disposal) were usually taken by the producers (79% of cases) or by the household head - in situations where owners were themselves dependants (10%). The proportion of goat owners who practised culling, castration, vaccination and deworming of their goat herds, was 54%, 60.5%, 95.4% and 69%, respectively. The corresponding figures for sheep flock owners were; 39.4%, 47%, 78.9% and 81.7%, respectively (Table 2.13). The reason given for the high incidence of castration in goats was to remove the taint associated with goat meat and to make the animals more manageable. Male sheep were usually not castrated because intact males are usually sold at a premium during Islamic religious festivities. Culling was practised to remove unproductive females and slow growing animals.

Feed sanitation was identified as the practice of cleaning feeding and drinking troughs at least twice weekly. Animal sanitation involved washing animals periodically to control mites, and housing sanitation was identified as the practice of cleaning the pens and holding areas of animals at least twice a week. Goats were, however, not washed as frequently as sheep because of the believe that goats do not like to get wet. Most producers used domestic detergents and water to

Table 2.13. Prevalence of some management practices among small ruminant producers.[1]

Type of practice	Goats	Sheep
Culling	54.0	39.4
Castration	60.5	47.0
Vaccination	95.4	78.9
Deworming	69.0	81.7
Animal sanitation	12.5	56.8
Feed sanitation[2]	94.0	--
Housing sanitation[2]	100.0	--

[1] Values are percent of respondents

[2]Combined value for goats and sheep

Number of respondents = 120

wash their animals while a few prepared solutions with lindane-based insecticides such as Gammalin-20.

The present observations support the hypothesis that the traditional livestock producer is very much aware of the role of management in the avoidance and control of diseases (Ibrahim, 1986; cited by Ntifo-Siaw and Ghartey, 1988). Many producers were aware of some of the prevalent diseases such as *peste de petits ruminants* (PPR), diarrhoea and worm infestations, and, as discussed later, took precautions such as routine vaccinations and deworming to prevent their occurrence.

Producers did not practice any form of controlled mating (90% of matings were random). The reason given for this was that animals were usually kept together or were allowed to move together with animals of other households, so there was no way of controlling breeding. The problem with this practice is that producers had no means of preventing or controlling inbreeding. On the whole one could conclude that the urban livestock producer is very

knowledgeable in terms of animal management. This is a valuable resource which should be exploited in any development strategy.

7. Marketing

Sheep and goat meat is an important source of animal protein in the urban and peri-urban centres throughout the year. The major route of disposal was by direct sale by producers at the farmgate. Buyers were mainly local restaurant (chop bar) operators, butchers, consumers and middlemen depending on the purpose for which animals were purchased. While restaurant operators, butchers and consumers slaughtered animals and sold the meat in one form or the other; the middlemen resold the animals, usually on the local small ruminant market at Asuasi. While it appeared that there was no particular time for disposing of animals, producers were inclined to market their animals during religious and social occasions because buyers were inclined to pay more for the animals than during other times of the year. All buyers identified, except the occasional consumer, are in the business to make profit, whereas urban producers keep their animals for a variety of reasons. The implication of this is that when producers require cash immediately to pay for unexpected expenditures, the price offered by the buyers is usually far below the market price. Some producers, however, did not consider this a major problem since they thought that they always recoup their profit during the religious holidays among the Moslem and Christian communities.

Another route of disposal in these areas was that sheep and goats were slaughtered on occasions by the producer and part or all the meat sold and consumed among neighbours. Because of the rapid increases in population, rural-urban migration and increases in income, demand for sheep and goat meat would continue to increase. Goat meat is now considered a delicacy among the urban elite and the not-so-wealthy folks so product market demand does not appear to be a problem for now and in the foreseeable future.

8. Constraints in urban livestock production.

Constraints were prioritized by respondents without prompting from the enumerators. Producers perceived lack of capital/credit as the single most important constraint. However, an *ex ante* analysis of the production system indicated that animal losses, due to health-related problems, could be the main factor retarding the small ruminant industry in the urban centres.

Losses were very high among the flocks. About 56% of owners had lost between four and ten goats the previous year. Sixty-three percent of owners lost between four and ten sheep. The main causes were theft (17%), accidents (12%), identifiable diseases (14%), unidentifiable diseases (20%) and miscellaneous causes such as poisonings, complications arising from castration, pregnancy and parturition (Table 2.14). If losses due to miscellaneous causes are grouped with diseases as health-related, then the health-related factors accounted for more than 70% of all losses. In Kumasi the second most important cause of loss was theft. The loss of animals through accidents and poisonings usually came about when producers allowed their animals to wander about without supervision or stray onto people's properties.

While losses involving vehicles (accidents) were not blamed on drivers, very few losses due to poisonings were deemed accidental by respondents. They believed that neighbours, opposed to their keeping animals, deliberately poison the animals in retaliation for the destruction of their food and ornamental crops or for what they consider as the nuisances they have to put up with all the time (e.g., noise, smell of manure and fouling of their compounds). Fights and litigations have occasionally broken out among producers and neighbours over these complaints. According to local government officials those are the main reasons why they have had to restrict the movement of animals within the municipalities. Within certain suburbs, animals found outside are impounded by local government officials and the owners fined before the animals are returned to them. Some producers complained that the amount demanded for the return of the animals was in most cases more than the market value of the animals.

As indicated earlier, mortality due to diseases among small ruminants in the urban areas is unacceptably high. The epidemic diseases such as *peste des petits ruminants* (PPR), contagious

caprine pleuropneumonia, mite and worm infestations are nation-wide health risks. In a study of the causes of mortality on farms in a district near Kumasi, Tuah *et al.*, (1988) found that PPR was the disease that caused the most deaths while parasitic gastro-enteritis was the most widespread disease among the farms. The same observation holds true for the Kumasi District, according to the Kumasi District Veterinary Officer (Dr. Akyeampong, personal communication). PPR is a viral disease of sheep and goats characterized by fever, diarrhoea and pneumonia. Infected animals usually die within a week after the start of the fever (Koper-Limbourg and Oyeyemi, 1993). PPR cannot be treated effectively but it can be prevented through yearly vaccination with the Tissue Cultured Rinderpest Vaccine (TCRV).

About 69% of respondents had taken measures, including vaccinations, to control their losses. Among those who had taken measures about 76% of them had found the measures taken to be effective. It is pertinent to note that most measures taken to reduce losses had been taken in consultation with veterinary officials. The competence and expertise of these officials is well documented but their efforts have occasionally been thwarted by logistical problems. Sarris and Shams (1991) in a publication for the International Fund for Agricultural Development noted that the Animal Health and Production Department of the Ministry of Agriculture (i.e., the Veterinary Services Department) is one of the most effective in West Africa. However, because

Table 2.14. Causes of small ruminant losses.

Cause	%
Identifiable diseases	14
Non identifiable diseases	20
Accidents	12
Theft	17
Miscellaneous	37

Number of respondents = 120

of delays in procuring drugs and vaccines due to fiscal constraints, some vaccination programs are not carried out on schedule with the result that outbreaks occur before measures are taken to bring them under control. Private companies are now allowed to procure and sell veterinary drugs and chemicals, including anthelmintics, coccidostats, disinfectants, feed additives, dressings and acaricides. With the availability of drugs and vaccines on the local market what is needed is to motivate veterinary officials so that they can pay frequent visits to producers to advise and assist them when necessary. This could effectively reduce most of the losses attributable to diseases.

It is to the credit of producers that they practice routine vaccinations but as noted above, occasionally there have been reports of lack of vaccines and/or ineffective vaccines being used (the result of ineffectual quality control and/or monitoring of the companies engaged in the importation and distribution of veterinary drugs). For example, the TCRV comes in vials with doses for 100 to 200 animals and once opened has a life span of only an hour. The small number

Table 2.15. Constraints on production of small ruminants.

Classification	%
Single constraints	
Health only	8
Credit only	20
Feeding	5
Multiple constraints	
Health and credit	15
Health and feeding	18
Credit and feeding	21
Others (e.g. space, theft, labour, etc.)	13

Number of respondents = 120

of animals and the spread of households in the urban centres indicate that fewer than 100 animals would be vaccinated within the one hour time frame. The need, therefore, exists for producers to organize themselves especially for PPR treatment. The huge losses suffered by producers as a result of diseases indicate that if improved control of diseases could be achieved, the potential for increasing flock sizes and production would be tremendous.

As reported earlier, the majority of respondents cited lack of credit/capital as the single most important constraint to increased productivity (20% compared with 8% who cited health, and 5% who cited problems related to feeding; Table 2.15). Credit/capital was required to (1) improve existing infrastructures (e.g., build pens/barns), (2) increase flock size, and (3) purchase drugs for routine drenching and vaccinations of animals. Respondents noted that credit from the formal sectors of the economy (financial institutions) was almost impossible to obtain because they lacked the collateral usually demanded by the institutions.

As noted by Winrock International (1983), the problems in supplying credit to small ruminant producers are similar to those for small holder credit problems in general. Some of the problems cited are that: (1) institutions are not geared to meet the needs of the small holder; (2) commercial institutions are reluctant to make loans because of high administrative costs; (3) lack of viable technologies needed to provide high rates of return needed to repay the loan; (4) the problem where loan proceeds are used for other purposes and; (5) problems of loan security and loan repayment difficulties. While it will take a considerable amount of time and goodwill on the part of producers and lenders to resolve these difficulties it is pertinent to note that the government and aid agencies can alleviate this situation by providing assistance in the form of what Winrock International (1983) calls production system support activities (i.e., research, extension and marketing infrastructure).

One major advantage of sheep and goats is their ability to reproduce rapidly and build up herd/flock numbers quickly. To some extent, this obviates the need for large amounts of capital for herd expansion. Another argument in favour of capital investments in production system

support activities is that the breeds of sheep and goats in the country have very good ability to respond to higher levels of feeding, management and health.

Devendra (1989) demonstrated that in situations like those described above the two primary considerations in the improvement of ruminant production systems and increasing productivity in ruminants under such circumstances is making maximum use of the animal genetic resources and taking full advantage of the available feed resources, with the ultimate objective of combining production with economic animal performance. This is essentially what the present research seeks to achieve (i.e., to match the existing livestock resources with the available feed resources in the most effective manner possible), and as much as possible reduce or eliminate the need for producers to depend on external sources to sustain the industry.

The feed constraint has both quantitative and qualitative dimensions. In most cases, producers provided enough feed in *ad libitum* amounts to their animals (as evidenced by large amounts of orts in most feeding troughs in households) but the quality of the feed was questionable in most cases. As noted in Table 2.10, about 40% of producers fed only by-products such as cassava peels, plantain peels, milling and brewing by-products. These feedstuffs are in most cases nutritionally inadequate or unbalanced in terms of essential nutrients. Apart from this, during the dry season producers who relied solely on pastures and browse found it difficult to provide enough feed for their animals during this time. However, they indicated that they could obtain cassava peels from the "chop bars" and "gari" factories if necessary. It therefore appears that if emphasis is placed on simple practices like processing (cutting and drying), storage of the most available feedstuffs (cassava peels), and supplementation to provide the deficient nutrients, alleviation of the feeding problem could be achieved. However, research on types of supplements and methods of supplementation are called for before specific recommendations can be made. The impact of attending to the feed problem is often spectacular. A comparison of goats fed under traditional village systems with those adequately fed in an experimental group showed more than a 50% increase in liveweight at comparable age (Devendra, 1989).

Past opinion in developing countries considered local animals to be low producers and therefore required to be replaced by superior breeds whenever development strategies were formulated. Such thinking resulted in the failure to see the potential of optimizing the use of indigenous breeds and locally available feed resources. Fortunately, the inherent potential of indigenous breeds has now been recognized. Small ruminants have been part and parcel of most urban and peri-urban households for a long time and their (sheep and goats) small sizes and low cost of production make them a unique resource particularly suited to the limited resource base of these households.

D. Conclusions

Figure 2.1 is a schematic representation of the small ruminant production system in the urban and peri-urban centres of Ghana. It summarises production resources, feeding systems, main product, marketing channels and constraints of the system. Current production resources are ecologically, socially and economically suited, and adequate to support a viable small ruminant industry. However, improvement of the feeding value of the feed resources through the strategic use of readily available and inexpensive supplements is required to ensure efficient utilization of the feed resources by the animals. Whatever supplement or method of supplementation chosen should be something producers can afford.

Constraints in the small ruminant production system were identified and discussed as if they were discrete factors, the interactions among them are the rule and not the exception. That was why it was necessary to consider the total system so that multiple interacting constraints could be identified and systematically resolved in order to achieve any improvement. For example, reduction in animal losses due to better disease control measures and adequate supervision to prevent accidents, poisonings and theft would dramatically increase animal numbers and would require higher management inputs. This could pose other problems since most producers are already engaged in other economic activities outside the household and may have to consider the opportunity cost of labour and the extra inputs.

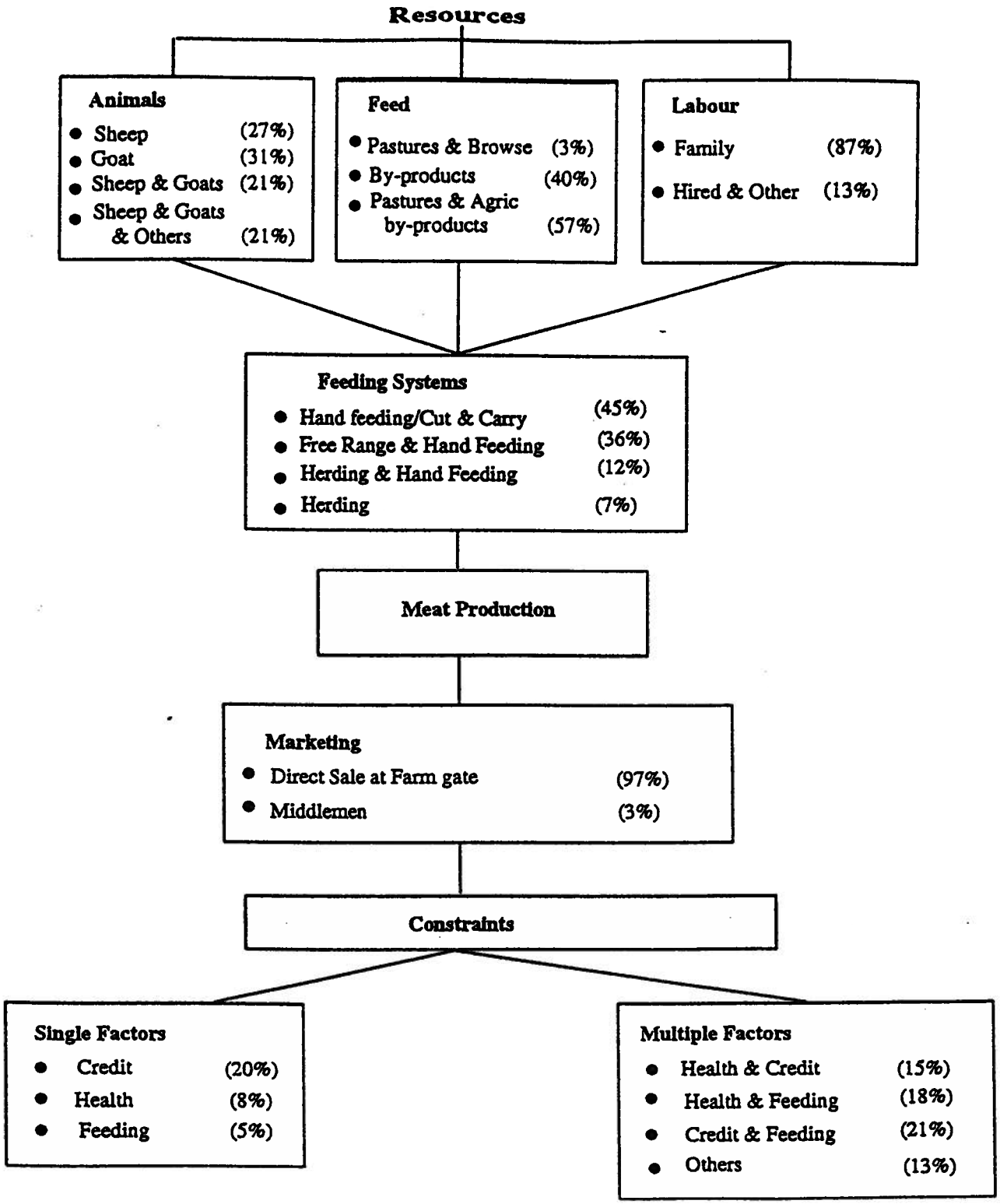


Figure 2.1. Schematic Representation of the Small Ruminant Production System in Urban and Peri-urban Centres of Ghana.
Figures in parentheses represent the proportion of producers in each category.
Number of respondents = 120.

Inspite of all the problems associated with urban small ruminant production, 92% of respondents were willing to increase their flock sizes. However, problems such as housing, conflicts with neighbours and diseases would require a very clear vision on the part of government to resolve. One cannot deny the fact that small ruminant production in the urban and peri-urban centres would continue to play essential economic and social roles in these households but if the ultimate objective of government is to provide adequate and cheap animal protein to the population then a vision of the type of production system to promote is required.

Because small ruminants tend to be dispersed in small herds/flocks among many producers in the urban centres, providing direct credit and extension services to the producers may not be technically or economically feasible in most cases. Therefore innovative schemes at the community level (co-operatives) should be encouraged among producers so that they can handle some of the routine vaccination and disease control measures themselves.

The need for research and extension efforts on small farm systems cannot be denied. However, it must be stressed that in order to meet the objective of providing affordable meat and animal products to society, attention would have to be focused on stimulation of operations outside residential areas and sufficiently large to adopt known technologies. This calls for greater encouragement of individuals and companies willing to go into commercial livestock production. The success of such an undertaking is exemplified in recent developments in the poultry industry. The level of production in some of these poultry enterprises in the country is comparable to that in some developed countries. In the short-term, however, because the movement of small ruminants has been restricted by producers themselves (to prevent losses among their animals due to accidents and poisonings), and by local government authorities because of the destructive activities of the animals, the need to provide adequate and nutritious feed to the animals is of paramount importance. Therefore, research on the available feed resources in these areas is required to identify and select feedstuffs which could be used to meet this nutritional demand.

CHAPTER 3 IDENTIFICATION AND SELECTION OF FEEDSTUFFS FOR SMALL RUMINANTS IN THE URBAN AND PERI-URBAN CENTERS OF GHANA

A. Introduction

The purpose of this chapter is to report on the selection of a basal and a supplementary feedstuff for feeding small ruminants in the urban and peri-urban areas of Ghana. The selection criteria and description of the basal feed and, supplementation principles are first reviewed.

The identified ruminant feed resources in the urban and peri-urban areas of Ghana were mainly agro-industrial by-products. Limited quantities of native pastures along roadsides and on abandoned or undeveloped pieces of land were also available but the agro-industrial by-products constituted the largest feed resource (Chapter 2). Considerable differences exist in the nutritive value of the different types of agro-industrial by-products. Even within the same by-product differences exist due to processing technique and duration of storage (Tuah and Orskov, 1989; Adegbola *et al.* 1989). Despite these differences the by-products share some common features such as being extremely fibrous and low in nitrogen and soluble cell wall contents. A primary limitation in the use of such feedstuffs by ruminants is the low digestibility and the slow rate at which the feed particles break down to sizes that can leave the rumen - these factors could reduce feed intake and ultimately animal productivity (Welch, 1982). For these reasons whenever agro-industrial by-products are used as feed, everything possible is done to optimize intake and digestibility through processing (physical, chemical or biological) and/or optimization of the rumen environment.

B. Preliminary Studies

1. Selection of basal feedstuff

Among the agro-industrial by-products identified during the survey of urban households, cassava peels was chosen as the basal feedstuff. The following were the major considerations which led to the choice of cassava peels over other feedstuffs:

1) The annual production of cassava in Ghana is about 3.6 million mt (FAO, 1992). The peels constitute approximately 11% of the root. This means that if all the peels were collected about 400,000 mt (on dry matter basis) of cassava peels would be available for livestock feeding annually.
2) Cassava is produced throughout the year and this makes the peels resulting from household food preparation and from factories in the cities available to livestock all year round. Minimal transportation costs are incurred, if any, in transporting the peels from the sites of production to animals.
3) It was the main household refuse/garbage currently fed in substantial quantities to livestock in the urban households.
4) Nearly every household surveyed produced a sizeable quantity of cassava peels as a result of food preparation and,
5) Cassava peels could also be obtained from neighbours, "chop bar" (local restaurant) operators and "gari" (fermented cassava product) processing factories at little or no cost.

1.1. Nature and chemical composition of cassava peels

Cassava peel is the main by-product from the processing of cassava roots (*Manihot esculenta* Crantz) for human consumption. The genus *Manihot* (Family: *Euphorbiaceae)* includes over 200 species of which *Manihot esculenta* Crantz is the most important, from the nutritional and economic points of view. Mature stem cuttings are universally used as propagating materials.

Adventitious roots, which form at nodes in the soil are all initially fibrous, but gradually some undergo enlargement. At maturity they become large, tuberous storage roots which may assume different shapes and sizes. The mature root possesses three distinct regions, namely, the phelloderm or peel, the cortex or flesh, and the central vascular core. The phelloderm is generally 1-4 mm thick and may account for about 10-12% of the total dry matter of the root (Nartey, 1979). The phelloderm is composed of an outer epidermis, a sub-epidermis and an inner layer readily separable from the bulk of the tuber. The cortex consists of a mass of parenchyma cells that constitutes the region of carbohydrate storage. Processing the tuber usually leaves a substantial amount of the storage tissues attached to the sub-epidermis.

Several researchers have reported on the chemical composition of cassava peels. The general conclusion drawn by all these researchers is that cassava peel has a low crude protein content (2.8 to 6.5% of dry matter; Adegbola *et al.* 1989; Ifut, 1989; Osei, 1990). The efficient exploitation of this feed resource by ruminants would require that the animals be provided with a protein supplement.

Preston and Leng (1981) have suggested that in order to optimize the utilization of fibrous agricultural by-products, animals must be provided with readily fermentable energy and protein; by-pass protein and by-pass energy and; micronutrients like sulphur, phosphorus and B vitamins. In Ghana, the cheapest means by which these requirements could be provided would be through the strategic use of fodder trees and shrubs as supplements. The improvement in digestibility, intake and growth rate of ruminants through supplementation of diets based on agricultural by-products with fodder trees and shrubs have been demonstrated by numerous workers (Fomunyam and Mbomi, 1989; Ifut, 1989; Yilala, 1989).

2. Selection of browse supplement

The survey of the sources of feed for small ruminants in the urban and peri-urban areas of Ghana revealed that the leaves of *Ficus exasperata* and *Terminalia* sp. have been an integral part of the traditional livestock production systems in these areas. Further investigations revealed that

Ficus sp. has traditionally been fed to livestock in the country. These two forages and Chaya (a forage with a crude protein content of 20% at full maturity and currently under investigation at the Department of Animal Science, University of Science and Technology, Kumasi), were evaluated as possible protein supplements for a cassava peel-based diet.

2.1. Principles of nitrogen supplementation of ruminant diets

The choice of an appropriate supplement requires a knowledge and an understanding of the nutritional value (digestion and associated constraints) of the available feedstuffs, the nutrient requirements of the animals involved and the economic realities of the production system.

Microbial protein synthesized in the rumen is the major source of nitrogen to the host animal, accounting for 60-85% of the total amino acids entering the small intestine (Orskov, 1982). Synchronization of the rate of degradation of feed nitrogen and carbohydrate components in the rumen is important for the synthesis of microbial protein (Meggison *et al.*, 1979; Satter and Roffler, 1981). Optimum microbial synthesis usually results from the synchronous release of ruminally degraded protein and carbohydrates from dietary ingredients (Russell and Hespell, 1981).

The rate of fermentation of feed in the rumen depends on the nature of the rumen environment. The rate of fermentation is reduced when the microbes cannot obtain sufficient quantities of nitrogen, sulphur and, probably some peptides or amino acids (Engels, 1986). The need for nitrogen is related to the fermentability of the plant material. When this is low, little energy becomes available per unit time, and so only small amounts of nitrogen are required and *vice versa.*

A rapid release of nitrogen not matched to the release of organic matter from the carbohydrate source could lead to a high absorption of ammonia from the rumen (Meggison *et al.*, 1979). The availability of suitable carbon skeletons and ATP is a requirement for the ammonia to be used for microbial protein synthesis (Czerkawski, 1986). The ammonia not captured in the rumen is absorbed and converted into urea in the liver, partly to be transferred to

the rumen or lost in the urine (Kennedy and Milligan, 1980) at a cost to the animal. This is because the synthesis of urea requires an expenditure of energy; synthesis of each mole of urea requires four moles of ATP (Martin and Blaxter, 1965). Degradation of the basal feedstuff therefore, has a tremendous influence on the choice of nitrogen source for efficient utilization.

The main objective of this experiment was therefore to select a browse supplement whose nitrogen might be released in synchrony with the release of the organic matter from the cassava peels in the rumen. In addition, the chemical composition of cassava peels collected from different locations in the urban centres was also determined in an effort to investigate the extent of variation in chemical composition of the peels.

C. Materials and Methods

1. Feeds

Cassava peels were obtained from "gari" processing factories and dried on concrete floors for about 5 d. The leaves of *Ficus exasperata* were also harvested from farms near the University of Science and Technology, Kumasi, Ghana, and dried for about 4 d. Both the intensity and duration of the sunlight determined the length of the drying period. The dried cassava peels and ficus leaves were then stored in bags until they were required for feeding. In addition, samples of cassava peels were collected every other day over a 2 wk period from ten different locations in Kumasi for chemical analyses. Another group of samples of cassava peels from seven different varieties of cassava were also obtained from the Crops Research Institute of Ghana, Kumasi Station, for chemical analyses.

2. Animals and feeding

Four wether sheep of the Djallonke breed (average weight, 37.8 kg; ± 0.92 kg) fitted with permanent rumen cannulae, were housed in individual slatted floor pens and given *ad libitum* access to water and a basal diet of dried cassava peels. In addition each animal received 200 g of

dried ficus leaves per day on an as-fed basis. The ficus leaves were offered in two equal portions at 0800 and 1600 hours. All animals used in this and subsequent experiments were cared for under guidelines similar to those outlined by the Canadian Council of Animal Care.

3. Supplements and incubation procedures

Fresh leaves of ficus, terminalia and chaya were also harvested from farms near the University and dried at 60°C to constant weight in a forced draught oven. The dried leaves and peels were then ground through a 2.5 mm screen. Duplicate samples of each (4 g) were weighed into nylon bags and inserted into the rumen of each sheep at the time of the morning feeding. The bags were made of monofilament nylon mesh (53 μm pore size, 5 cm x 20 cm; Ankom, Fairport, New York). The bags were retrieved after 4, 8, 12, 36, 48, 72 and 96 h of incubation.

Immediately after removal, bags were immersed in a plastic bucket of cold water and gently washed by hand under running tap water until the water from the bags was clear. The bags and contents were then dried at 60°C to constant weight in a forced draught oven. A duplicate set of bags containing samples of cassava peels and ficus leaves were immersed in water at 39°C for 1 h and treated as above. This was used as an estimate of 0 h disappearance. The above incubation procedure was repeated three times. Animals were given another 2 wk to adapt to their new experimental diets before incubations started.

4. Chemical analysis and calculations

Samples from the oven-dried cassava peels, ficus leaves, terminalia leaves and chaya leaves were analyzed for dry matter, organic matter and Kjeldahl nitrogen according to AOAC (1985) procedures. Neutral detergent fibre analysis was performed as described by Goering and Van Soest (1970).

The degradation characteristics of DM and nitrogen in cassava peels, ficus leaves, terminalia leaves and chaya leaves were determined by fitting the following modified version of the exponential equation of Orskov and McDonald (1979) to accommodate a lag phase:

$$p = a + b(1-e^{(-c(t-lag))}) \text{ for } t > lag; \qquad [1]$$

where p is the disappearance (%) of DM or nitrogen from the bag, a is the fraction which disappears rapidly, b is the slowly disappearing fraction, e is the base at the natural logarithm, c is the fractional rate of disappearance (%/h), and t is time (h) of incubation. The a, b, c and lag were estimated by an iterative least-square procedure (Appendix 3.1) with the SAS (1990) software package. Effective disappearance (EFFD) was then calculated from the estimates of a, b and c assuming a fractional outflow rate of solids from the rumen (Kf) of 0.06% h^{-1} using the following equation:

$$EFFD = a + (((bc)e^{(clag)})/ (c + Kf))e^{(-(c + Kf)lag)} \qquad [2]$$

where a, b and c are as defined in equation [1]. The potential disappearance of a component such as dry matter or nitrogen was calculated as the sum of the a and b fractions of that component i.e. (a+b).

The rumen degradation characteristics of dry matter and nitrogen in cassava peels and leaves of chaya, ficus and terminalia were analyzed as a randomised incomplete complete block design with animals as blocks and type of feed as treatments. The model used was:

$$Y_{ij} = \mu + \beta_i + \tau_j + \varepsilon_{ij} \qquad [3]$$

where Y_{ij} represents an observation in the ith animal, β, (i = 1 to 4), receiving the jth treatment, τ, (j = 1 to 4). The overall mean was expressed as μ, and the residual error as ε_{ij}. Differences between treatment means were determined with Tukey's studentized range test (HSD). The General Linear Model of the Statistical Analysis Institute (SAS, 1990) was used for the analysis.

D. Results and Discussion

1. Chemical composition

The chemical composition of cassava peels obtained from different sources in Kumasi and the three tree leaves are presented in Tables 3.1 and 3.2. Most of the cassava cultivated in Ghana is of the Ankra variety. Varietal trials comparing this variety with new high yielding varieties developed at the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria are currently underway at the Crops Research Institute of Ghana. The peels collected from the different locations were therefore all of the Ankra variety grown and brought into Kumasi from different parts of the country. Local 1 and 2 were composite samples of cassava peels (produced as a result of daily food preparation) collected over the 2 wk period from two households.

The organic matter of the cassava peel samples ranged from 91.6% to 96.7%. The nitrogen and neutral detergent fibre contents ranged from 0.59 to 1.34% (mean, 1.02%) and 46.8to 69.3% (mean, 54.1%), respectively. The difference between the chemical composition of cassava peels from the various locations could be due to the edaphic and climatic conditions under which they were grown. In terms of the nitrogen content of the peels, Ankra appears to be slightly superior to all the new varieties undergoing trials.

The level of nitrogen in the cassava peels observed in this study is in close agreement with values reported in the literature. Osei and Twumasi (1989) working with a variety grown in Ghana reported a value of 0.912% while Ifut (1989) in Nigeria reported a value of 0.96% (SE, 0.38). The extent of variation in nitrogen content of the peels offers the possibility for selection in breeding programs.

Table 3.1. Organic matter, nitrogen and neutral detergent fibre content of different varieties of cassava peels, and cassava peels collected from different locations in Kumasi (% DM).

Source of peels	Organic matter	Nitrogen	Neutral detergent fibre
Railways	96.2	1.0	46.8
Mbrom	91.6	0.59	49.3
Ayigya	96.4	1.04	48.1
Kadjetia	95.5	1.07	53.6
Asokwa	94.7	1.28	49.3
Asafo	94.3	0.99	50.2
Atonsu	96.4	1.02	62.3
Stadium	96.3	0.93	51.6
Local-1	95.3	0.99	49.0
Local-2	96.5	1.13	48.1
Variety of cassava			
Ankra	94.9	1.34	60.7
TMS63397	92.9	0.93	64.4
TMS00110	96.7	0.78	58.7
TMS00942	94.5	1.11	57.1
TMS30572	93.2	1.23	53.3
TMS80441	96.1	0.89	69.3
TMS00058	96.2	1.10	48.1
Mean (SD)	95.2 (1.4)	1.02 (0.17)	54.1 (6.6)

Table 3.2. Organic matter, nitrogen and neutral detergent fibre content of leaves of *Ficus* sp., *Terminalia* sp. and chaya (% DM).

Description	Organic matter	Nitrogen	Neutral detergent fibre
Ficus leaves	83.8	3.1	44.1
Terminalia leaves	90.3	1.7	56.2
Chaya leaves	93.1	3.4	40.3

The organic matter content of the tree leaves ranged from 83.8 for ficus to 93.1% for chaya leaves. The nitrogen content of chaya leaves was highest (3.42%), followed by ficus (3.11%). The nitrogen content of terminalia was the lowest at 1.66%. While there are no literature values for comparison of the values of chaya it is, however, important to note that the value 3.42 compares favourably with the predominant browse legumes notably, *Leucaena leucocephala* (3.58%), *Gliricidia sepium* (3.68%) and *Sesbania grandiflora* (3.76%) as reported by Smith (1992). The nitrogen content of the *Ficus exasperata* leaves found in the present study was, however, higher than the value of 2.37% reported by Smith (1992). In a review of potential fodder trees and shrubs in range and farming systems in tropical Africa, Smith (1992) classified *Ficus exasperata* as of medium quality in terms of its protein content and *in vitro* organic matter digestibility. He reported values of 90.5, 25.0 14.8% for organic matter, neutral detergent fibre, crude protein content and 45.5% for *in vitro* organic matter digestibility. Growing conditions and stage of maturity could be partly responsible for differences in some of the chemical components observed in the present study and by Smith (1992).

2. Dry matter disappearance

A number of variables affect the degradation of feedstuffs in the rumen. ARC (1980) recognized that feedstuffs did not have a constant degradability value but that values would vary with the nature of the basal diet fed and the level of feeding. Apart from that, the proportion of

roughage to concentrate, particle size of feed and environmental temperature are among the factors known to alter rumen liquid turnover rate. Consequently, the mean retention time of small particles in the rumen is likely to vary with the same factors and this ultimately influences the extent of degradation of components in the feed (e.g., dry matter and nitrogen).

The cassava peels consumed by the animals contained 95% organic matter, 60% neutral detergent fibre and 1.3% nitrogen on DM basis. The ficus leaves contained 3.5% nitrogen and 53% neutral detergent fibre. Average daily dry matter intake of animals was 1.3 kg ± 0.23 kg.

The nylon bag studies revealed large differences in the rumen degradation patterns of DM in cassava peels and the tree leaves. The dry matter disappearance of cassava peels was 43% at 24 h of incubation. At 48 h of incubation, 53% of the DM had disappeared (Figure 3.1). The proportion, which if given enough time would disappear (potential disappearance) was about 71%. Chaya leaves were rapidly degraded in the rumen, about 79% of the DM had disappeared after 24 h incubation. In contrast, only about 36% of the DM in terminalia leaves had disappeared by 24 h. After 48 h of incubation 91% of the DM of chaya leaves had disappeared. This was inclose agreement with 90% DM disappearance in sesbania (Jong Ho Ahn *et al.*, 1989). The disappearance of the DM of ficus leaves was intermediate; about 48% of it had disappeared at 24 .h and 64% by 48 h. The disappearance of DM in terminalia leaves at 48 h was close to the 73% reported for gliricidia (Veereswara Rao *et al.*, 1993).

The degradation characteristics of cassava peels, chaya leaves, ficus leaves and terminalia leaves are presented in Table 3.3. The rapidly disappearing DM fraction "a" of chaya leaves (38.8%) was highest, followed by that of terminalia leaves (29.4) and ficus leaves (25.5%) ($P<0.05$). The high "a" value for chaya leaves was similar to values reported for Sesbania (40.5%) and Gliricidia (35%) by Veereswara Rao *et al.* (1993). The "a" fractions in both terminalia leaves and ficus leaves were higher than the value for Leucaena (17.5%) also reported by Veereswara Rao *et al.* (1993). The disappearance rate (c), of the "b" fractions of chaya leaves and terminalia leaves were similar ($P>0.05$), however, they were about twice the value of ficus leaves. Among the tree leaves, the rate of disappearance of the "b" fraction of ficus leaves was

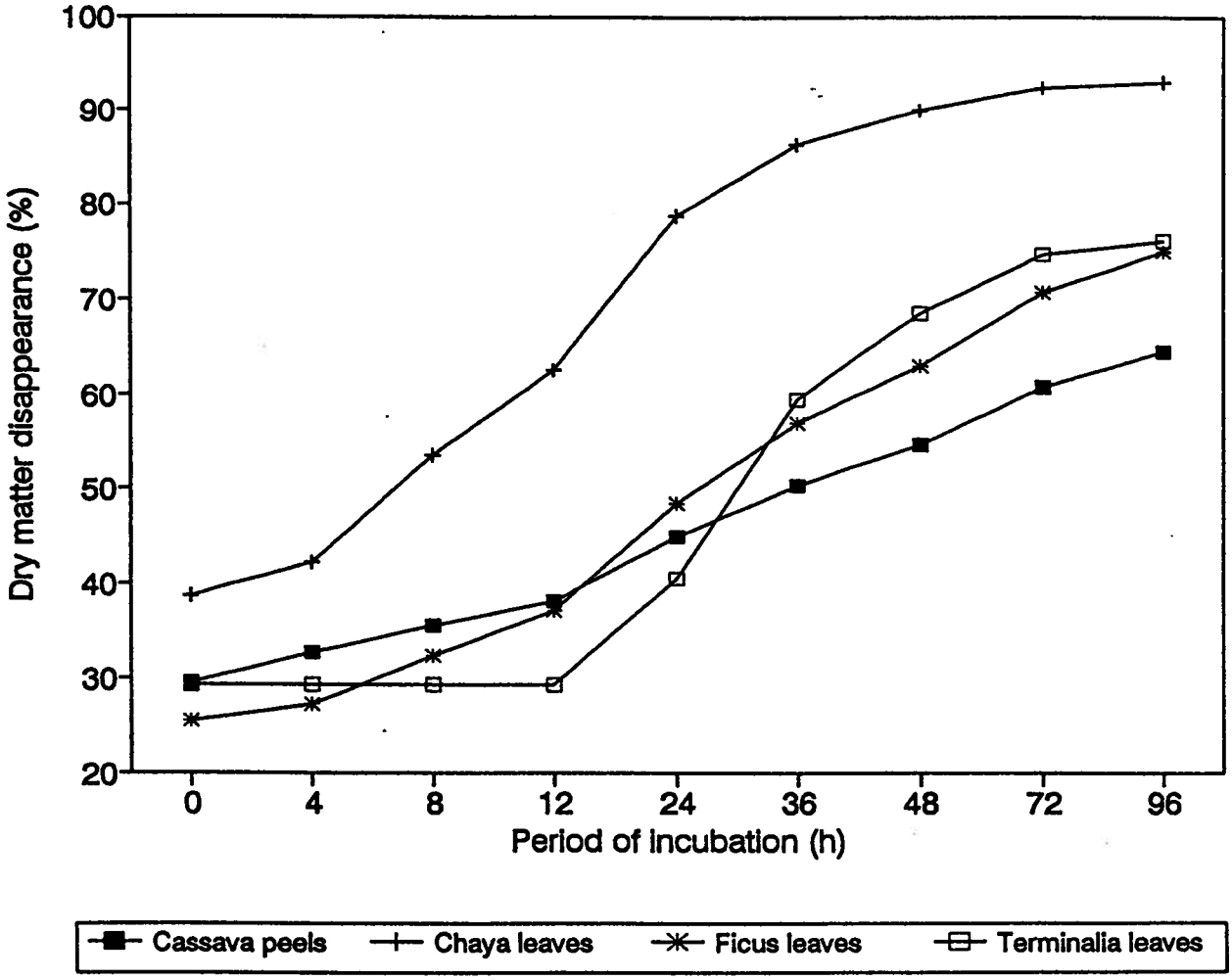


Figure 3.1. Disappearance of dry matter from cassava peels, and from leaves of ficus, chaya and terminalia incubated in rumen of sheep.

Table 3.3. Rumen degradation characteristics (%) of dry matter and nitrogen of cassava peels, and leaves of chaya, ficus and terminalia incubated in rumen of sheep.[1]

Degradation characteristics	Feed type[2]				
	Cassava	Chaya	Ficus	Terminalia	SEM[3]
Dry matter					
a	29.5[a]	38.8[b]	25.5[c]	29.4[a]	0.32
b	41.3[a]	54.3[b]	54.4[b]	47.2[c]	0.31
c (%/h)	0.020[a]	0.063[b]	0.026[a]	0.062[b]	0.004
lag (h)	0.3[a]	2.3[b]	2.8[b]	6.8[c]	0.92
Effective disappearance	43.1[a]	68.3[b]	44.6[a]	42.4[a]	1.06
Potential disappearance	70.8[a]	93.1[b]	79.9[c]	76.6[d]	0.63
Nitrogen					
a	18.1[a]	37.3[b]	20.2[a]	26.1[c]	1.12
b	57.2[a]	54.7[b]	46.5[c]	51.5[d]	0.22
c (%/h)	0.145[a]	0.133[a]	0.087[c]	0.052[d]	0.006
lag (h)	2.0[b]	1.1[a]	2.9[a]	6.6[c]	0.85
Effective disappearance	53.9[a]	72.6[b]	43.3[c]	42.2[c]	1.26
Potential disappearance	75.3[a]	92.0[b]	66.7[c]	77.6[a]	1.34

[1]Rumen degradation constants, and potential disappearance of DM and N were calculated from the following equation, a modified version of the Orskov and McDonald (1979) model:

$p = a + b(1-e^{(-c(t-lag))})$ for $t > lag$ where; a = rapidly disappearing fraction; b = slowly disappearing fraction; c = rate constant of b and; a+b = potential disappearance.

Effective disappearance (EFFD) = $a + (((bc)e^{(clag)})/(c + Kf))e^{(-(c + Kf)lag}$; Kf, assumed to be 0.06.

Number of observations per treatment = 4.

[2]Means within rows with different letters are significantly different ($P<0.05$).

[3]Standard error of pooled mean.

closest to that of cassava peels (0.020).

The lag phase of the degradation of dry matter in chaya leaves (2.3 h) and ficus leaves (2.8 h) were not significantly different ($P>0.05$). Both were, however, significantly ($P<0.05$) less than the value for terminalia leaves (6.8 h). However, the rapid rate at which the disappearance of the "b" fraction in terminalia leaves proceeded apparently compensated for the long lag phase; so that at 48 h of incubation about the same amount of DM in terminalia leaves, ficus leaves and cassava peels had been effectively degraded. The proportion of chaya leaves which, if given enough time would disappear (potential disappearance), was 93%, followed by that of ficus (80%) and terminalia leaves (77%). The differences were significant ($P<0.05$).

3. Nitrogen disappearance

There were significant ($P<0.05$) differences among the disappearance rates and lag phases in the disappearance of nitrogen of the browses. The initial lag phase (6.60 h) in disappearance of terminalia leaves (Table 3.3), was the longest ($P<0.05$). Most of the nitrogen disappearance in terminalia leaves and ficus leaves occurred between 8 and 48 h (Figure 3.2). In contrast almost all of the nitrogen disappearance in chaya leaves occurred between 4 and 24 h. Chaya leaves also had the shortest lag phase, 1.1 h ($P<0.05$).

As noted earlier, the presence of nitrogen in a forage does not always guarantee its availability to the rumen microbes. It is influenced by the pattern of its release and the outflow rate from the rumen (Orskov and Robinson, 1981). Balancing the rate of supply of nitrogen and energy yielding substrates to rumen micro-organisms ensures maximization of the capture of rumen degradable nitrogen. It also leads to the optimization of microbial growth and efficiency by ensuring the synchronous release of nitrogen and energy.

Based on the release of organic matter from the cassava peels, the three supplements were assessed as to their ability to release nitrogen in synchrony with the fermentation of organic matter from the cassava peels. The ARC (1980) estimated that the required ratio of nitrogen released in the rumen (rumen degradable nitrogen) to rumen degradable organic matter for

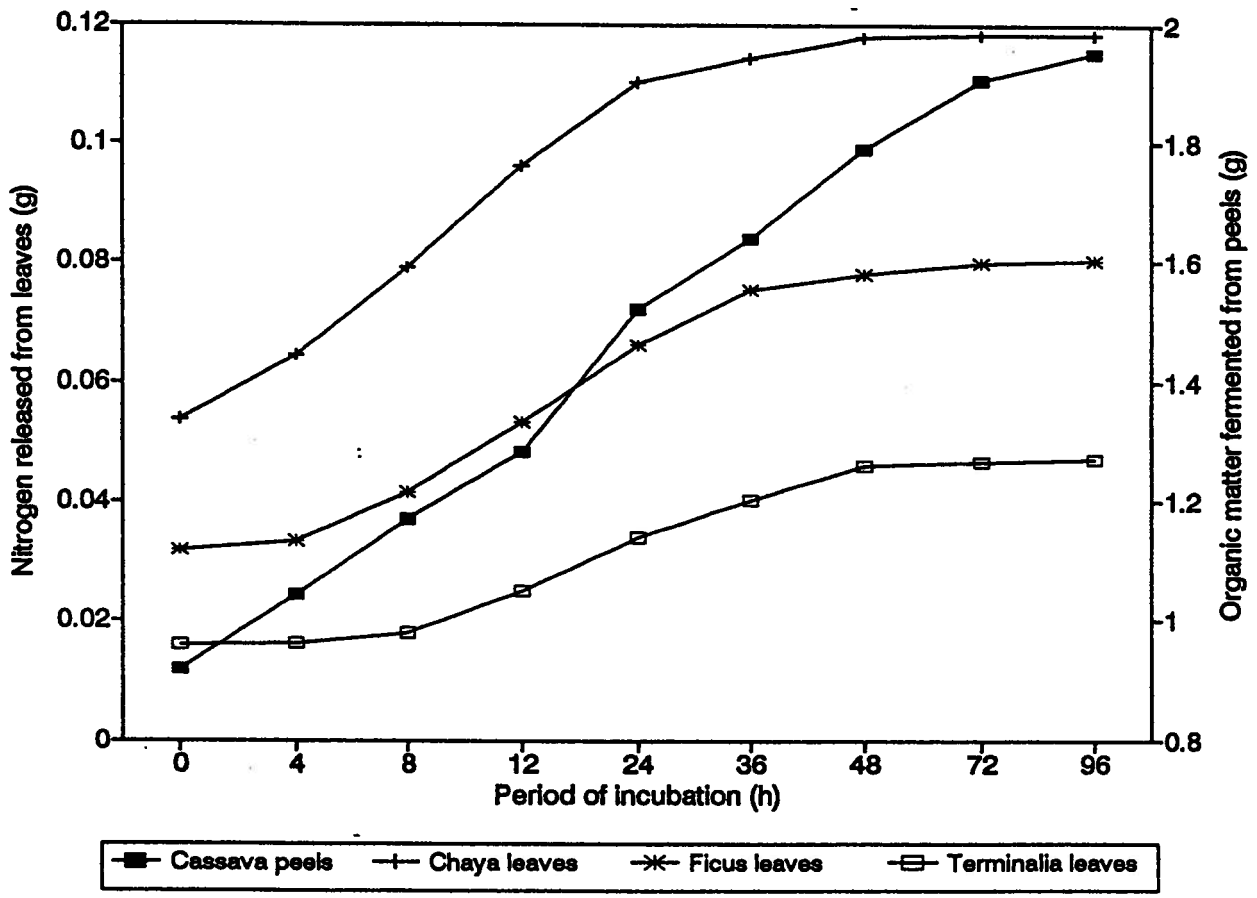


Figure 3.2. Fermentation of organic matter in cassava peels and release of nitrogen from leaves of chaya, ficus and terminalia in the rumen of sheep.

optimum microbial synthesis was 1:33. An examination of the degradation characteristics of the three forages and that of cassava peels indicated that ficus leaves would be a suitable supplement to cassava peels because the rate of release of nitrogen from the degradation of the ficus leaves would match the rate of degradation of the organic matter in the peels. This would ensure synchrony in the release of energy and nitrogen.

The ratio of nitrogen released from terminalia leaves to organic matter fermented from the cassava peels between 4 and 12 h of incubation was always more than 1:60. Even at 72 h the ratio was 1:40. This clearly indicates that if terminalia leaves were fed as the sole nitrogen supplement with a cassava peel based diet, the organic matter from the cassava peels may not be efficiently utilized due to an inadequacy of nitrogen released. However, the long lag phase and its slow rate of degradation could make terminalia leaves a potential by-pass protein source. But if it is to be used as a supplement to provide nitrogen to the rumen microbes it may not be the ideal supplement. The release of nitrogen from the chaya leaves on the other hand was too rapid compared to the release of organic matter from the cassava peels. If chaya leaves and cassava peels were fed together, it could lead to a situation where the rumen microbes may not get enough energy from the organic matter released to make efficient use of the nitrogen released from the chaya leaves (the ratio of nitrogen released from chaya leaves to organic matter fermented from the cassava peels was 1:15.5 or less). Part of the excess nitrogen could be lost in the urine (Kennedy and Milligan, 1980).

E. Conclusions

Under the prevailing Ghanaian conditions, the provision of nitrogen to ruminants is expensive; therefore, everything possible must be done to avoid wastage. Among the tree leaves only ficus leaves appeared to be suitable in terms of supplying nitrogen in synchrony with the fermentation of organic matter in cassava peels. During the initial phases of the degradation i.e. during 4 and 8 h of incubation the ratio of nitrogen released to organic matter fermented was about 1:30. This value fell to 1:23 at 24 h.

As noted earlier the leaves of *Ficus exasperata* have traditionally been fed to livestock in Ghana and is found in relative abundance on the outskirts of cities and towns in Ghana; so, based on its nitrogen content, degradation characteristics and availability, it was selected as the supplement for sheep on a cassava peel-based diet.

CHAPTER 4 MICROBIAL DIGESTION OF CASSAVA PEELS AND FICUS LEAVES

A. Introduction

The voluntary intake and digestion of low quality feedstuffs by ruminants depends to a large extent on the rate of feed degradation in the mouth and forestomachs. Particles longer than 1 mm are selectively withheld for a longer time in the forestomachs, and this reduces the possibility of renewed feed intake (Nicholson, 1984; Minson, 1985). The reduction in particle size is accomplished principally through chewing during ingestion and rumination, and to a lesser extent, microbial degradation. Generally, microbial digestion proceeds best when degradable organic matter, and nitrogen and minerals in the rumen, are present in sufficient quantities throughout the day (Kellaway and Leibholz, 1983). It is therefore important that the microbes in the forestomachs are provided with an environment conducive for their function. This is more so because their growth results in an important, and often, the main source of protein for the host animal (Orskov, 1989).

Most methods of feedstuff improvement aim at altering the feedstuff to increase degradation or creating favourable conditions within the rumen to increase digestion and subsequently improve intake. Several aspects of roughages including solubility, potential digestibility and rate at which the insoluble components are fermented contribute to the feeding value of the roughage. Alkali treatment of straw for example, increases the rate of degradation of straw samples incubated in nylon bags in the rumen. In addition, the degradation of untreated straw is improved when it is incubated in the rumen of animals given alkali-treated straw compared with those given untreated straw because of an increase in digestible celluloses and hemicelluloses (Silva and Orskov, 1987). Wagner (1989) also demonstrated that legume supplementation of grass diets with less than 7% crude protein increased digestion, dry matter intake and animal performance.

Orskov *et al.* (1983) demonstrated differences in degradation of protein supplements in sheep which received either concentrate or hay diets. Also, protein supplements of vegetable origin, e.g. soybean meal and groundnut meal, were degraded more slowly in animals given a high-concentrate compared with a high-roughage diet. Therefore the degradation of feed substances in the rumen appears to be profoundly affected by the environment within the rumen.

Devendra (1988) suggested that the optimum dietary level of proteinaceous forages should be 30-50% of diet dry matter or 0.9-1.5% of liveweight. Therefore, in the determination of the optimum feeding level of *Ficus exasperata* as a supplement, it was necessary to evaluate first, the effect of level of supplementation on the rumen environment.

Most methods of feedstuff evaluation have routinely involved laboratory analyses of various chemical fractions in an effort to develop relationships between the chemical fractions and nutritive value. The relevance of some routine measurements are difficult to justify because animal performance cannot be reliably predicted from chemical analyses (Orskov and Reid, 1989).

The critical role of micro-organisms in degradation of feedstuffs, and the myriad of factors which affect their activity makes it imperative that whenever possible, feedstuffs must be evaluated within the rumen environment. Measurement of the degradation characteristics of feedstuffs using the nylon bag technique (Orskov and McDonald, 1979) was chosen as the method of evaluation of the different rumen environments because the exponential equation used in the description of the degradation curve has important biological attributes. Each of the factors in the exponential equation has some relationship with animal performance through their effect on voluntary feed intake. The general form of the equation is given as:

$$P = a + b(1-e^{-ct}) \text{ where;}$$

"P" is the amount of the feedstuff or a portion of a nutrient in the feedstuff which disappears or is degraded at time "t", "a" is the immediately soluble or fraction which disappears rapidly, "b" is

the insoluble but degradable fraction (slowly disappearing fraction), "e" is the base at the natural logarithm, and "c" is the fractional rate of degradation or disappearance of "b". The immediately soluble fraction "a", occupy little space in the rumen and therefore reduces rumen "fill"; (100-(a+b)) the totally undegradable material determines the amount which will occupy space in the rumen at all times and therefore contributes to rumen "fill". The rate constant "c" determines the time during which the degradable portion occupies space in the rumen. The method is therefore a useful diagnostic tool in feedstuff evaluation.

The objective of the present study was therefore to determine the influence of level of supplementation of leaves from *Ficus exasperata* on the degradation characteristics of dry matter and nitrogen of both cassava peels and ficus leaves in nylon bags incubated separately in the rumens of sheep on a cassava peels-based diet.

B. Materials and Methods

1. Animals and feeding

Six Djallonke wethers (body weight 33 ± 2.7 kg) fitted with permanent ruminal cannulae were used in the following experiment. Animals were kept in individual pens with wooden slatted floors. Each animal had *ad libitum* access to sun-dried cassava peels and water. In addition each animal was given one of the following levels of sun-dried ficus leaves; 0, 50, 100, 150, 200, or 250 g per day on an as-fed basis. The daily allowances of ficus leaves were offered in two equal portions at 08.30 and 16.30 hours.

2. Incubation procedure

After a 14-day adaptation period, the six animals were used in a randomized incomplete block experimental design to investigate the effect of level of ficus leaf supplementation on the rumen degradation characteristics of cassava peels and ficus leaves.

Samples of cassava peels and ficus leaves were milled to pass through a 2.5 mm screen. Duplicate samples of each feed (4 g) were placed in separate nylon bags (53 μm pore size, 5 cm x 20 cm; Ankom, Fairport, New York) and incubated in the rumen of each animal during each incubation period. The four bags (two containing each feed type) were inserted in the rumen of each animal just before the morning feeding. Each set of four bags was withdrawn from the rumens after 2, 4, 6, 9, 12, 24, 48, 72, and 96 h of incubation.

Immediately after removal, bags were immersed in a plastic bucket of cold water and gently washed by hand under running tap water until the water from the bags was clear. The bags and contents were then dried at 60°C to constant weight in a forced draught oven. Dry matter and nitrogen disappearance from each bag were measured. Dry matter and nitrogen were analyzed according AOAC (1985) procedures. A duplicate set of bags containing samples of cassava peels and ficus leaves were immersed in water at 39°C for 1 h and treated as above. This was used as an estimate of 0 h disappearance.

The above incubation procedure was repeated once after re-randomization of the level of ficus leaf supplementation among the animals. Animals were given another 2 wk to adapt to their new experimental diets before incubations started.

3. Calculations and statistical analyses

The DM and N losses from each bag were fitted to a modified version of the exponential model of Orskov and Mcdonald (1979) with a lag phase:

$$p = a + b(1-e^{(-c(t-lag))}) \text{ for } t > lag; \qquad [1]$$

where p is the disappearance (%) after t hours, a is the fraction which disappears rapidly, b is the slowly disappearing fraction, c is the fractional rate of disappearance (%/h) of fraction b, and t is time (h) of incubation. The a, b, c and lag were estimated by an iterative least-square procedure (Appendix 3.1) with the SAS (1990) software package. Effective disappearance (EFFD) was

then calculated from the estimates of a, b and c assuming a fractional outflow rate of solids from the rumen (kf) of 0.06% h^{-1} using the following equation:

$$EFFD = a + (((bc)e^{(clag)}) / (c + kf))e^{(-(c + kf)lag)}; \qquad [2]$$

where a, b and c are as defined in equation [1]. The potential degradation or disappearance of a component such as dry matter or nitrogen was calculated as the sum of the a and b fractions of that component i.e. (a+b).

The rumen degradation characteristics of cassava peels and ficus leaves were analyzed as separate experiments using a randomised incomplete block design with animals as blocks and level of supplementation as treatments. The model used was:

$$Y_{ij} = \mu + \beta_i + \tau_j + \varepsilon_{ij}; \qquad [3]$$

where Y_{ij} represents an observation on the ith animal, β, (i = 1 to 6), receiving the jth treatment, τ, (j = 1 to 6). The overall mean was expressed as μ, and the residual error as ε_{ij}. The General Linear Model of the Statistical Analysis Institute (SAS, 1990) was used for the analysis. Whenever the model was significant, mean differences between treatments were determined with Tukey's studentized range test (HSD).

C. Results and Discussion

The average daily intake of dry matter by the animals was 1.2 kg (± 0.33 kg). The cassava peels consumed contained 94% organic matter, 58% neutral detergent fibre and 1.2% nitrogen on DM basis. The ficus leaves contained 3.3% nitrogen and 54% neutral detergent fibre.

1. Degradation of dry matter and nitrogen in cassava peels

The degradation characteristics of cassava peels and ficus leaves incubated in the rumens of sheep receiving different levels of ficus leaf supplementation are presented in Tables 4.1 and

Table 4.1. Rumen degradation characteristics of dry matter and nitrogen of cassava peels in sheep receiving different levels of ficus leaves as supplement.[2]

Characteristic	Level of supplement (g d^{-1})						
	0	50	100	150	200	250	SEM[4]
Dry matter[3]							
a (%)	12.8^{a}	14.3^{b}	15.8^{c}	17.1^{d}	18.9^{e}	18.1^{f}	0.31
b (%)	43.1^{a}	41.7^{b}	44.0^{c}	46.4^{d}	48.8^{e}	50.1^{f}	0.32
c (%/h)	0.093^{c}	0.096^{bc}	0.086^{d}	0.109^{a}	0.093^{c}	0.102^{b}	0.002
a + b (%)	55.9^{d}	56.0^{d}	59.8^{c}	63.4^{b}	67.7^{a}	68.2^{a}	0.63
lag (h)	1.5^{a}	1.3^{a}	1.5^{a}	1.5^{a}	1.8^{b}	1.4^{a}	0.023
Nitrogen[3]							
a (%)	13.7^{c}	14.0^{c}	14.3^{c}	16.2^{b}	17.1^{ab}	17.5^{a}	0.23
b (%)	39.4^{c}	39.3^{c}	43.9^{b}	44.8^{b}	46.8^{a}	46.7^{a}	0.31
c (%/h)	0.070^{d}	0.089^{cd}	0.076^{d}	0.125^{a}	0.103^{bc}	0.119^{ab}	0.005
a+b (%)	53.1^{d}	53.3^{d}	58.2^{c}	61.0^{b}	63.9^{a}	64.2^{a}	0.54
lag (h)	4.4^{b}	4.4^{b}	4.1^{b}	5.3^{a}	4.1^{b}	4.4^{b}	0.18

[2]Rumen degradation constants and potential disappearance of DM and nitrogen were calculated from the following equation, a modified version of the Orskov and McDonald (1979) model: $p = a + b(1-e^{(-c(t-lag))})$ for $t > lag$ where; a = rapidly disappearing fraction; b = slowly disappearing fraction; c = rate constant of b and; a+b = potential degradability or disappearance.

Number of observations per treatment = 4.

[3]Means within rows with different superscripts are significantly different, ($P<0.05$).

[4]Standard error of the pooled mean.

Table 4.2. Rumen degradation characteristics of dry matter and nitrogen of ficus leaves in sheep receiving different levels of ficus leaves as supplement.[2]

Characteristic	Level of supplement (g d^{-1})						
	0	50	100	150	200	250	SEM[4]
Dry matter[3]							
a (%)	15.7^{c}	15.7^{c}	15.7^{c}	16.7^{b}	17.5^{a}	17.2^{a}	0.11
b (%)	56.8^{e}	57.5^{de}	58.1^{cd}	58.4^{c}	59.5^{b}	61.5^{a}	0.18
c (%/h)	0.028^{c}	0.027^{dc}	0.027^{d}	0.066^{b}	0.075^{a}	0.076^{a}	0.0003
a + b (%)	72.5e	73.2^{d}	73.8^{d}	75.1^{c}	77.0^{b}	78.7^{a}	0.29
lag (h)	3.7^{a}	3.6^{ab}	3.5^{ab}	3.6^{ab}	3.5^{ab}	3.5^{ab}	0.04
Nitrogen[3]							
a (%)	14.7^{d}	12.9^{e}	13.5^{de}	18.2^{c}	21.6^{d}	22.8^{a}	0.28
b (%)	47.9^{e}	52.4^{b}	55.1^{a}	51.9^{bc}	50.1^{d}	51.3^{c}	0.25
c (%/h)	0.185^{a}	0.133^{c}	0.122^{c}	0.159^{b}	0.186^{a}	0.162^{b}	0.0046
a+b (%)	62.6^{f}	65.3^{e}	68.2^{d}	70.1^{c}	71.7^{b}	74.1^{a}	0.53
lag (h)	5.2^{a}	2.1^{d}	2.1^{d}	3.2^{c}	3.9^{b}	3.3^{c}	0.12

[2]Rumen degradation constants and potential disappearance of DM and nitrogen were calculated from the following equation, a modified version of the Orskov and McDonald (1979) model: $p = a + b(1-e^{(-c(t-lag))})$ for $t > lag$ where; a = rapidly disappearing fraction; b = slowly disappearing fraction; c = rate constant of b and; a+b = potential degradability or disappearance.

Number of observations per treatment = 4.

[3]Means within rows with different superscripts are significantly different, ($P<0.05$).

[4]Standard error of the pooled mean.

4.2. Ficus leaf supplementation significantly increased ($P<0.05$) the rapidly disappearing fraction and the potentially degradable fraction of the DM in cassava peels. The values for the rapidly disappearing, slowly disappearing and potentially degradable DM fractions from cassava peels incubated in animals which received no supplement were 12.8%, 43.1% and 55.9% respectively; compared with 18.1%, 50.1% and 68.2% in animals which received 250 g d^{-1}. Similarly, the rapidly disappearing, slowly disappearing and potentially degradable nitrogen fractions from cassava peels in the rumens of animals which did not receive any supplement were 13.7%, 39.4% and 53.1%, respectively compared to 17.5%, 46.7% and 64.3% in animals which received 250 g d^{-1} of ficus leaves. The potentially degradable fraction of cassava peels was raised ($P<0.05$) from 55.9% (no supplementation) to 68.2% (250 g d^{-1} of ficus leaves). The greater ruminal disappearance of DM and nitrogen of cassava peels as a result of increases in the level of ficus leaf supplementation underscores the importance of creating a conducive rumen environment for the digestion of low quality feedstuffs. It also lends support to the use of supplementation as a method of improving the digestibility of low quality feedstuffs. Appropriate supplementation would usually lead to the development of a microbial population that is suitable for the digestion of the ingested feedstuffs.

There was no consistent trend in the influence of level of supplementation on the lag phase in the disappearance of DM and nitrogen in cassava peels. The lag in the degradation of DM in the rumen of animals which received 200 g d^{-1} of ficus leaves was higher (1.8 h; $P<0.05$) than all the other treatments. The differences between the others were not significant ($P>0.05$). The reason for the long lag phase in the disappearance of DM in rumen of animals which received 200 g d^{-1} of ficus leaves was not apparent.

There was also no consistent trend in the effect of level of supplementation on the rate of disappearance of the slowly degradable DM fraction. However, the rate of disappearance of the nitrogen in cassava peels increased significantly ($P<0.05$), with increasing level of ficus leaf supplementation. The lowest rate of disappearance was observed in animals which did not receive any supplement (0.07% h^{-1}). The fastest rate of disappearance (0.125% h^{-1}), observed in

animals which received 150 g d^{-1} of ficus leaves, was significantly ($P<0.05$) higher than the value of 0.103% h^{-1} observed in animals which received 200 g d^{-1} of ficus leaves.

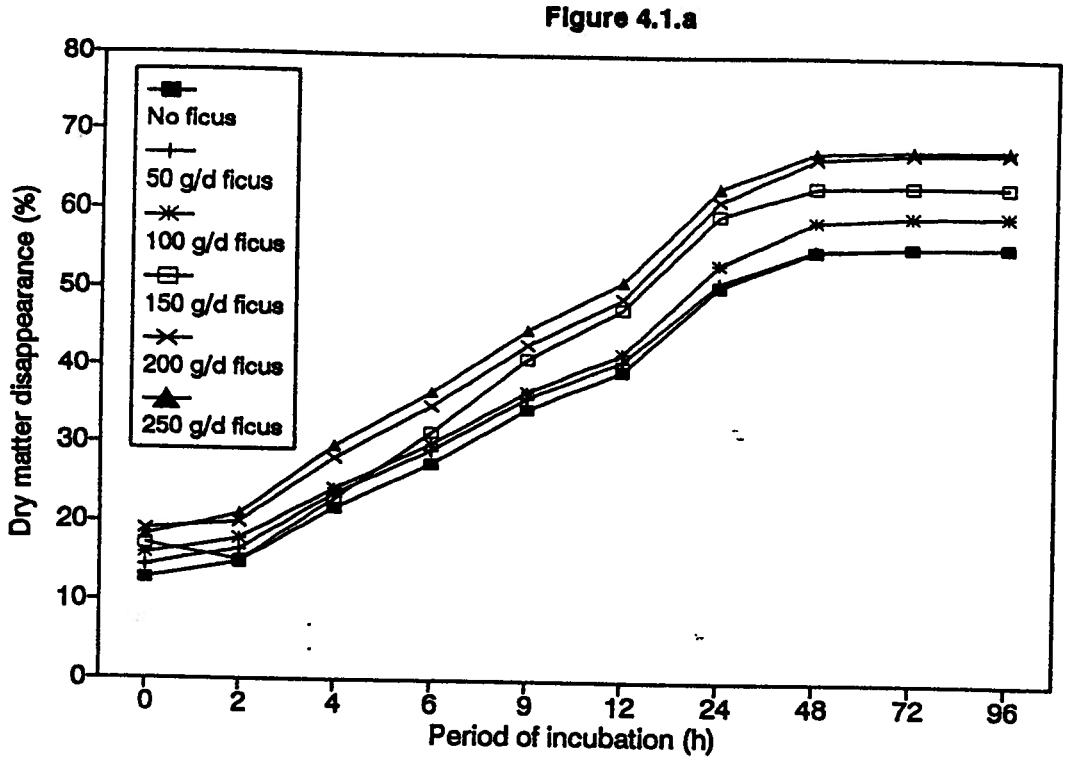
2. Degradation of dry matter and nitrogen in ficus leaves

The rapidly and slowly disappearing fractions of DM in ficus leaves were significantly ($P<0.05$) affected by the level of ficus leaves supplementation. The rapidly disappearing fraction of the DM from ficus leaves incubated in the rumen of animals which did not receive any supplement and those which received 50 and 100 g d^{-1} was 15.7%. Values from the rumen of animals which received 200 and 250 g d^{-1} were not significantly different ($P>0.05$) from each other (17.5% and 17.2%); but both were significantly higher than those which received 150 g d^{-1}.

The rapidly disappearing fraction of nitrogen was also influenced by the level of supplementation; from a low level of 12.9% for animals on 50 g d^{-1} to 22.8% for animals on 250 g d^{-1}. The potentially degradable nitrogen fractions increased from 62.6% in animals which did not receive any supplement to 74.1% in animal that received 250 g d^{-1}.

The increase in the lag phase of the disappearance of nitrogen in ficus leaves with increasing level of supplementation could be due to the difference in nitrogen contents of the basal feed and the ficus leaves incubated (Chapter 3, Tables 3.1 and 3.2). The incubation of ficus leaves with its higher level of nutrients (in a rumen environment deficient in these nutrients), would probably lead to some diffusion of the nutrients from the ficus leaves which would act as chemo-attractants for the rumen microbes (Orpin and Letcher, 1978). This could lead to a faster rate of colonization and/or establishment of microcolonies and digestion of the ficus leaves in the nutrient "deficient environment" compared to the other treatments with appreciable levels of these nutrients in the rumen as a result of ficus leaves supplementation. However, this faster rate of colonization and initiation of digestion would not necessarily lead to a higher and/or sustainable rate of degradation because of the eventual depletion of nutrients.

Irrespective of level of supplementation, maximum DM and nitrogen disappearance from cassava peels (Figures 4.1.a and 4.1.b) and ficus leaves (Figures 4.2.a and 4.2.b) occurred about 48 h post incubation. Very little change in disappearance of DM and nitrogen occurred after 48



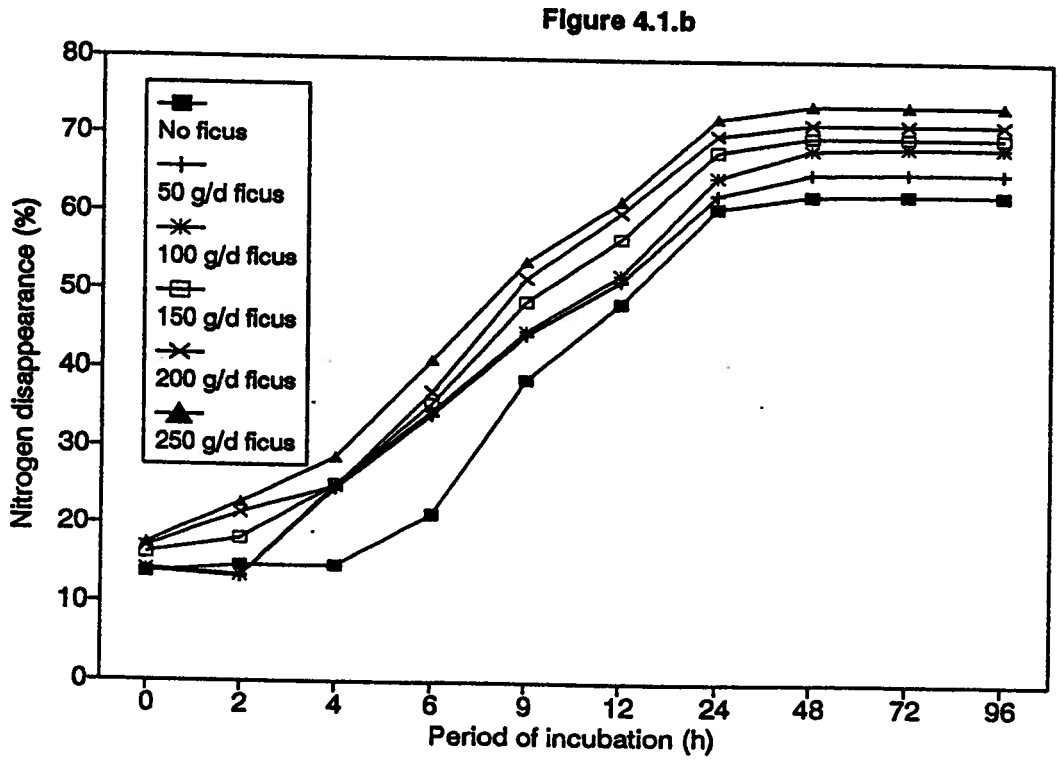


Figure 4.1.a. Dry matter disappearance (%) from cassava peels incubated in rumen of sheep consuming cassava peels *ad libitum* and graded levels of ficus leaves.
Figure 4.1.b. Nitrogen disappearance (%) from cassava peels incubated in rumen of sheep consuming cassava peels *ad libitum* and graded levels of ficus leaves.

Figure 4.2.a

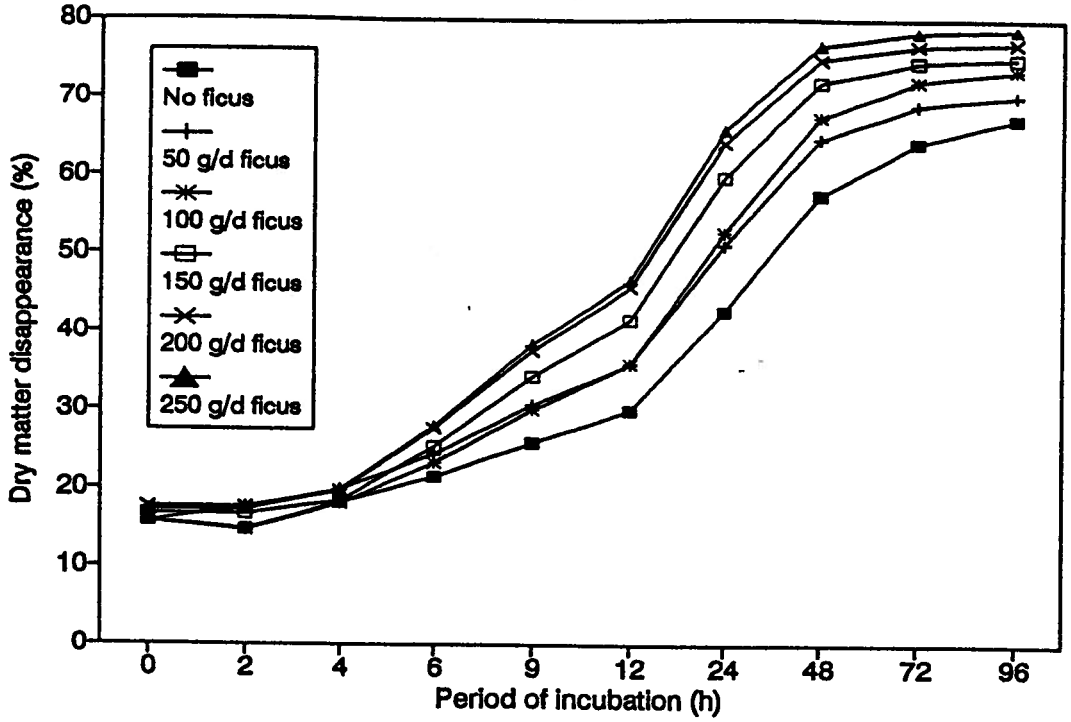


Figure 4.2.b

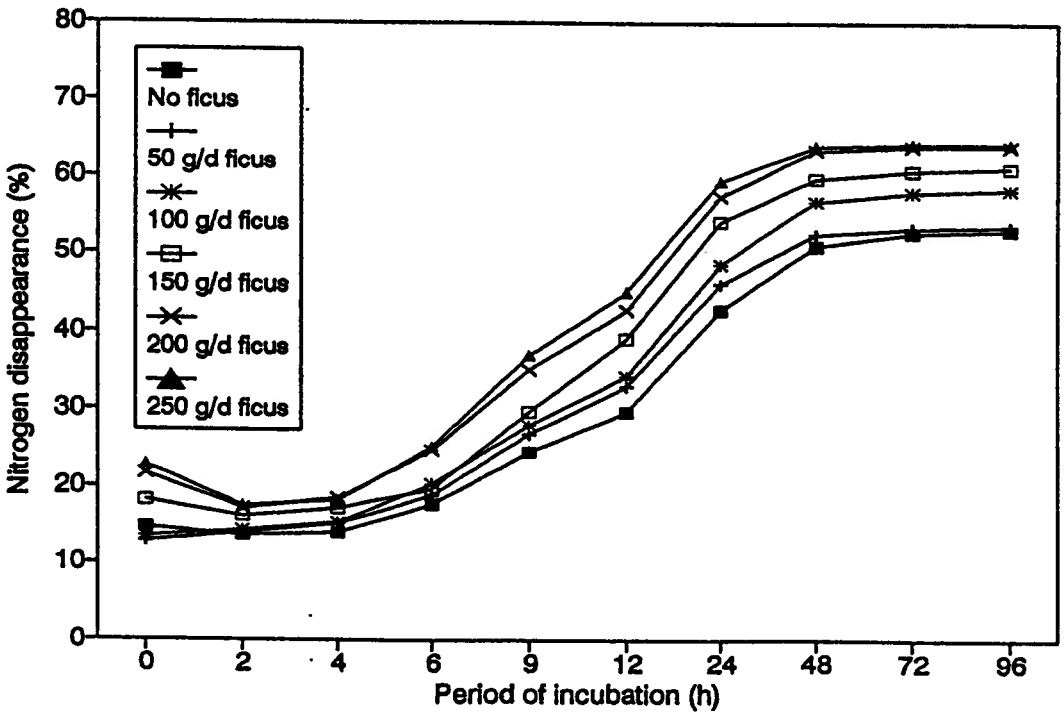


Figure 4.2.a. Dry matter disappearance (%) from ficus leaves incubated in rumen of sheep consuming cassava peels *ad libitum* and graded levels of ficus leaves.
Figure 4.2.b. Nitrogen disappearance (%) from ficus leaves incubated in rumen of sheep consuming cassava peels *ad libitum* and graded levels of ficus leaves.

h. This is in agreement with Negi *et al.* (1990) and Veereswara Rao *et al.* (1993) who also reported maximum disappearance of DM and nitrogen at 48 h in tree forages incubated in nylon bags in sheep rumen.

The difference between the rate of disappearance of the slowly disappearing nitrogen fractions in ficus leaves and cassava peels could be due to the nature of the protein substrates in ficus leaves and cassava peels and the effect of the proteolytic activity in the rumen. Hazlewood *et al.*, (1983) reported that the nature of the protein substrate in the basal diet influences the proteolytic activity in the rumen. They observed that hydrolysis of leaf Fraction I protein was stimulated relative to casein, when fresh fodder was used as a supplement, compared to a diet consisting of hay and concentrates. Nugent *et al.*, (1983) also made similar observations. They reported that fresh herbage promoted an activity up to nine times higher than that found with dry rations.

D. Conclusions

The present results show that supplementation of a cassava peel-based diets with small quantities of ficus leaves could improve the rumen environment. The study also indicated that the nylon bag technique is a useful tool in feedstuff evaluation which should be employed in the study of rumen environments.

The composition of a feed, its rate and extent of degradation and the characteristics of the rumen environment are indicative of the nutritive value of the feed. However, the ultimate criterion for the selection of one feed over another is the performance of animals. Long term feeding trials are therefore required to fully evaluate and determine the ultimate supplementation level of ficus for sheep.

CHAPTER 5 EFFECT OF SUPPLEMENTATION WITH GRADED LEVELS OF FICUS LEAVES ON THE UTILIZATION OF CASSAVA PEELS BY SHEEP.

A. Introduction

This chapter describes the second experiment conducted to determine the optimum level of feeding ficus leaves to sheep given *ad libitum* access to dry cassava peels. The experiments were conducted to determine nutrient intake, *in vivo* digestibility and growth rate of sheep on the cassava peels-based diets.

The nutritive value of a feedstuff is an intrinsic characteristic which enables it to supply nutrients to meet all or part of the physiological requirements of the animal. Nutritive value can therefore be divided into four components; relative proportion of nutrients, the digestibility of the nutrients, the animal's voluntary intake and the metabolism of the products of digestion (Seone, 1983). Because of this, most procedures of feedstuff evaluation have routinely involved laboratory analysis, intake and digestibility of the feedstuff. In some cases the end products of digestion (e.g., volatile fatty acids and amino acids), have been quantified. It must, however, be noted that the performance of animals (e.g., growth rate or milk production) is the ultimate measure of the usefulness or quality of the feedstuff. The relevance of the other measurements, in most cases, lie in their ability to identify factors within the feed, which could either increase or reduce the performance of animals. The identification of such factors is required to develop appropriate strategies or techniques to promote the efficient utilization of the feed.

Most agricultural by-products are deficient in protein, essential minerals and in some cases have a high fibre content. The consequences of such a profile for ruminants are a low intake (1-1.25 kg dry matter/100 kg live weight), poor digestibility (30-45%) and, a low level of performance (Smith, 1993). Low intake and poor digestibility, which ultimately reflect in poor animal performance, could be due in part, to factors such as the high lignin content and its association with other cell wall carbohydrates, i.e. cellulose and hemicellulose (Van Soest, 1975).

Cassava peels have been evaluated by a number of workers as a feedstuff for sheep (Adebowale, 1981; Adegbola and Asaolu, 1986; Adegbola *et al.*, 1989), goats (Ifut, 1989), poultry (Osei *et al.* 1990) and pigs (Obioha and Anikwe, 1982). The results of the analysis of the chemical composition of cassava peels reported by the above researchers indicate the following chemical composition: dry matter (86.5 to 94.5%), organic matter (89.0 to 93.9%), crude protein (4.2 to 6.5%), neutral detergent fibre (34.3%) and lignin (8.4%). The protein and mineral content of the peels has in most cases been inadequate to support optimum rumen function and productivity in animals raised solely on this feedstuff (Ifut, 1989; Adegbola *et al.*, 1989; A. K. Tuah, personal communication). The efficient utilization of this abundant resource by ruminants in Ghana would require that the animals be provided with an appropriate supplement which would supply the deficient nutrients.

The study of the degradation characteristics of cassava peels in the rumen of sheep which received different amounts of the leaves of ficus as a supplement indicated that significant improvement in degradation could be achieved through supplementation (Chapter 4). By giving animals about 200 g d^{-1} of ficus leaves the potential dry matter degradability of cassava peels in the rumen could be increased from about 56% (no supplementation) to 68%. There were significant improvements in other rumen degradation characteristics as a result of increasing the level of ficus leaf supplementation. Even though the leaves are found in relative abundance their acquisition has its associated cost, i.e. labour and transportation. Hence the need to determine its optimum feeding level in order to avoid wastage and to reduce the overall cost of production of animals fed this supplement.

The overall objective of this experiment was therefore to use animal performance as the criterion to determine the optimum feeding level of ficus leaves when used as a supplement for sheep fed a cassava peels based diet. The specific objectives were to determine the effect of level of ficus leaf supplementation on voluntary feed intake, digestibility and liveweight gain of sheep given *ad libitum* access to cassava peels.

B. Materials and Methods

1. Feeds and experimental diets

Fresh cassava peels were obtained from "gari" processing factories in Kumasi. Fresh ficus leaves were harvested periodically from farms near the University. The fresh cassava peels and ficus leaves were sun-dried on concrete floors for 4-6 d. Both the intensity and duration of sunlight determined the duration of the drying period. The dried cassava peels and ficus leaves were then stored in bags until required for feeding. The cassava peels and ficus leaves were used to formulate the following dietary treatments:

T1 - cassava peels *ad libitum* + no supplement;
T2 - cassava peels *ad libitum* + 50g ficus leaves d^{-1};
T3 - cassava peels *ad libitum* + 100g ficus leaves d^{-1};
T4 - cassava peels *ad libitum* + 150g ficus leaves d^{-1};
T5 - cassava peels *ad libitum* + 200g ficus leaves d^{-1};
T6 - cassava peels *ad libitum* + 250g ficus leaves d^{-1}.

2. Animals and experimental design

Fortyd-eight Djallonke wethers and ewe lambs weighing an average of 13.5 kg (SD, 1.2 kg) were purchased from local producers, dewormed, vaccinated against PPR, dipped, and randomly allocated to the six dietary treatments. The group of animals on each dietary treatment was balanced in terms of sex and weight. Each animal was randomly allocated to one of 48 pens with wooden slatted floors.

The first 14 d of the experiment were used to adapt the animals to their experimental diets and pens. This was followed by a 14 wk period during which daily voluntary intake of cassava peels and liveweight gain of the sheep were determined. The daily allowance of ficus leaves was offered in two equal portions at 09.00 and 17.00 h. The peels and leaves were offered in separate feeding troughs. Fresh water was provided *ad libitum* everyday in large plastic buckets in the

pens. The entire experiment was divided into seven 2 wk experimental periods and all animals were weighed at the end of each fortnightly period during the entire experiment.

3. Sampling and analytical procedures

A grab sample of cassava peels and ficus leaves was obtained at each feeding and pooled over every 2 wk experimental period. Refused feed from each animal was weighed separately and subtracted from the amount offered the previous day to obtain the amount consumed. The refused feed was then sampled for chemical analysis and the rest discarded prior to each morning feeding. Two 5 d faecal grab samples were obtained from the rectum of each animal during the last two experimental periods (weeks 12 and 13). The two 5 d faecal samples from each animal were thoroughly mixed, dried at 60°C for 48 h in a forced draught oven and milled for subsequent laboratory analyses.

Samples of feed offered, feed refusals and faeces were analyzed for dry matter (DM), nitrogen and ash according to AOAC (1985) procedures. Neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and acid insoluble ash were analyzed with the methods of Goering and Van Soest (1970) as modified by Van Soest *et al* (1991).

4. Calculations and statistical analyses

Organic matter (OM) was calculated as the difference between the DM and total ash of the samples. Cellulose content was estimated from the difference between the ADF and the sum of lignin and acid insoluble ash. Hemicellulose was estimated as the difference between NDF and ADF (Van Soest *et al.*, 1991). Digestibility was estimated by the use of acid insoluble ash as an internal marker (Van Keulen and Young, 1977). A linear model was used to determine the effects of level of ficus leaf supplementation, experimental week, and sex of animal on intake and digestibility of nutrients and, growth rate of sheep. The model used was:

$$\chi_{ijk} = \mu + \tau_i + \beta_j + \omega_k + \omega\tau_{ik} + \varepsilon_{ijk} \text{ where;} \quad [1]$$

χ_{ijk} is an individual observation; μ is the overall mean; τ_i is the effect of ficus leaf supplementation; β_j is the effect of sex; ω_k is the effect of experimental week; $\tau\omega_{ik}$ is the interaction between ficus leaf supplementation and experimental week and ε_{ijk} is the overall error term. Significant differences between treatments were determined using Tukey's studentized range test (HSD). The liveweight (LW) of each animal used with regard to daily intake of nutrients was the average liveweight recorded at the beginning and end of each 2 wk period. The statistical programs used were all from SAS (1990).

C. Results and Discussion

Cassava peel refusals as a percentage of total offered, averaged 15.7% (range 10 to 20%). All animals consumed their allowance of ficus leaves within 2 h. One sheep on T1 died during week 12. Autopsy showed generalized edema. Another sheep on T4 was removed from the experiment because it was found to be pregnant. Therefore data on intake, digestibility and growth rate for these two treatments were based on seven observations instead of the eight for the other treatments.

1. Chemical composition

The chemical compositions of the cassava peels and ficus leaves are presented in Table 6.1. Acid detergent fibre, acid insoluble ash, cellulose and nitrogen contents of ficus leaves were higher than corresponding values in cassava peels. However, the cassava peels contained higher levels of NDF and ADL. The nitrogen content of the cassava peels was similar to values reported by Ifut (1989) and Osei (1990). It is interesting to note that the level of nitrogen and NDF was similar to the average of the samples analyzed and reported earlier (Chapter 3). This marginal level of nitrogen may, however, not be adequate for optimum intake and digestion of the basal

Table 5.1. Chemical composition of dry cassava peels and ficus leaves.

Component	Cassava peels	Ficus leaves
Proximate composition (%DM)		
Organic matter	91.1	83.8
Nitrogen	1.0	2.9
Neutral detergent fibre	57.4	43.9
Acid detergent fibre	28.4	36.5
Hemicellulose	29.0	7.4
Cellulose	20.8	31.1
Acid insoluble ash	2.6	3.4
Acid detergent lignin	5.0	2.0
Macro minerals (%DM)		
Calcium	0.7	4.4
Phosphorus	0.10	0.19
Magnesium	0.15	0.55
Sulphur	0.08	0.24
Micro minerals (ppm)		
Copper	11	10
Zinc	21	31
Manganese	86	51

diet. The critical level of nitrogen below which appetite is supposedly depressed is between 0.96 to 1.28% of diet dry matter, (Minson, 1982; Forbes, 1986).

The nitrogen content of the ficus leaves (2.9%) was higher than the values reported by Smith (1992) and Devendra (1992) for ficus leaves. The nitrogen content was also higher than values reported by Reed *et al.* (1990) for fodder trees such as *Acacia cyanophylla* and *A. Sieberana* but it was lower than the value reported in an earlier study (Chapter 3). Except for

sulphur and phosphorus the mineral content of the cassava peels appeared to be adequate for this class of sheep for the elements analyzed (NRC, 1985). Although the nitrogen/sulphur ratio (12.4:1) was within the recommended range of 10-13.5:1 (Bird, 1972) it should be noted that the sulphur content of the cassava peels (0.08%) was far below the recommended level of 0.14% (NRC, 1985) for animals of this age and physiological stage.

2. Feed intake

Daily intake of DM and nitrogen, and the average daily growth rate of sheep on each of the dietary treatments are given in Table 5.2. Supplementation significantly increased ($P<0.05$) total intake of DM and nitrogen. Mean daily total DM intake ranged from 44.0 g kg^{-1} $LW^{0.75}$ for animals on T1 to 81.2 g kg^{-1} $LW^{0.75}$ for animals on T6. Daily nitrogen intake increased from 0.44 g kg^{-1} $LW^{0.75}$ by animals on T1 to 1.33 g kg^{-1} $LW^{0.75}$ by those on T6. The differences in DM intake between animals on the different treatments were significant ($P<0.05$). The only exception was the difference between animals on T5 and T6. The low DM intake by sheep on T1 and T2 could have been due to the low level and poor balance of certain nutrients especially nitrogen and sulphur. As suggested by Preston and Leng (1986), an imbalance or inadequacy of nutrients would reduce rumen ammonia production and microbial growth and activity. This would indirectly slow down the rates of digestion and passage and subsequently reduce intake. Total daily DM intake by animals on T3, T4, T5 and T6 were all above the "expected intake" value of 58.9 g kg^{-1} $LW^{0.75}$ for this class of animals (NRC, 1985). Total DM intake increased from 2.44% of body weight for animals on T1 to 3.65% for those on T5.

The influence of level of supplementation on intake of the basal ration (cassava peels) was determined on the basis of OM intake (Figure 5.1). There was no significant ($P>0.05$) difference in consumption of the basal ration between animals on T1 and T2 or between those on T4, T5 and T6. The intake of OM from the basal ration rose from 41.2 g kg^{-1} $LW^{0.75}$ for animals which received no supplement to a maximum of 51.8 g kg^{-1} $LW^{0.75}$ for those which received 200 g/day of ficus leaves. Thereafter intake of cassava peels decreased (though not significantly, $P>0.05$)

Table 5.2. Daily intake of dry matter (DM) and nitrogen and growth rate of sheep fed cassava peels-based diets with graded levels of ficus leaves.

	Dietary treatment[1,3]						
	T1	T2	T3	T4	T5	T6	SEM[4]
Dry matter intake (g kg^{-1} $LW^{0.75}$)							
Total DM	44.0[a]	50.5[b]	63.8[c]	74.5[d]	78.7[e]	81.2[e]	2.44
Cassava peels	44.0[a]	43.6[a]	49.6[b]	55.1[c]	54.1[c]	53.8[c]	0.84
Total nitrogen	0.44[a]	0.63[b]	0.90[c]	1.11[d]	1.25[e]	1.33[f]	0.053
Avg. DM intake (g d^{-1})	289.6[a]	281.4[b]	406.0[c]	507.6[d]	590.7[e]	672.4[f]	24.16
Dry matter intake (% LW)[2]							
Cassava peels	2.44	2.40	2.56	2.55	2.55	2.38	0.013
Supplement	-	0.38[a]	0.72[b]	0.91[c]	1.10[d]	1.18[e]	0.013
Total	2.44[a]	2.78[b]	3.29[c]	3.47[d]	3.65[e]	3.57[e]	0.073
Initial live weight (kg)	13.06	13.02	13.60	13.50	13.50	13.60	0.039
Final live weight (kg)	11.89[a]	11.74[a]	12.35[a]	14.63[b]	16.18[c]	18.85[d]	0.429
Live weight gain (g d^{-1})	-11.9[a]	-13.1[a]	-12.8[a]	11.5[b]	27.5[c]	53.6[d]	2.53
Gain:Feed ratio	-0.04[a]	-0.05[b]	-0.03[c]	0.02[d]	0.05[e]	0.08[f]	0.003

[1] T1=cassava peels + no supplement; T2=cassava peels + 50g of ficus per day; T3=cassava peels + 100g of ficus per day; T4=cassava peels + 150g of ficus per day; T5=cassava peels +200g of ficus per day; and T6=cassava peels + 250g of ficus per day.

[2] LW= live weight

[3]Means within rows with different letters are significantly different ($P<0.05$).

[4]Standard error of the pooled means.

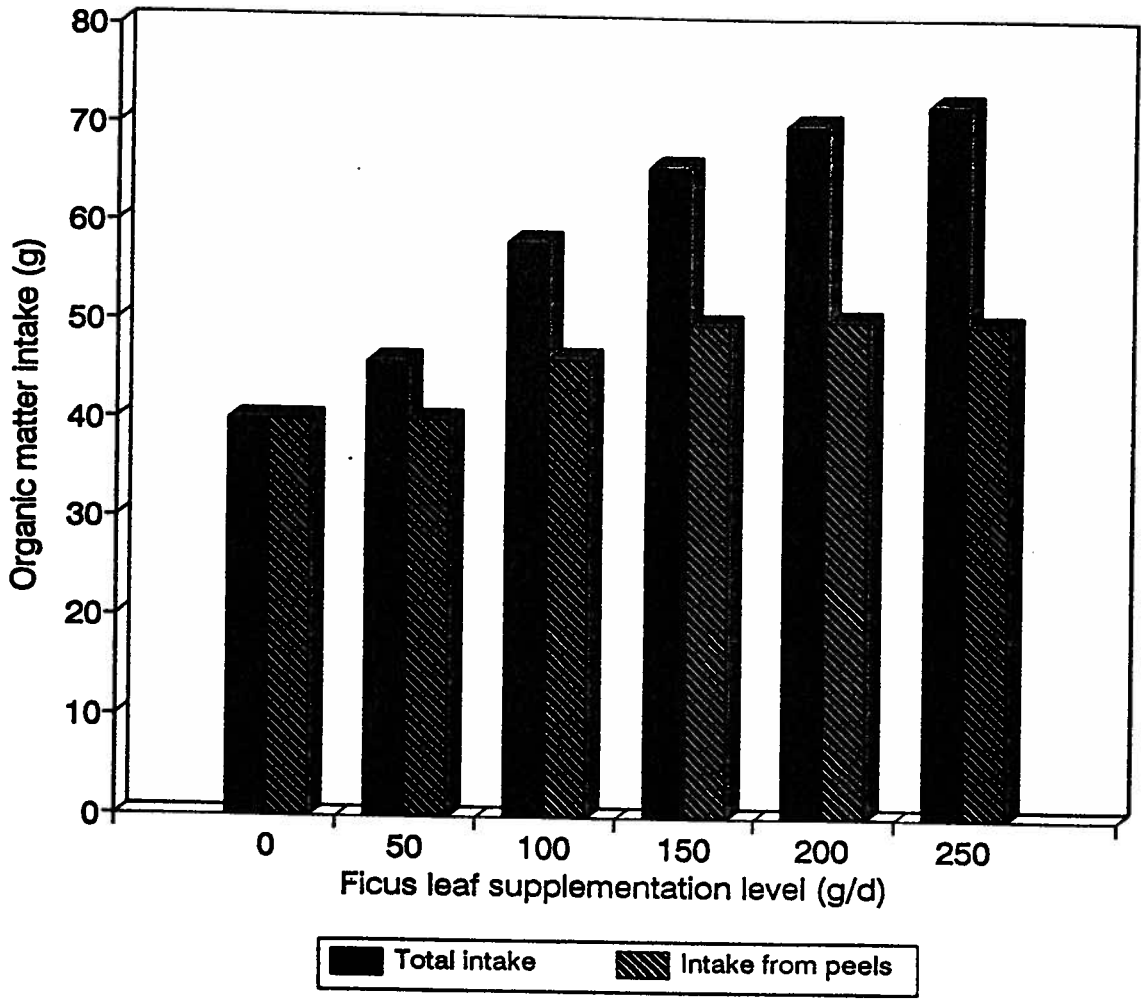


Figure 5.1. Effect of level of ficus leaf supplementation on daily voluntary intake ($g/kg^{0.75}$) of organic matter by sheep.

even though the total OM intake continued to increase. It is pertinent to note that about 26% of the total DM consumed by the animals on T4 was from the supplement (ficus leaves), while those on T5 and T6 consumed the supplement in excess of 30% of their total DM intake. Generally, asupplement consumed in excess of 30% of the dietary DM may not be an ideal supplement, it could be regarded as part of the basal diet.

When intake of the basal ration (DM intake) was expressed in relation to live weight there were no differences due to the level of supplementation. According to Veira *et al.* (1994) this is a better comparative measure of intake because it removes the variability caused by differences in live weight which result from increased gain due to treatment.

3. Apparent digestibility coefficients

Apparent digestion coefficients of nutrients are presented in Table 5.3. Increases in the level of ficus leaves supplementation significantly ($P<0.05$) depressed digestibilities of DM, OM and ADF of the diets. The apparent dry matter digestibility (DMD) and organic matter digestibility (OMD) coefficients of T1 and T2 were not significantly different ($P>0.05$). They were, however, significantly higher ($P<0.05$) than the coefficients for the other dietary treatments. The lower DMD and OMD coefficients for diets containing ficus leaves could have been due to either low digestibility of ficus leaves and/or the effect of higher intake and higher rumen rate of passage (Van Soest, 1982). The DMD and OMD coefficients observed in the present study are comparable to the 72.0 and 77.4 % reported by Ifut (1989) for goats fed cassava peels.

Supplementation increased ($P<0.05$) the coefficient of neutral detergent fibre digestibility (NDFD) from 48.7% (T1) to 55.3% (T4) and declined thereafter; probably the result of the interaction between intake and rumen clearance rate (Van Soest, 1982). Ifut (1989) also observed an improvement in digestibility of the NDF fraction of cassava peels as a result of supplementation. Supplementation apparently depressed ($P<0.05$) the digestibility of the acid detergent fibre (ADFD) fraction of the whole diet.

Nitrogen digestibility coefficients improved as a result of supplementation. The greatest effect of supplementation on nitrogen digestibility was observed in animals on T6. However, the difference between T6 and those on T4 and T5 were not significant (P>0.05).

A major limitation to the use of cassava peels and other low quality agricultural by-products is the low nitrogen content. Supplementary nitrogen has been shown to improve utilization in many experiments (Devendra, 1992; Reed *et al.*, 1990; Adegbola *et al.*, 1989; Mosi and Butterworth, 1985), but what constitutes an optimum level of supplementation is still a matter of conjecture. Horton and Holmes (1976) did not observe any responses by sheep on a low nitrogen diet to nitrogen supplementation. This may reflect the fact that even if feedstuffs are low in nitrogen there may be sufficient present for optimum utilization of the amount of energy

Table 5.3. Apparent digestion coefficients of cassava peels-based diets (%).

	Dietary treatment[1,2]						
Component	T1	T2	T3	T4	T5	T6	SEM[3]
Dry matter	78.1[a]	77.3[a]	74.8[b]	75.0[b]	73.9[b]	73.9[b]	0.27
Organic matter	81.4[a]	81.3[a]	79.1[b]	79.1[b]	77.9[b]	77.5[b]	0.25
Nitrogen	50.7[a]	56.8[b]	58.1[b]	68.7[bc]	69.2[c]	71.6[c]	1.28
Neutral detergent fibre	48.7[a]	50.8[b]	56.4[c]	55.3[c]	53.5[d]	52.5[d]	0.43
Acid detergent fibre	50.9[a]	48.7[a]	44.5[b]	46.4[b]	46.8[ab]	44.2[b]	0.39

[1] T1=cassava peels + no supplement; T2=cassava peels + 50g of ficus per day; T3=cassava peels + 100g of ficus per day; T4=cassava peels + 150g of ficus per day; T5=cassava peels +200g of ficus per day; and T6=cassava peels + 250g of ficus per day.

[2]Means within rows with different superscripts are significantly different (P<0.05).

[3]Standard error of the pooled means.

available (Orskov and Grubb, 1975). The amount of nitrogen available to support rumen fermentation depends, among other things, on the total quantity of nitrogen in the diet, the degradation of the nitrogen source in the rumen, the outflow rate from the rumen and nitrogen recycling.

In production trials it has been suggested that the maximum overall digestibilities of low quality feedstuffs can be achieved by supplementation with nitrogen to obtain a crude protein level of 7 to 8% of total diet dry matter (Allden, 1982). Broster *et al.* (1979) stated that intake and digestibility of dry matter of low quality diets was not affected when crude protein levels exceeded 8.5% of the dry matter of the diet. Other researchers have found that maximum fibre digestion in the rumen occurs with about 12% crude protein in the diet (Kropp *et al.* 1977; Pritchard and Males, 1985). McAllan *et al.* (1982) found that maximum digestion of dietary crude fibre in the rumen occurred when dietary crude protein was between 12 and 16%. It appears that the optimum level of dietary crude protein required depends on the basal diet. Based on the nitrogen intake in the present study, it appears that for sheep given *ad libitum* access to cassava peels the minimum daily intake of protein required for optimum OM and fibre (NDF) digestion is 5.6 g kg^{-1} $LW^{0.75}$ d^{-1}.

4. Weight gain

The level of ficus leaf supplementation significantly ($P<0.05$) improved live weight gain (Figure 5.2). Animals on T1, T2 and T3 lost weight throughout the experiment while those on T4, T5 and T6 steadily gained weight (Table 6.2). The mean growth rate of 53.6 g d^{-1} for sheep on T6 was the highest, followed by those on T5 (27.5 g d^{-1}) and T4 (11.5 g d^{-1}). The differences were significant ($P<0.05$). The highest growth rate observed in the present study was comparable to the 59 g d^{-1} reported for the same breed of sheep fed cassava peels supplemented with 20% gliricidia leaves (Adegbola *et al.*, 1989). The growth rates of animals on T4, T5 and T6 reflected the higher intake of these diets and the balance of essential nutrients provided by the higher level of ficus leaves supplementation. Once animals started gaining weight every gram of ficus leaf DM

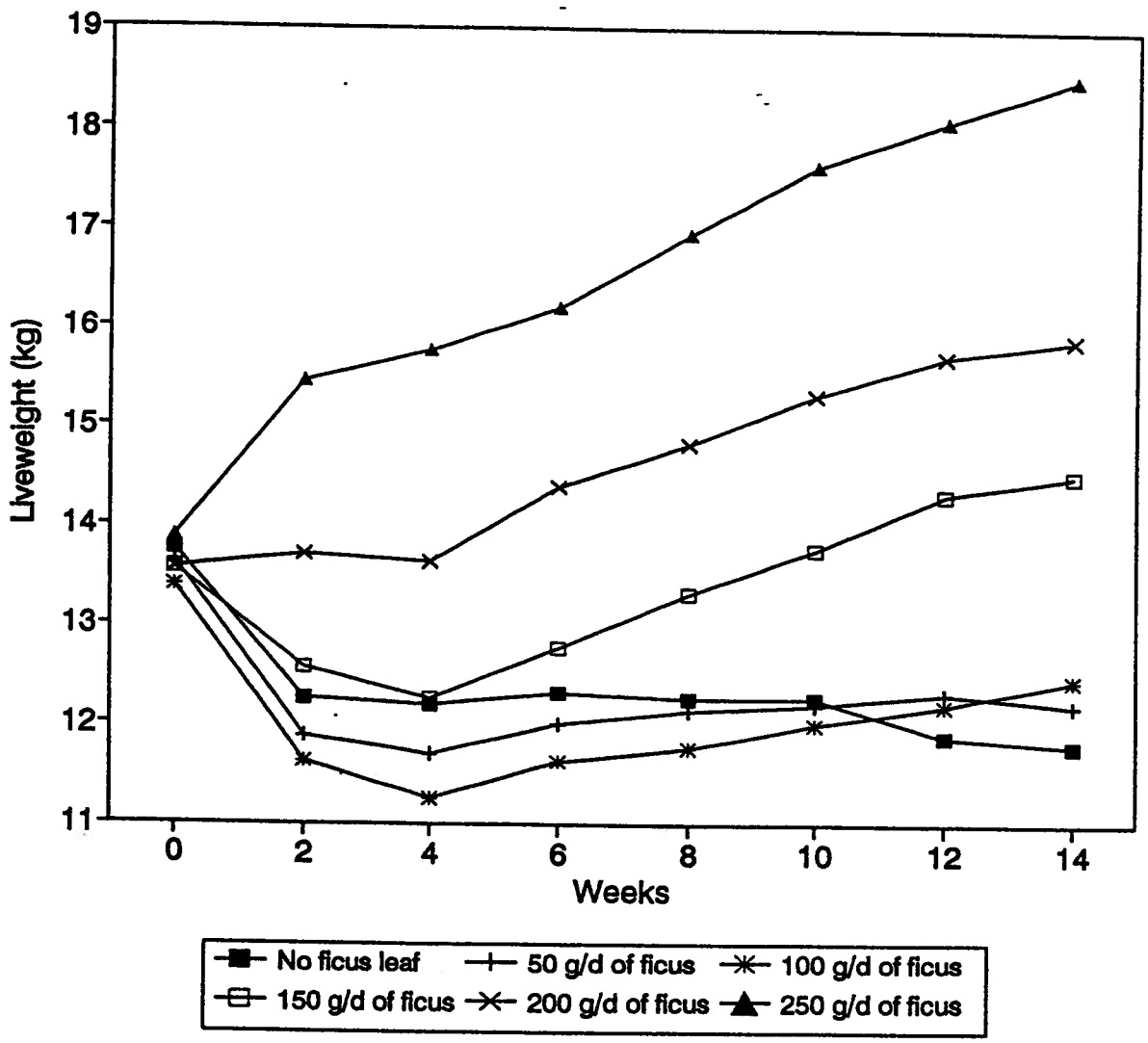


Figure 5.2. Effect of level of ficus leaf supplementation on liveweight changes in sheep.

intake resulted in approximately 0.48 g d^{-1} additional gain in weight. It appears that the supplementation of cassava peels with 150g of ficus leaves per day may be sufficient to prevent this class of sheep from losing weight.

Generally, the Djallonke breed has a low growth rate. Pre-weaning growth rate is about 60 g d^{-1} (Tuah and Baah, 1985). The average daily gain for the breed, at a comparable age (6-12 months) has been reported to be 25 g (Wilson, 1991). Therefore the average daily gains observed in animals on T5 and T6 are quite remarkable.

5. Prediction of nutritive value

The quest for a reliable and inexpensive technique to evaluate ruminant feedstuffs and also to predict animal performance has been a long one. The *in vitro* digestion procedure (Tilley and Terry, 1963); the number of chews required per unit of feed (Balch, 1969); the detergent fibre analysis system (Van Soest, 1982;) the *in vitro* gas production technique of Menke and Steingass (1988); grinding resistance (Minson, 1990) and particle density (Lechner-Doll *et al.*, 1990) are all recent examples of attempts to predict animal performance from feedstuffs. Even if all these methods were reliable, the laboratory conditions required would put them beyond the reach of most laboratories in the developing countries because of technical and economic difficulties. The nylon bag (*in sacco*) estimation of degradability has been suggested as an inexpensive and reliable method of estimating the feeding value of ruminant feedstuffs (Orskov and Reid, 1989). An attempt was therefore made to evaluate this method in terms of its ability to predict animal performance on the feedstuffs used in this study.

Data acquired in the present study on total dry matter intake, dry matter digestibility, organic matter digestibility and growth rate of animals on the different dietary treatments were individually regressed on degradation characteristics (i.e., A, the rapidly disappearing fraction in the feed; B=a+b, the potential degradation or disappearance; C, the rate constant and; the lag determined for cassava peels in the different rumen environments created by the different dietary

Table 5.4. Prediction of dry matter intake, dry matter digestibility, organic matter digestibility and growth rate in sheep from degradation characteristics[1]

Factors[a]	Y variable[b]	Prediction equation	r^2	P level[c]
B	DMI	Y= -1328.6 + 28.9B	0.981	0.0001
B+lag	DMI	Y= -1262.1 + 30.7B - 118.6lag	0.993	0.001
A	DMD	Y= 87.3 - 0.73A	0.914	0.002
A+C	DMD	Y= 84.8 - 0.77A +32.3C	0.932	0.02
B	OMD	Y= 97.3 - 0.29B	0.928	0.002
B+C	OMD	Y= 95.2 - 0.31B + 32.8C	0.950	0.01
B	GR	Y= -275.3 + 4.6B	0.854	0.009
A+B	GR	Y= -381.9 - 11.8A + 9.4B	0.929	0.019

[1]The equation was; $p = a + b(1-e^{(-c(t-lag))})$ for t > lag; where p is the disappearance (%) after t hours, a is the fraction which disappears rapidly, b is the slowly disappearing fraction, c is the fractional rate of disappearance (%/h), and t is time (h) of incubation.

[a] A=rapidly soluble or disappearing fraction of the feed determined by soaking the feed in water (39°C) for 1 h; B=insoluble but fermentable substrate (a+b)-A i.e. asymptote less the rapidly soluble fraction; C=rate constant of the degradation of B i.e. the same as c in the above equation.

[b] DMI=dry matter intake; DMD=*in vivo* dry matter digestibility; OMD=*in vivo* organic matter digestibility; GR=growth rate (g d^{-1}).

[c] Level of significance.

treatments determined in an earlier study) (Chapter 4). The regression procedures of the SAS (1990) were used.

The single most important degradation characteristic which was significantly correlated with all the variables measured (intake, digestibility and growth rate) was B, the potentially degradable fraction (Table 5.4). The predictive ability of B was improved in the case of dry matter

intake by adding the factor lag (from an r^2 of 0.98 to 0.99; $P<0.001$); in the case of organic matter digestibility by adding the factor C (from an r^2 of 0.93 to 0.95; $P<0.01$) and; in the case of growth rate by adding the factor A (from an r^2 of 0.85 to 0.93; $P<0.02$). Orskov and Ryle (1990) in experiments using the same principle reported r^2 values of 0.83, 0.70 and 0.84 using factor B alone to predict dry matter intake, dry matter digestibility and growth rate respectively. These r^2 values were improved to 0.89, 0.85 and 0.91 respectively by adding the factor C. In another study, Kibon and Orskov (1993) fed six browse species to goats in Nigeria and reported that adding the factor C improved the ability of B to predict dry matter intake (r^2=0.99), dry matter digestibility (r^2=0.88) and, growth rate (r^2=0.99). Characteristics of feedstuffs such as the solubility, the potential digestibility and the rate at which the insoluble part of the feed is fermented all contribute to the feeding value of the feedstuff in one way or the other. It is therefore not surprising that the contribution of each of these factors varied in importance in the predictive equations depending on what aspect of feeding value was being measured. For example the B fraction appears to feature prominently in all the predictive equations because it is the amount of the feedstuff digested and from which the animal would ultimately derive the bulk of it nutrients for its requirements if the A fraction was small.

The fact that each factor (A, B, C, or lag) included in the regression equations developed in the present study was statistically significant does not necessarily mean that they are the causal factors in the responses which were measured i.e. intake, digestibility and growth rate. Thus there is no direct evidence that B (the potentially degradable fraction in a feedstuff) for example, determines the total dry matter intake, organic matter digestibility and growth rate of sheep.

is no direct evidence that B (the potentially degradable fraction in a feedstuff) for example, determines the total dry matter intake, organic matter digestibility and growth rate of sheep. Voluntary intake, digestibility and growth are complex physiological processes which are influenced by combinations of factors in feedstuffs and in animals. Therefore, the significance of these statistical relationships lie in their ability to identify some of these factors which could then be utilized in the development of models to explain and predict the physiological processes.

D. Conclusions

The results of the study indicated that feeding 150g d^{-1} of ficus leaves to sheep will elicit optimum response in terms of dry matter intake of a basal diet of cassava peels, and digestibility of the nutrient fractions in the total ration. Moderate growth rates were achieved with this level of ficus leaf supplementation, however, the results further indicated that higher growth rates were possible with higher levels (200-250 g d^{-1}) of ficus leaf supplementation. These higher levels of supplementation are recommended in areas where the cost of obtaining the leaves can be justified. However, in cases where it may be difficult to obtain ficus leaves it would be necessary to provide other sources of supplemental nitrogen and minerals.

CHAPTER 6 MICROBIAL COLONIZATION OF FEED PARTICLES AND ENUMERATION OF BACTERIA IN THE RUMEN OF SHEEP FED CASSAVA PEELS AND GRADED LEVELS OF FICUS LEAVES

A. Introduction

In an earlier study (Chapter 3), the potential disappearance/degradability of the dry matter fraction in cassava peels and ficus leaves was estimated to be 71 and 80%, respectively. The rate of degradation of the dry matter of cassava peels was 0.020% h^{-1} and ficus leaves 0.026% h^{-1}. At 48 h only 43.1% and 44.6% of the dry matter of cassava peels and ficus leaves respectively, had been effectively degraded. In another *in vivo* study (Chapter 5) reductions in total dry matter digestibilities with increasing levels of ficus leaf supplementation were observed in sheep fed cassava peels *ad libitum*. With such high potential degradabilities and slow rates of degradation it was necessary to investigate the causes for these slow rates in order to develop appropriate measures to increase the degradation rates and ensure the efficient utilization of these valuable feed resources.

The unique ability of ruminant animals to utilize low quality feedstuffs derives primarily from the microbial population (especially the cellulolytic bacteria) in their rumen. Current understanding of microbial digestion of feed particles which enter the rumen is that microbial adhesion to ingested feed particles is of pivotal importance in digestion because all cellulolytic and most amylolytic micro-organisms must attach themselves to their insoluble substrates in order to effect their digestion (Kudo *et al.*, 1986; McAllister *et al.*, 1990a).

Many rumen bacteria operate optimally within complex adherent consortia (Kudo *et al.* 1990). Also the type of microbial populations which develop within the rumen, though complex, is highly dependent on the chemical micro-environments provided by nutrients in the ingested feed. Once established they are very stable and only change when the nutrients are changed (Cheng and Costerton, 1980). An ecological analysis of the rumen population, including the types, and relative proportions of the microbes, is necessary for a complete understanding of the microbial digestion of feedstuffs. The purpose of this chapter is to report two experiments

conducted to determine the extent of microbial colonization and digestion of cassava peels and ficus leaves and, the effect of level of ficus leaf supplementation on the total and cellulolytic bacterial populations in the rumen of sheep. A brief overview of studies on microbial colonization and digestion of feedstuffs and factors affecting microbial populations in the rumen are presented first.

1. Microbial colonization and digestion of feedstuffs

Most bacteria in the rumen are associated with feed particles and the digestion of these feed particles depends on the adhesion of the bacteria to their specific insoluble nutrient substrates (Cheng *et al.*, 1984; Kudo *et al.,* 1987; McAllister *et al.*, 1990a. B). The colonization and digestion of feed particles in the rumen follow a sequential pattern. Microscopic examination of forage tissues undergoing digestion in the rumen has shown that cell wall types vary in their susceptibility to microbial attack. Generally, phloem contains highly digestible cell walls, the parenchyma cells are only slightly digested. The remaining vascular bundles (with a composition and structure that depends on its maturity and location in the plant) as well as the epidermis are, almost non digestible (Akin, 1980; Van de Meer *et al.*, 1987). Extensive studies on the sequential colonization and digestion of fresh legumes (Cheng *et al.*, 1980), hay (Stewart *et al.*, 1979); straw (Akin, 1980) and grains (McAllister *et al.*, 1990b, c) by rumen bacteria have been conducted.

Specific histological staining techniques have revealed that the digestion rates of specific tissues relate to the cell wall composition, particularly, to the extent of lignification. However, similar tissues in different forage species, or even cultivars within species, with apparently similar lignin content are often degraded at different rates (Gordon *et al.*, 1985). This suggests that other structural constraints and not the content of lignin *per se* may be responsible for the differences in rates of microbial digestion.

2. The rumen bacterial population

Two methods have generally been used to estimate bacterial numbers in the rumen. These are direct counts and viable (culture) counts. Appropriate dilution of rumen contents and inoculation of known quantities into culture media yield a value called the culture or viable count. While this is not necessarily identical with the number of cells in the rumen contents, it nevertheless provides a means of detecting relative differences in numbers between samples. Generally, the bacterial population in the rumen is in the order of 10^9 to 10^{10} ml^{-1} of rumen fluid. The most reliable method for determining the total number of bacteria in the rumen is by direct microscopic counts. The major limitation of this method is that it may not reflect accurately the bacteria attached to digesta particles.

A number of factors are known to affect the population and activities of rumen microbes. These include: the type and quantity of feed; factors such as species, age and size of animal; individual animal differences; frequency of feeding; and, season. In general, bacterial concentrations are higher in those animals consuming a high-concentrate diet (Hungate, 1966; Grubb and Dehority, 1980; Leedle and Hespell, 1980). However, there have also been several researchers who have found that bacterial numbers are equal or higher in animals fed high-roughage diets (Bryant and Robinson, 1968; Latham *et al.*, 1971; Van der Linden *et al.*, 1984; Leedle *et al.*, 1986). The culture count per millilitre is usually higher just before feeding, diminishes during feeding because of high dilution rates, and ultimately increases after feeding (Hungate, 1966).

Thorley *et al.* (1968) compared bacterial concentrations in two cows fed *ad libitum* on either long grass or the same grass ground and pelleted. Mean colony counts were significantly higher when the animals were given ground grass (15.7×10^9 ml^{-1}) rather than long grass (10.5×10^9 ml^{-1}). Differences between such factors as percentage of concentrate in the diet, feeding frequency, feeding level and sampling time, all appear to influence bacterial concentrations and in turn make comparisons difficult. However, the available data seem to indicate that bacterial concentrations do tend to increase with an increased intake of available energy.

3. The ciliate protozoa and fungi

The majority of rumen protozoa are ciliates. They are the most active and most obvious micro-organisms when rumen contents are observed in a light microscope. The ciliates may contain up to 40% of the microbial nitrogen under favourable conditions and account for up to 60% of the total fermentation products (Hungate, 1966). For this reason, they were considered essential to the host animal, but some experiments indicated that ruminants could survive and grow without a rumen ciliate population (Abou Akkada and El Shazly, 1964; Williams and Dinussen, 1973). Bacteria are engulfed by ciliates and digested. Some of the digestion products are used for protozoal growth while the remainder, principally amino acids, are released back into the rumen where they are fermented by bacteria. Part of the fermentation products are used for bacterial growth but the remainder circulate in the rumen (Williams and Coleman, 1992). This recycling of bacterial carbon and nitrogen represents an energy and nitrogen loss as far as the host animal is concerned and may be of crucial importance in animals fed diets low in nitrogen.

The ciliates have been divided into the holotrichs (Family *Isotrichidae*) and the entodiniomorphs (Family *Ophryoscolecidae* of the order *Entodiniomorphida*). Their population density is normally in the range 10^4-10^6 ml^{-1}, of which the majority are members of the *Ophryoscolecidae*. Factors such as type of diet (Wedekind *et al.* ,1986), level of feed intake (Dehority, 1986), and frequency of feeding (Kaufman *et al.*, 1980; Bragg *et al.*, 1986) have been shown to affect their population in the rumen. Seasonal changes also affect their numbers. Protozoan species and populations have also been found to vary from one geographic location to another (Dehority and Orpin, 1988).

The holotrichs in the rumen include *Isotricha prostoma*, *I. intestinalis*, and *Dasytricha ruminantium*. Holotrichs have complete body ciliation, move quickly, and rapidly assimilate soluble sugars. The entodiniomorphs lack complete body ciliation but have bands of syncilia for movement and feed ingestion. They are a more diverse group than the holotrichs and are

represented in the rumen by many genera including *Ophryoscolex, Epidinium, Diplodinium* and *Polyplastron* (Williams and Coleman, 1992).

The phycomycete fungi are a recently discovered group of rumen micro-organisms. Their life cycles consist of an alternation of generations between a motile zoospore stage free in rumen liquor, and a non-motile, vegetative reproductive stage which occurs on digesta particles (Orpin, 1975, 1977a, b; Bauchop, 1979). Because of the intimate association of rumen phycomycetes with the digesta particles, it has not yet been possible to arrive at accurate figures for their biomass in the rumen. However, it is estimated that under favourable conditions, up to 8% of the microbial biomass may consist of phycomycete fungi (Orpin, 1981).

Previous knowledge of the chemical composition of cassava peels and ficus leaves, coupled with the current understanding of microbial digestion of feedstuffs, indicate that structural constraints in both cassava peels and ficus leaves could be responsible for the slow rate at which they are digested in the rumen. Combining scanning electron microscopy (SEM) with electron dispersive X-ray analysis (EDXA) offers a combination of visual inspection with semi-quantitative information on the distribution of tissues and certain elements in cell walls and their physical relationship with rumen micro-organisms. A combination of this technique with degradability estimates would be particularly useful in the evaluation of novel feedstuffs like cassava peels and ficus leaves and help identify any features in the feedstuffs which could impede their digestion. In EDXA a specimen is bombarded with electrons which then emit X-rays whose energies are characteristic for each element present. A detector is used to capture and measure the intensity of the emitted X-rays (Van der Meer *et al.*, 1987).

The digestion of ficus leaves and cassava peels has never been examined by SEM. Neither is there any information on the relative proportion of cellulolytic bacteria to the total bacteria population in the rumen of sheep in Ghana. Such knowledge may be essential in identification of constraints associated with the digestion of feedstuffs and the development of processing techniques which could aid in their digestion.

Therefore the main objectives of the experiment described here were;

1) to study the microbial colonization and digestion of cassava peels and ficus leaves by electron microscopy.

2) to identify the features of cassava peels and ficus leaves which could impede their digestion *in vivo*, and

3) to determine the effect of level of ficus leaf supplementation on the total and cellulolytic

bacteria populations in the rumen of sheep fed a cassava peel-based diet.

B. Materials and Methods

The extent of microbial colonization and digestion of cassava peels and ficus leaves was examined with the aid of scanning electron microscope (SEM) to which was attached an electron dispersive X-ray analyzer (EDXA). The anaerobic culture technique of Hungate (1950) was used to obtain the total and cellulolytic bacteria populations in the rumen.

1. Animals and feeding

Six rumen fistulated Djallonke wethers (average body weight was 33.6 ± 2.7 kg) and fitted with permanent rumen cannulae were used in a completely randomized design. Animals were kept in individual pens with wooden slatted floors. Each animal had *ad libitum* access to sun-dried cassava peels and water. In addition each animal was given one of the following levels of sun-dried ficus leaves; 50, 100, 150, 200, and 250 g day^{-1}. One animal did not receive any supplement and this was used as the control animal. The daily allowances of ficus leaves were offered in two equal portions at 08.30 and 16.30 h.

2. Incubation and sample preparation for SEM

Samples of either cassava peels or ficus leaves were cut into approximately 5 x 5 mm pieces, placed in nylon bags and incubated in the rumens of the six wethers. The bags were made

of monofilament nylon mesh (53 μm pore size, 5 cm x 20 cm; Ankom, Fairport, New York). The bags were withdrawn from the rumen after 2, 4, 6, 9, 12, 24, 48, 72 and 96 h of incubation. The bags and contents were immediately rinsed under cold running tap water and the contents fixed for 3 h in 5% glutaraldehyde in 0.1 M sodium cacodylate acid buffer (pH 7.2). After the 3 h of fixation, the fixative solution was pipetted off and a wash solution consisting of 0.1 M cacodylate buffer was added to the samples and allowed to stand for 20 min. The wash solution was removed after this and a fresh wash solution added. The washing was repeated (three washes in all). The samples were then stored in the final wash solution at 4°C.

Samples were later dehydrated at room temperature in a graduated ethanol series (30 min each in 10, 20, 30, 50, 70, 90, 95 and 100% ethanol). The samples were then critical point dried (Cohen *et al.*, 1968). Samples were then mounted on aluminium stubs with silver paste, viewed with a Hitachi S-570 scanning electron microscope at an accelerating voltage of 15 KeV and photographed with Kodak film. After mounting on aluminium stubs some specimens were vacuum coated with evaporated carbon and viewed with an SEM equipped with a Kevex 8000 energy dispersive X-ray analyzer (Kevex Instruments, Inc. San Carlos, California).

3. Sampling, media and cultural methods for bacterial counts

Rumen contents were sampled 2.5 h after the morning feeding. The sample of rumen contents was immediately strained through two layers of cheese cloth into a beaker and taken to the laboratory within 30 min for subsequent dilution. The pH of the ruminal fluid was determined at this time with an Omega pH meter (Model PHH-63; Omega Engineering Inc. Stamford, Connecticut, USA) and at five other times after the morning feeding i.e. 2, 3, 7, 15 and 17 h after feeding.

Methods for obtaining total viable counts of "total culturable" bacteria and cellulolytic bacteria were those of Hungate (1950) as modified by Bryant and Burkey (1953a). Bacteria were cultured anaerobically in Scott and Dehority (1965) artificial medium with rumen fluid and the following modifications. For the total count, glucose was decreased from 0.5% to 0.025% w/v;

and cellobiose and starch were included at 0.025% and 0.05% w/v respectively. For cellulose digestion, the glucose in the medium was replaced with 1 cm x 1 cm Whatman No.1 filter paper.

Roll tubes inoculated with ruminal fluid samples for the total "culturable counts" were incubated at 39°C for 7 d after which colonies were counted. Tubes containing filter paper were examined after 2 wk for turbidity and the most probable number method used to estimate the cellulolytic bacteria population (Jones, 1979).

C. Results and Discussion

1. Colonization and digestion of feed particles

There were no discernable differences in the extent of microbial colonization and digestion of either the cassava peels or the ficus leaves which could be attributed to the different rumen environments which resulted from feeding the graded levels of ficus leaves. Examination of samples of micrographs of cassava peels and ficus leaves incubated in the rumen of the animals appeared to indicate that irrespective of level of supplementation, 4 h post incubation was representative of the initiation of digestion. The plateau in digestion appeared to be 24 h in most of the samples examined.

The micrographs revealed that a tremendous diversity of micro-organisms were involved with the digestion of cassava peels and ficus leaves. Even though the microbial digestion of feedstuffs in the rumen usually involves morphologically different bacteria and protozoa (Cheng *et al.* 1984; McAllister *et al.*, 1990c), the morphological diversity of the micro-organisms observed in the present study was much greater than have previously been observed during SEM studies on the digestion of other feedstuffs (T.A. McAllister, personal communication). Numerous morphological types of bacteria (rods, ovals and cocci; Plate 1a), protozoa (*Entodinium caudatum*; Plate 1b and dividing *Entodinium sp.*; Plate 1c) and fungi (Plate 1d) could be seen to be involved in the digestion of cassava peels and ficus leaves in most of the micrographs examined.

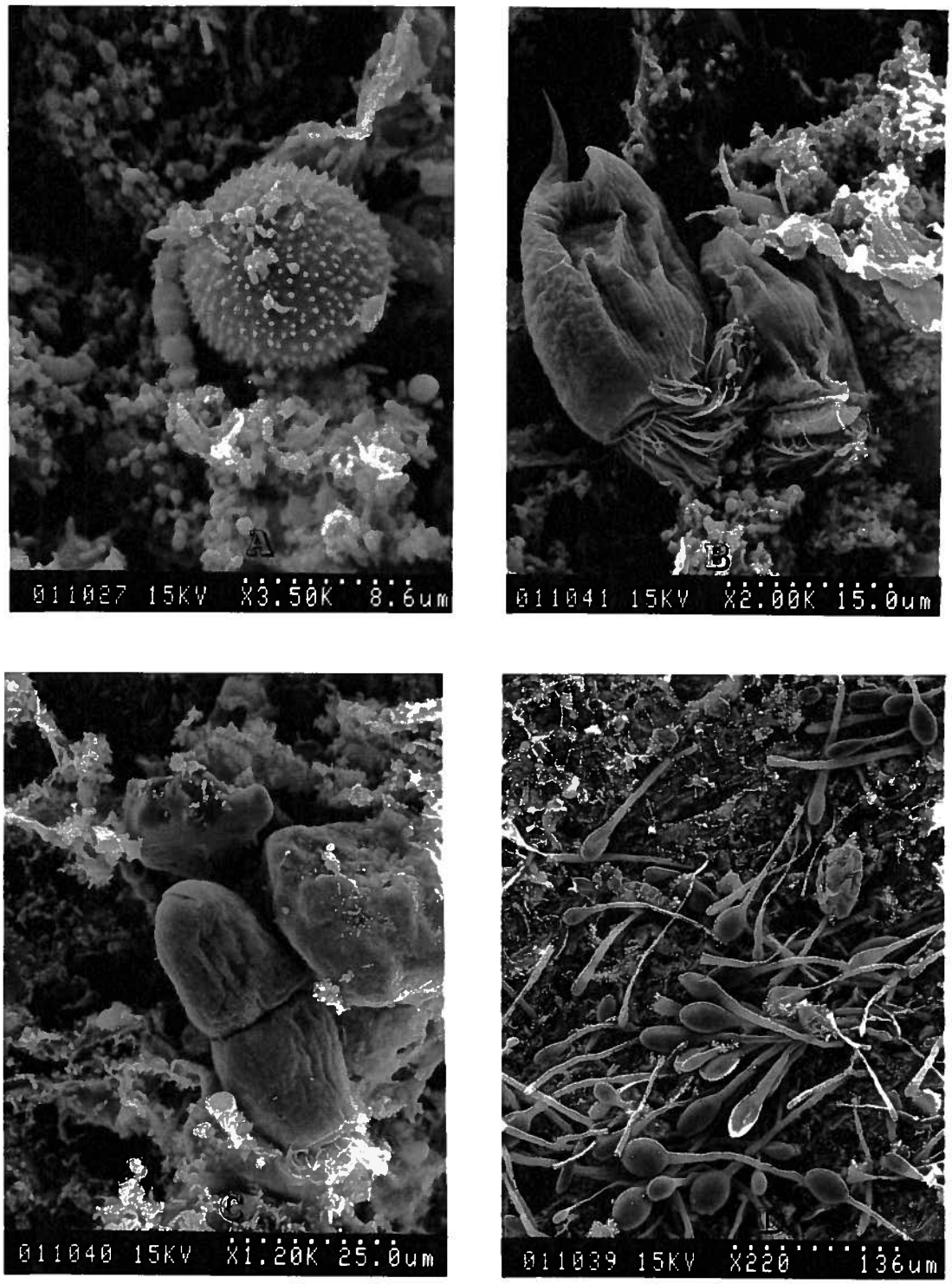


Plate 1a, 1b, 1c and 1d. Micrographs depicting the morphological diversity of the microbial population in sheep fed cassava peels and ficus leaves.

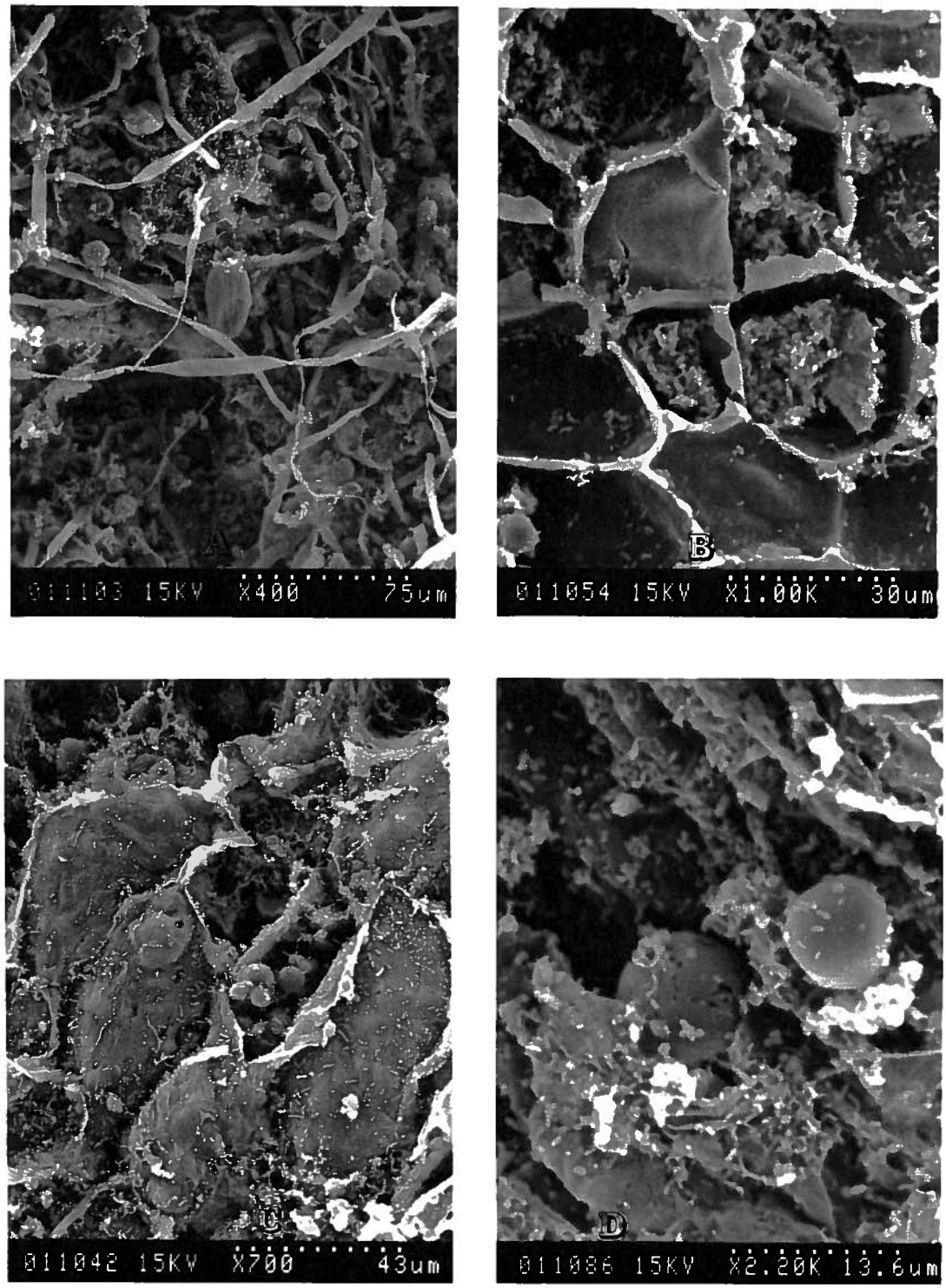


Plate 2a. Micrograph of the cortex of cassava peel incubated in sheep rumen (4 h). Note colonization of the peel by bacteria, protozoa, fungi and the distinctive digestive colonies.

Plate 2b. Micrograph of the outer epidermis of cassava peel incubated in sheep rumen (24 h). Note sparse colonization.

Plate 2c. Micrograph of parenchyma cells of the cortex of cassava peel in sheep rumen (24 h). Note resistance to digestion.

Plate 2d. Micrograph of starch grains of cassava peel in sheep rumen (4 h). Note few pit formations.

One of the most striking observations was the numerous micrographs showing rumen fungi to be involved in the digestion of these feedstuffs (Plates 1d and 2a). A lot of the micrographs indicated that feed particles had been penetrated by rhizoids. This association of rumen fungi with feed particles is a phenomenon relatively easy to observe in *in vitro* studies of the digestion of feed particles by fungi. The ubiquity of this phenomenon in the present *in vivo* study probably indicates the special role of rumen fungi in the digestion of low quality feedstuffs in these tropical animals. The major species of fungi produce a wide range of predominantly extracellular enzymes that degrade the plant cell wall. According to Fonty and Joblin (1991), even though the fungi are unable to use pectin or lignin as carbon sources, they can solubilize lignin. Akin *et al.*, (1989) have, however, postulated that the most important function of the fungi is to weaken plant tissues by the penetration of the rhizoids. Microscopic examination of the cassava peels prior to incubation in the rumen revealed that most parts of the phelloderm were colonized by fungal mycelia but after 4 h of incubation only certain portions of the peels were colonized. It is most likely that fungi found on the pre-incubated phelloderm were aerobic and were therefore destroyed upon introduction into the rumen and their place taken over by the anaerobic ones in the rumen. As with both bacteria and protozoa, initial colonization of feed particles by fungi can occur within 15 minutes (Ho *et al.*, 1988).

The cell walls of the outer epidermis and parenchymatous cells of the sub-epidermis of cassava peels were sparsely colonized by bacteria even after 24 h of incubation in the rumen except for damaged spots (Plates 2b, and 2c). Cell walls of the sub-epidermis and cortex were composed of parenchymatous cells which contained starch granules that were similar to those of barley, (French, 1984; McAllister *et al.*, 1990a). Although microbial colonization of these granules had occurred by 2 h, it appeared that 4 h was close to the initiation of digestion (Plate 2d). At 4 h of incubation, starch granules in the sub-epidermis of the cortex were heavily colonized by bacteria (Plate 3a) and digestive microcolonies could be seen by this time (Plate 2a).

At 24 h most of the cell walls holding the starch grains had been digested to expose the starch grains and distinctive bacterial microcolonies of one or two morphotypes were observed

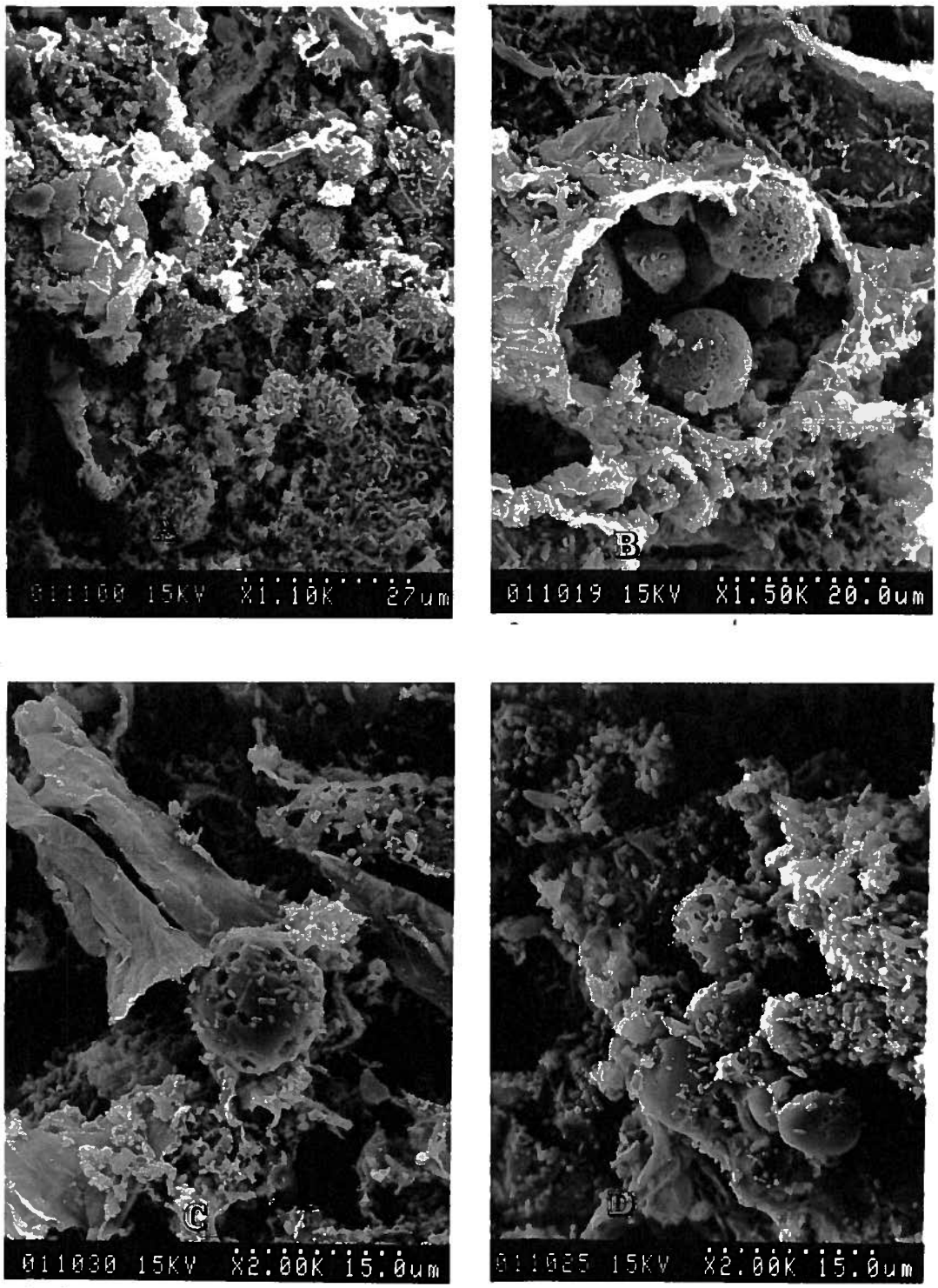


Plate 3a. Micrograph of the cortex of cassava peel in sheep rumen (4 h) showing heavy microbial colonization of starch grains.

Plate 3b. Micrograph of starch grains of cassava peel in sheep rumen showing distinct pit formations (24 h).

Plate 3c. Micrograph of starch grains in parenchyma cells of cassava peel exposed in sheep rumen (24 h).

Plate 3d. Micrograph of starch grains in sheep rumen (24 h) with deep cavitations.

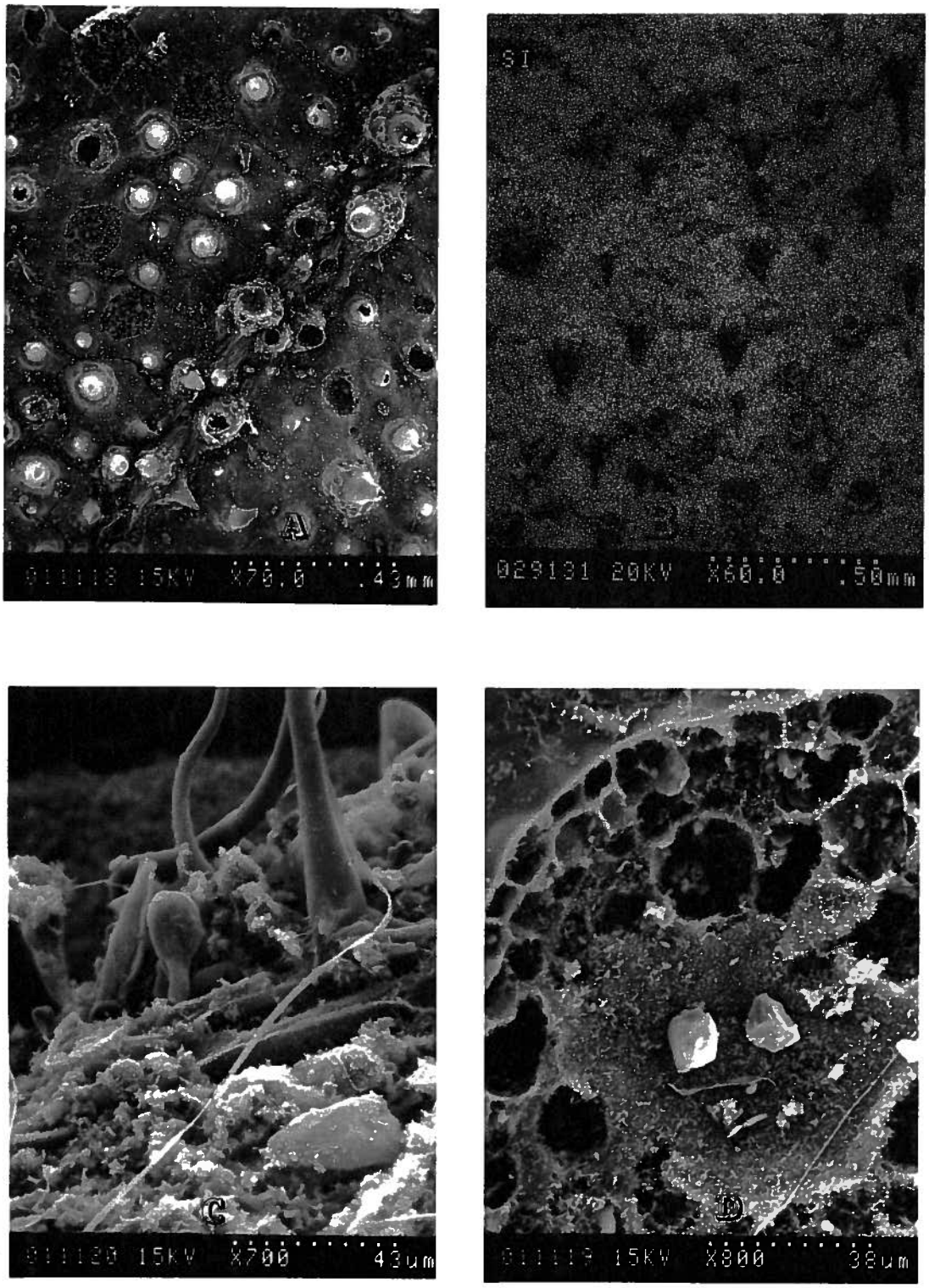


Plate 4a. Micrograph of the upper surface of *Ficus exasperata* leaf showing trichomes and silica bodies.
Plate 4b. Silicon elemental dispersion map of the surface of *Ficus exasperata* leaf.
Plate 4c. Micrograph of the damaged leaf surface of *Ficus exasperata* in the rumen of sheep (4 h).
Plate 4d. Micrograph of damaged regions of *Ficus exasperata* leaf.

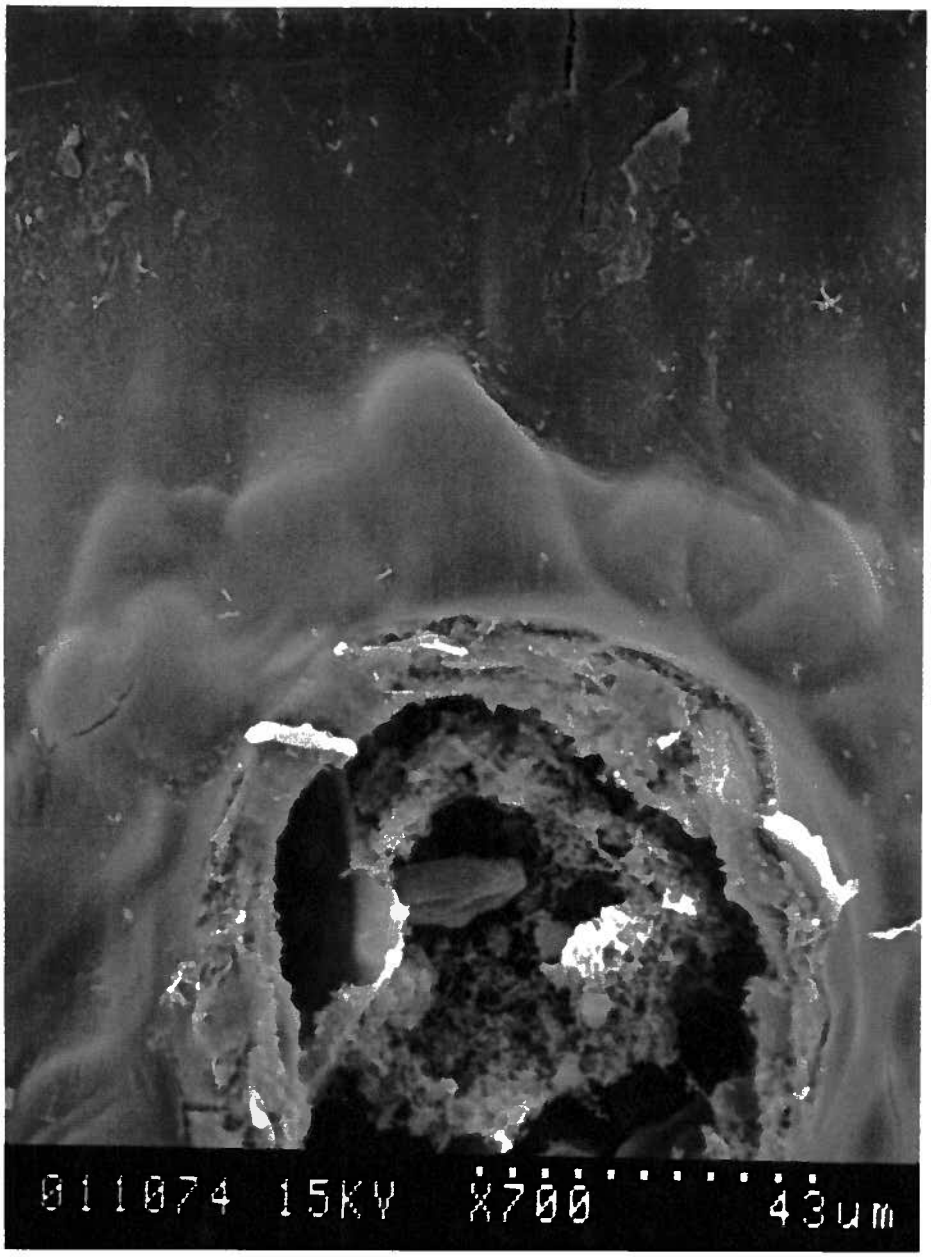


Plate 5. Micrograph of the surface of *Ficus exasperata* leaf with silicon body broken off. Note the absence of microbes on the surface.

adhering to and effecting the digestion of starch grains as evidenced by the formation of pits and cavitations on the grains (Plate 3b, 3c, and 3d). A similar pattern of colonization has been reported in studies of cereal grains by McAllister *et al.*, (1990d). However, the starch grains in cassava peels appeared to be packed individually in the parenchymatous cells (similar to starch found in wheat) and not held together by a protein matrix as found in the starch of maize grains (Plates 2c and 3b). Even if a protein matrix was present it was easily digested and did not constitute a barrier to digestion as observed in the digestion of maize starch by selected species of rumen bacteria by McAllister *et al.*, (1990b).

Microscopic examination of both the upper and lower epidermis of the ficus leaf indicated that both surfaces were covered with numerous hairs, bristles and solid projections which are referred to as phytoliths in this paper (Plates 4a). Measurements made by EDXA on specimens of ficus leaves indicated that the phytoliths and the entire cuticularized epidermis except damaged sites contained silicon (Plate 4b). All these protuberances could have given ficus leaves the rough "sand paper-like" feel. Further examination of these phytoliths indicated localized concentrations of silicon far higher than the background level found on the entire leaf. The relative concentrations of the major elements in the phytoliths were Si (76.8%), Ca (11.4%), Na (5.8%) and Al (4.1%) (Figure 6.1).

Both the lower and upper leaf surfaces appeared to be extremely resistant to microbial colonization and digestion, although there were damaged regions in the leaf on which rumen microbes concentrated their attack. The undamaged parts of the lower and upper epidermis of the ficus leaves were sparsely colonized, even after 24 h very little evidence existed to indicate that any digestion had occurred. It appeared that the epidermis was highly resistant to digestion. However, damaged areas were heavily colonized by 4 h (Plate 4c). Upon gaining entry into the leaf, digestion of mesophyll cells was evident at 4 h (Plate 4d). Continued digestion led to cuticular breakage either by physical action or by microbial action underneath the cuticle. Even after 24 h the only visible effect of the continued digestion on the cuticle and vascular tissues was the physical disruption of the cuticle. (Plate 5).

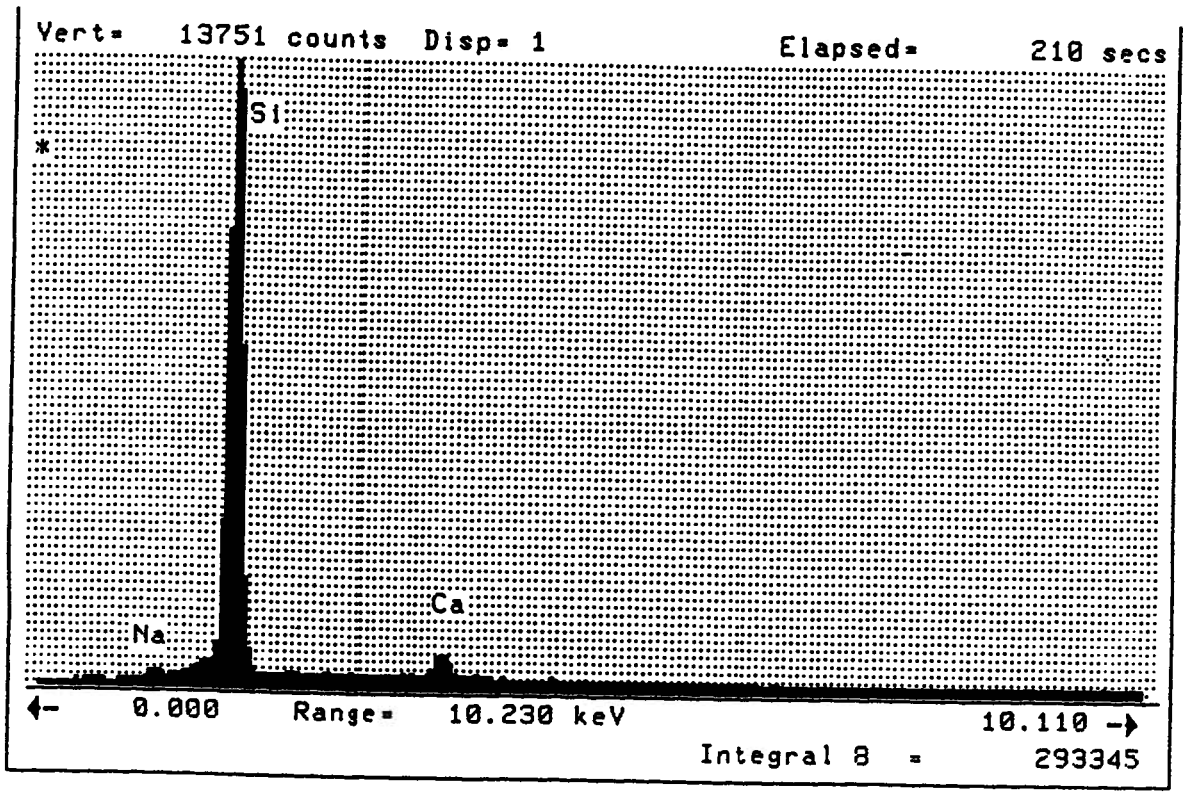


Figure 6.1. Electron dispersive x-ray analysis (EDXA) of a silicon body on the upper surface of a *Ficus exasperata* leaf showing elemental composition.

Bauchop (1980) and Cheng *et al.* (1984) also observed that intact outer plant surfaces were not colonized by microbes and that the major route of invasion and colonization of plant was by epidermal lesions.

Silicon appeared to be part of each epidermal cell in ficus leaves and could be acting as a structural inhibitor to digestion as described by Habers and Thouvenelle (1980). Habers *et al.* (1981) also found that the cuticle *per se* could act as a structural inhibitor to colonization and digestion even in the absence of silicon. Denium (1974) noted that silicon acts as a structural inhibitor during digestion by preventing microbial penetration into the leaves. It does not hinder mesophyll digestion once microbes gain access through exposed surfaces (edges, and macerated parts). Two structural components in forages; silica and lignin, have been known to be responsible for the incomplete digestion of forages by ruminants (Van Soest and Jones, 1968). This silica includes silicon deposits in the epidermal tissue, silicon associated with cellulose as a second layer in the epidermis and silicon linked to organic compounds in other cells (Yoshida *et al.*, 1962). As observed in the present study, silica deposited in the epidermal tissue could have prevented rumen microbial attachment and penetration through that tissue but, it apparently had no effect on degradation of the inner tissues once micro-organisms were exposed to them (inner tissues). That could account for the appreciably high potential degradability value observed in the nylon bag studies on ficus leaves reported in Chapter 3 and the depression in digestibility with increasing levels of ficus leaf supplementation of the diets in Chapter 5. Van Soest and Jones (1968) observed a 3% decrease in digestible dry matter for every unit of silica in a wide range of grasses. However, Smith *et al.* (1971) observed only a 1% decrease in organic matter digestibilities of grasses in the South-western part of the United States.

2. Viable counts of total and cellulolytic bacteria populations

The mean values of rumen pH, total viable counts and cellulolytic bacteria in the rumen of sheep fed the different levels of ficus leaves are presented in Table 6.1. Supplementation had no significant effect ($P>0.05$) on the pH of the rumen. The total culturable bacteria population

ranged from 2.05 to 2.13 x 10^8. The cellulolytic bacteria population in the different rumen environments ranged from 5.07 to 5.10 x 10^7. Supplementation again had no significant (P>0.05) effect on the number of total culturable and cellulolytic bacteria populations. Similar observations have been made by Burroughs *et al.* (1950) who fed corn cobs and alfalfa hay and Bryant and Burkey (1953b) who fed wheat straw to cattle. Burroughs et al. (1950) demonstrated that roughage digestion and total counts of ruminal bacteria in cattle were not affected by adding alfalfa to a low protein basal ration of corn cobs. Adding starch and protein to a wheat straw diet did not affect the total counts of bacteria in the experiment of Bryant and Burkey (1953b).

Table 6.1. Effect of different dietary treatments on total culturable and cellulolytic bacteria populations and pH in ruminal fluid of sheep.

	Dietary treatment[1]						
Variable[2]	T1	T2	T3	T4	T5	T6	SEM[4]
Total viable bacteria (x10^8 ml^{-1})	2.08	2.08	2.08	2.13	2.05	2.08	0.010
Cellulolytics (x10^7 ml^{-1})	5.07	5.07	5.08	5.08	5.07	5.10	0.005
Ratio of Cellulolytics:Total bacteria	1:4.1	1:4.1	1:4.1	1:4.2	1:4.0	1:4.1	0.025
pH[3]	6.68	6.77	6.72	6.69	6.76	6.65	0.019

[1] T1=cassava peels + no supplement; T2=cassava peels + 50g of ficus per day; T3=cassava peels + 100g of ficus per day; T4=cassava peels + 150g of ficus per day; T5=cassava peels +200g of ficus per day; and T6=cassava peels + 250g of ficus per day.

[2] Mean of three determinations from the same animal.

[3] Mean of six determinations from six animals.

[4] Standard error of the mean.

Bryant and Burkey (1953b) found that the cellulolytic bacteria accounted for 5.2% of the bacteria cultured from the rumen when a concentrate diet was fed; and 28% when a wheat straw ration was fed. However, in a study of the effect of different protein supplements on the numbers and types of cellulolytic bacteria in the rumen of sheep fed a low protein teff hay, van Gylswyk (1970) found that the cellulolytic bacteria constituted about 1-3% of the total culturable bacteria. While the total culturable counts ranged between 1-4 x 10^9 , the cellulolytic population was in the order of 2-14 x 10^7. Winsryg *et al.* (1991), however reported that 3-6% of the total viable bacteria (10 x 10^{10}) in the rumen of cattle were cellulolytic. The lack of dietary response in the present study could be due to the fact that the diets were not markedly different especially in terms of the total amount of cellulose.

D. General Discussion

SEM observations of the breakdown of cassava peels and ficus leaves undergoing digestion in the rumen have demonstrated that many bacteria, protozoa and sporangia of anaerobic fungi are involved in the digestion of these feedstuffs. The rumen bacteria (especially the cellulolytic ones) are the most important degraders of cellulolytic materials (Bryant, 1973). In general, the feeding of diets which provide readily available forms of fermentable carbohydrates results in higher numbers of bacteria in the rumen (Latham *et al.*, 1971). In some feedstuffs, such easily available energy (e.g., sugars and starches) may be scarce. The total numbers of cellulolytic bacteria have been reported to decline with the feeding of grain but numbers of certain cellulolytic types, notably the cocci, are relatively constant during concentrate and roughage feeding (Henning *et al.*, 1980). Moreover, when meals are separated by long intervals, microbes may decrease in number because of lack of nitrogen and/or energy and, the microbial population may change. The feeding of cassava peels *ad libitum* in this study ensured a continuous supply of an energy source, while the twice daily feeding of ficus leaves provided essential nutrients to the microbes throughout the day. The lack of response to the different levels of ficus leaf supplementation could therefore be due to the fact that the diets were not significantly different

in terms of digestible energy and the supply of essential nutrients from the feedstuffs, though small, could have been adequate for microbial growth.

The role of protozoa in fibre digestion appears to depend on the type of diet (Orpin, 1983, 1985; Coleman, 1985). Enhanced cellulose digestion in the presence of *Entodinium* was observed whenever readily fermentable carbohydrates were fed, Jouany *et al.* (1988). Orpin (1985) reported that *Entodinium spp.* are not directly involved in the digestion of fibre but their role lies in their ability to decrease the numbers of amylolytic bacteria notably *S. bovis*, thereby preventing the lowering of rumen pH which could decrease the number of cellulolytic bacteria. This moderating effect of protozoa on rumen pH probably accounts for the relatively high pH values even in the rumen of the animals which consumed only cassava peels (Table 6.1).

The attachment of cellulolytic microbes to feed particles requires both time and a readily available energy source (Engels, 1986). In the rumen, insoluble nutrients such as cellulose, (Minato and Suto, 1978) and starch (Minato and Suto, 1979) are rapidly colonized by sub-populations of bacteria, protozoa and fungal zoospores that use them as substrates. Consortia develop in which substrates are efficiently passed from one microbial population to the other. A variety of soluble nutrients are produced which support the growth of a rich diversity of bacterial species (Cheng *et al.*, 1977; McAllister *et al.*, 1990b, c). Cassava peels and ficus leaves are structurally and chemically complex and the process of microbial attack is similar to that described in whole cereal grains (McAllister *et al.*, 1990d); smooth brome and tall fescue (Habers *et al.*, 1981) and whole legume leaves (Cheng *et al.*, 1980). Entry of microbes into plant materials is by preference via damaged surfaces, cut edges and natural openings such as stomata (Chesson and Orskov, 1984). As in both whole cereal grains and forages, the most readily digestible tissues in cassava peels and ficus leaves were located inside the plant and the microbes gain access to these digestible tissues only through damaged sites. Rumen fungi could play an important role in this regard by penetrating parts of the plant unattainable by bacteria and thereby creating more avenues for the bacteria to enter through later. The existence of a more favourable nutrient melieu inside the plant promoted bacterial proliferation and digestion of the

carbohydrates and the proteinaceous substrates and the subsequent development of thick bacterial biofilm which when passed from the rumen into the lower gut could be an important source of metabolizable energy to the host animal (Rode *et al.*, 1986; McAllister *et al.*, 1990c).

The ecological niches which developed inside the cassava peels and ficus leaves were heavily colonized by 4 h and the climax population consisted of different bacterial morphotypes; some attached to the digestible tissues while others were embedded in large amounts of exopolysaccharide products. The cuticularized layers of both cassava peels and ficus leaves were avoided by rumen micro-organisms. In the case of cassava peels the parenchymatous cells containing starch granules were penetrated and digested to expose the starch granules which were then penetrated and cavitated. This whole process of digestion of the peel and the starch granules was consistent with the 'inside-out" process of digestion of feedstuffs by rumen micro-organisms described by Cheng *et al.* (1991). This process of digestion of feedstuffs by rumen micro-organisms implies that the nutritionally poor outer plant tissues (are barriers to digestion); and these have to be penetrated first by micro-organisms before digestion proper begins with the more digestible internal tissues. The outer less digestible tissues are the last to be attacked.

E. Conclusions

The results of the present study indicate that two types of cells found in cassava peels (outer corky epidermis and parenchymatous cell walls which hold starch grains) are resistant to digestion in varying degrees (compared to the rest of the cells in the peels). Microbial colonization and digestion of the inner tissues were possible only after these tissues had been breached. Both the upper and lower epidermis of ficus leaves were covered with silica deposits and silica bodies (phytoliths). These epidermal layers were extremely resistant to microbial colonization and digestion. The coating of silica could be partly responsible for the long lag phase in the digestion of ficus leaves.

Observations in this study also indicate that the effect of silica on the digestion of ficus leaves could be moderated by processing of the leaves to open up more avenues for microbial

penetration. The presence of the numerous phytoliths on the ficus leaves could in some cases aid the digestion of the leaf in that it appears to be easier for physical action either outside or within the rumen to break off the phytoliths and create more damaged avenues through which the microbes could enter the leaf.

The large morphological diversity of microbes found to be associated with feed particles undergoing digestion in the rumen of animals used in this study calls for further studies in rumen ecology, especially the contribution of protozoa and fungi in digestion. The role of these microbes may have been previously underestimated.

CHAPTER 7 GENERAL CONCLUSIONS AND RECOMMENDATIONS

Producers of small ruminants in the urban and peri-urban areas of Ghana have and will continue to play an important role in the provision of animal protein in the diets of the ever increasing urban population in the country. The animals raised also play important roles in the lives of producers; most importantly apart from the fact that they are used to supplement household income they also provide a ready source of cash to meet both expected and unexpected expenditures. The need for extra income in Ghanaian households is universal and probably explains the popularity of small ruminant production among the different ethnic, social, educational, age and economic groups encountered in this study. The low feed requirements of small ruminants and their resourcefulness in terms of their ability to forage and thrive on relatively low quality feedstuffs, coupled with the low management level required to make an economic profit make small ruminant production in these areas the preferred agricultural activity. The rapid increases in urban population which has a positive effect in terms of ensuring a continual demand for meat has, however, meant that animals have to be confined in most cases. Confinement has led to the demand for greater management input especially in terms of provision of adequate and nutritious diets to the animals.

Fortunately considerable amount of browses and by-products from food processing industries exist in and around the urban areas. This study has successfully identified and evaluated cassava peels and the leaves of *Ficus exasperata* as feedstuffs which could be utilized to meet this demand for nutritious feed. In this study the evaluation of the feeding value of cassava peels and ficus leaves involved chemical, microbiological, nylon bag degradation, *in vivo* digestibility, feed intake and growth studies. The methodology and equipment required in some of these studies are cumbersome and expensive and may not be appropriate for most developing countries. It appears that the potential degradation and the degradation constants generated from the mathematical description of degradation with time of feedstuffs incubated in the rumen of animals (*in sacco* method), may be an easy and reliable technique to evaluate feedstuffs and the rumen environment.

From the results of the study of small ruminant production systems and the nutritional evaluation of the selected feedstuffs (cassava peels and ficus leaves), it was concluded that:

1. The potential exists in the urban and peri-urban centres of Ghana for a viable small ruminant production industry. There is, however, the need to strengthen traditional and local institutions by organizing producers into co-operatives and associations so that they can address their concerns collectively. A major advantage of this would be the establishment of better communication channels between the producers and the government agencies so that concerns of producers can be better articulated. It would also make it easier for the delivery of veterinary services and could also open up avenues for individual producers to secure small loans for stock improvement.

2. A successful small ruminant feeding system can be based on cassava peels and ficus leaves. Respectable liveweight gains (25 and to 54 g d^{-1}) can be achieved in Djallonke wethers and ewe lambs raised solely on a combination of cassava peels and 200 to 250 g d^{-1} of air-dried ficus leaves. There are also indications that higher levels of supplementation (in areas where they can be provided) would result in faster growth rates and, feeding as little as 100 -150 g d^{-1} of ficus leaves would be sufficient to prevent sheep raised solely on cassava peels from loosing weight.

3. The outer layer of cassava peel is extremely resistant to microbial colonization and degradation. Before techniques are identified to improve the colonization and degradation of this layer (which constitutes about 15% of the dry matter of the peel), its removal (a popular practice among producers who feed cassava peels) should be encouraged. This could lead to an increase in the rate of digestion of the peels and a reduction in its "filling effect" which could ultimately increase total dry matter intake by the animals.

4. The lower and upper epidermis of ficus leaves are covered with silicon deposits. Microbial colonization and/or penetration of the leaves occurs only in damaged spots. There are indications that the detachment of the silicon bodies (one of the group of structures on the surface of the leaves) from the leaf surface creates avenues for rumen microbes to invade the more digestible inner parts. Any processing or treatment which would lead to detachment of more of these silicon bodies could be an effective way of creating avenues for microbes to invade the more digestible internal tissues of the leaf.

5. Studies are required to ascertain the exact influence of silicon on bacterial attachment and on processing techniques which would lead to a more efficient utilization of both cassava peels and ficus leaves.

6. The rumen ecology of these animals needs to be investigated further. The large number of protozoa and fungi found to be involved in the digestion of cassava peels and ficus leaves in the animals used in these experiments could be an indication of the greater role these microbes play in the digestion of feedstuffs and, in the nutrition of the animals in this tropical environment.

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APPENDICES

Appendix 2.1. Key topics explored in diagnostic survey

1. Household information: ethnic background, number of people, education, and major occupation of members.
2. Type and numbers of small ruminants.
3. Ownership, acquisition and disposal.
4. Feed resources and feeding practices.
5. Management practices.
6. Major constraints.

Appendix 2.2.

Sample questionnaire used to gather information on the small ruminant production systems in the urban and peri-urban households in Ghana

SCHEDULE 1.

HOUSEHOLD INFORMATION SHEET/CHECK LIST

This information was gathered from each selected household.

Interviewer Date of visit Suburb House No.

Name of Household head Name of respondent

(001) Location 01 Kumasi 02 Effiduasi

(002) Sex of respondent 01 Male 02 Female

(003) Religion 01 Christian 02 Moslem 03 Others

(004) Age of respondent (years)
01 <20 02 20 - 29 03 30 - 39 04 40 - 49
05 50 - 59 06 60+

(005) Education 01 No formal education 02 Below Sch. Certificate.
03 Below diploma 04 Diploma 05 Up to University
(006) Major occupation 01 Farmer 02 Civil servant
03 Technician/artisan 04 Trader 05 Student
06 Pensioner 07 Unemployed/Homemaker 08 Other

(007) Household Ownership 01 Owned 02 Rented 03 Caretaker

(008) Family size	(009) No. of men	(010) No. of women
01 1 - 4	01 1 - 4	01 1 - 4
02 5 - 8	02 5 - 8	02 5 - 8
03 9 - 12	03 9 - 12	03 9 - 12
04 >12	04 >12	04 >12
	05 Zero	05 Zero

(011) No. of children
01 1 - 4
02 5 - 8
03 9 - 12

04 >12
05 Zero

LAND

(012) Access to land 01 Owned 02 Share Cropping
03 Family 04 Others 05 N/A

(013) Farm/land size in terms of:
01 excess 02 adequate 03 inadequate 04 N/A

(014) Major crops grown 01 Food Crops (Maize, Plantain, Cassava, cocoyam, etc.)
02 Cash Crops (Cocoa, Oil Palm etc.)
03 01 and 02 04 Others 05 N/A

(015) Yield (Current/Previous year)
01 Excess 02 Adequate 03 Shortage 04 N/A

(016) Site of farm (distance from home)
01 <1 km 02 1 - 2 km 03 >2 km 04 N/A

(017) Access to labour for rearing (both family and hired - indicate numbers and seasonality)
01 Family 02 Hired 03 Respondent alone 04 Others
05 01 and 02 06 01 and 04 07 02 and 03 08 02 and 04
09 03 and 04 10 More than two sources

(018) Assets (very broad items like houses, machines, etc.)
01 House 02 Machines 03 Vehicle 04 Others 05 None
06 01 & 02 07 02 & 03 08 01 & 03 09 01, 02 & 03
(019) Other employment opportunities (apart from major occupation and farming, i.e. part-time jobs, trading, etc.)
01 Trading 02 Artisan 03 Others 04 None

(020) Major items sold - last year (rank in order of income)
01 Farm produce (Crops) only 02 Livestock only 03 None Agric. Items 04 None
05 01>02 06 02>01

(021) Major items purchased - last year (rank in order of expenditure)
01 Vehicle only 02 House/Building materials only
03 Household Appliances only 04 Other Items 05 None
06 01 > Other Items 07 02 > Other Items 08 03 > Others

(022) Rank major staples in order of consumption
01 Root Crops > Plantains > Cereals

02 Plantains > Root Crops > Cereals
03 Cereals > Root Crops > Plantains
04 Cereals > Plantains > Root Crops
05 Plantains > Cereals > Root Crops
06 Root Crops > Cereals > Plantains
07 Other Combinations

(023) Any plants in the vicinity of household? 01 Yes 02 No

(024) Name or type of plant 01 Terminalia spp. 02 Ficus spp.
03 Fruit plants 04 Others 05 N/A

SCHEDULE 2

LIVESTOCK REARING ACTIVITIES

LIVESTOCK STRUCTURE

(025) Which of these animals do you keep?
01 Goats 02 Sheep 03 01 and 02 04 Others 05 01 and 04
06 02 and 04 07 03 and 04

(026) How many goats do you have?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(027) How many of these are adult males?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(028) How many of these are adult females?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(029) How many of these are young males?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(030) How many of these are young females?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(031) How many sheep do you have?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(032) How many of these are adult males?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(033) How many of these are adult females?

01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(034) How many of these are young males?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(035) How many of these are young females?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(036) How many goats did you have last year?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(037) How many of these were adult males?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(038) How many of these were adult females?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(039) How many of these were young males?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(040) How many of these were young females?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None (041) How many sheep did you have last year?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(042) How many of these were adult males?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(043) How many of these were adult females?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(044) How many of these were young males?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

(045) How many of these were young females?
01 1-5 02 6-10 03 11-15 04 16-20 05 >20 06 None

ACQUISITION AND DISPOSAL

What are your main reasons for keeping these animals? (Prioritize reasons for each species)

(046) Goats:
01 Financial Only 02 Meat Only 03 Recreational/Hobby Only
04 Religious/Social Only
05 01 > Other Reasons

06 02 > Other Reasons
07 03 > Other Reasons
08 04 > Other reasons
09 Other Reasons
10 N/A

(047) Sheep:
01 Financial Only 02 Meat Only 03 Recreational/Hobby Only
04 Religious/Social Only
05 01 > Other Reasons
06 02 > Other Reasons
07 03 > Other Reasons
08 04 > Other reasons
09 Other Reasons
10 N/A

How long since rearing activities started (by species)?

(048) Goats: 01 1yr 02 2yrs 03 3yrs 04 >3yrs 05 N/A

(049) Sheep: 01 1yr 02 2yrs 03 3yrs 04 >3yrs 05 N/A

(050) How did you acquire your first animals?
01 Gift 02 Purchased 03 Caretaker 04 Others

Age of disposal

(051) Goats: 01 1yr 02 2yrs 03 3yrs 04 >3yrs 05 N/A

(052) Sheep: 01 1yr 02 2yrs 03 3yrs 04 >3yrs 05 N/A

Time of disposal

(053) Goats: 01 Religious/Social occasions 02 Financial need
03 No specific time 04 N/A

(054) Sheep: 01 Religious/Social occasions 02 Financial need
03 No specific time 04 N/A

Preferred sex

(055) Goats: 01 Male 02 Female 03 Both 04 N/A

(056) Sheep: 01 Male 02 Female 03 Both 04 N/A

(057) Method of disposal 01 Direct sale (farm gate) 02 Middlemen 03 Market 04 Meat 05 Gifts 06 Batter 07 Other 08 N/A 09 01 and 02 10 01 and 03 11 01 and 04 12 02 and 03 13 02 and 04 14 Other combinations

Prices

(058) Goats: 01 <5,000 02 5-10,000 03 >10,000 04 N/A

(059) Sheep: 01 <5,000 02 5-10,000 03 >10,000 04 N/A

Number born last year

(060) Goats: 01 1-3 02 4-6 03 7-10 04 >10 05 N/A

(061) Sheep: 01 1-3 02 4-6 03 7-10 04 >10 05 N/A

Number disposed off last year (sold, consumed, given away etc.).

(062) Goats: 01 1-3 02 4-6 03 7-10 04 >10 05 N/A

(063) Sheep: 01 1-3 02 4-6 03 7-10 04 >10 05 N/A

MANAGEMENT PRACTICES

Does the farmer carry out any of these practices?

Culling

(064) Goats: 01 Yes 02 No 03 N/A Why

(065) Sheep: 01 Yes 02 No 03 N/A Why

Castration

(066) Goats: 01 Yes 02 No 03 N/A Why

(067) Sheep: 01 Yes 02 No 03 N/A Why

Vaccinations

(068) Goats: 01 Yes 02 No 03 N/A Why

(069) Sheep: 01 Yes 02 No 03 N/A Why

Deworming

(070) Goats: 01 Yes 02 No 03 N/A Why

(071) Sheep: 01 Yes 02 No 03 N/A Why

(072) Which of the following does the farmer practice?
01 Selective mating 02 Random mating 03 Both

(073) Does the farmer breed during a particular season?
01 Yes 02 No Why

(074) Who makes management decisions concerning animals?
01 Farmer/Respondent 02 Household head 03 Collective 04 Any member of household 05 Spouse 06 Children
07 01 and 02 08 01 and 05 09 02 and 05

Numbers in breeding herd

(075) Female goats:
01 1-3 02 4-6 03 7-9 04 10+ 05 N/A

(076) Male goats:
01 1-3 02 4-6 03 7-9 04 10+ 05 N/A

(077) Female sheep:
01 1-3 02 4-6 03 7-9 04 10+ 05 N/A

(078) Male sheep:
01 1-3 02 4-6 03 7-9 04 10+ 05 N/A

Mortalities last year (both adults and young ones)

(079) Goats: 01 1-3 02 4-6 03 7-9 04 >10 05 N/A

(080) Sheep: 01 1-3 02 4-6 03 7-9 04 >10 05 N/A

(081) What were the main causes of mortalities/losses? List in order of importance.
01 Diarrhoea/PPR(Diseases) 02 Accidents 03 Poisoning/Theft 04 Cause not known 05 Miscellaneous Factors 06 None
07 01 and Other Causes 08 02 and Other Causes
09 03 and Other Causes

(082) Have you taken any measures to reduce mortalities or losses?
01 Yes 02 No 03 N/A Explain

(083) How effective have these measures been?

01 Improvement/Reduction in mortalities
02 Same/No improvement 03 Worse 04 N/A

FEEDING

(084) Method of feeding:
01 Roadside herding/grazing - please indicate time(s) of day and the duration of grazing activity.
02 Free range grazing/browsing or scavenging
03 Hand feeding
04 Any other 05 01 and 02 06 01 and 03 07 02 and 03
08 01, 02 and 03
N.B. For each method of feeding record distance between current source of feed and point of utilization.

(085) Person responsible for feeding animals.
01 Farmer/Respondent 02 Children/Family member
03 Hired labour 04 Others 05 01 and 02 06 01 and 03
07 01 and 04 08 02 and 03 09 02 and 04 10 03 and 04
11 More than two categories from 01 - 04

(086) Cost per unit of feed if purchased (does this vary with season? If so record prices by seasons)
01 <1,000/yr 02 1-4,000/yr 03 >4,000 but <10,000/yr
04 >10,000/yr 05 N/A 06 Negligible

(087) Cost of transporting each type of feed.
01 <1,000/yr 02 1-4,000/yr 03 >4,000 but <10,000/yr
04 >10,000/yr 05 N/A 06 Negligible

(088) Physical form in which each feed type is obtained
01 Dry 02 Wet 03 Other

(089) Any physical processing before feeding? If yes please describe briefly.
01 Yes 02 No 03 N/A

(090) Which of these feed sources are commonly used?
01 Pastures, forages, hay etc.(specify, species, source and quantity)
02 Grains, root and grain by-products, (types, sources and quantities)
03 Protein concentrates, commercial feed mix (types, sources and quantities)
04 Household garbage/refuse (types, sources and quantities)
05 01 and 02 06 01 and 03 07 01 and 04 08 01, 02 and 03 09 01, 02 and 04 10 01, 03 and 04
11 02 and 03 12 02 and 04
13 02, 03 and 04 14 03 and 04 15 All sources

Please indicate the importance of each method/kind of feeding by

(091) Season 01 Yes 02 No Why?

(092) Sex of animal 01 Yes 02 No Why?

(093) Age of animal 01 Yes 02 No Why?

(094) Condition of animal 01 Yes 02 No Why?

FEED STORAGE FACILITIES

(095) Does the farmer have any feed storage facilities?
01 Yes 02 No

(096) Type of storage/container
01 Silos/Rooms 02 Barrels/Drums 03 Baskets
04 Bags 05 Others 06 N/A 07 More than one type

(097) Storage capacity
01 Adequate 02 Inadequate 03 N/A

(098) Duration of storage
01 <1 month 02 1-3 months 03 >3 but <6 months
04 >6 months 05 N/A

(099) Any processing before storage? 01 Yes 02 No 03 N/A

(100) Direct cost of storage
01 <1,000/yr 02 1-4,000/yr 03 >4,000 but <10,000/yr
04 >10,000/yr 05 N/A 06 Negligible

SANITATION

(101) Animal sanitation 01 Yes 02 No Explain

(102) Housing sanitation 01 Yes 02 No Explain (e.g. methods of cleaning and disinfecting).

(103) Water and Feed sanitation 01 Yes 02 No Explain

(104) Person responsible for sanitation related duties
01 Farmer/Respondent 02 Children/Family member
03 Hired labour 04 Others 05 01 and 03 06 01 and 04
07 02 and 03 08 02 and 04 09 03 and 04
10 More than two categories from 01 - 04

(105) Sanitation related problems 01 Yes 02 None Explain

SCHEDULE 3

EXPANSION POTENTIAL AND WILLINGNESS TO INVEST

(106) Is the farmer willing to increase his flock numbers?
01 Yes 02 No Why?

(107) Constraints as seen by farmer (prioritize/rank)
01 Labour only 02 Marketing only 03 Health only
04 Credit only 05 Feeding only 06 Theft only
07 Space only 08 Others 09 01 and 03 10 01 and 04
11 01 and 05 12 01 and 07 13 03 and 04 14 03 and 05
13 03 and 07 14 04 and 05 15 04 and 06 16 04 and 07
17 05 and 06 18 05 and 07 19 01 and 06
20 More than two of the above.

(108) Possible solutions (farmer's views)

(109) Constraints as seen by interviewer - prioritize

(110) Are there any current compensating strategies? Prioritize.

(111) Options and opportunities for improvement (through research, and policy changes, i.e. identify researchable problems)

(112) If farmer had access to credit or excess liquidity how would he/she invest or utilize it?

Appendix 3.1.

Sample of SAS program used to solve the modified version of Orskov and McDonald (1979) equation with a lag phase. Program was written by Dr. John Hall of Agriculture Canada, Vancouver, BC. Canada.

```
      *ORSKOV EQUATIONS WITH LAG PHASE SOLUTION;
OPTIONS PAGESIZE=90;
TITLE 'Dry matter degradation';
FILENAME SASDATA 'DMDEG';
DATA DMD ;
INFILE SASDATA MISSOVER;
INPUT TIME FEED $ an TRT DMD  ;
RUN;
PROC SORT;
BY FEED an;
PROC NLIN  ITER=50 METHOD=MARQUARDT;
BY FEED an;
PARMS A=15 B=40 C=.04 LAG=0,3,6;
  BOUNDS LAG>=0;
 IF LAG<0.0 THEN DO;
 LAG = 0.0;
 END;
 IF T<LAG THEN DO ;
 MODEL DMD = A;
 DER.A = 1. ;
 DER.B = 0. ;
 DER.C = 0. ;
 DER.LAG = 0. ;
END ;
ELSE DO ;
MODEL DMD = A + B*(1.-EXP(-C*(T-LAG))) ;
DER.A = 1. ;
DER.B = (1.-EXP(-C*(T-LAG))) ;
DER.C = B*(T-LAG)*EXP(-C*(T-LAG)) ;
DER.LAG = -B*C*EXP(-C*(T-LAG)) ;
END ;
OUTPUT OUT=B PREDICTED=YHAT RESIDUAL=YRES PARMS=A B C LAG;
PROC PRINT DATA=B ;
PROC PLOT ;
 BY FEED an;
OPTIONS PAGESIZE=25;
PLOT DMD*T='0' YHAT*T='P' / OVERLAY ;
RUN;
DATA SUM(DROP= YHAT YRES ) ;
```

```
OPTIONS PAGESIZE=90;
*CALCULATING  EFFECTIVE DEGRADABILITY;
SET B;
IF T < 48 THEN DELETE;
IF T > 48 THEN DELETE;
 *THE CALCULATED CONSTANTS ARE THE SAME FOR EACH INCUBATION
TIME
  THIS STATEMENT DELETES ALL BUT ONE TIME;
  TO=LAG;
Kf=.06;
  *Kf IS THE FRACTIONAL RATE OF PASSAGE;
   EFFDGRD=A+(((B*C)*EXP(C*TO))/(C+Kf))*EXP(-(C+Kf)*TO);
PUT FEED an A B C LAG Kf EFFDGRD;
RUN;
PROC PRINT ;
RUN;
```