STUDIES ON THE EFFECT OF MICROBIALLY DEGRADED AGRO-BY-PRODUCT FEEDS ON DIGESTIBILITY AND GROWTH PERFORMANCE IN DOMESTIC RABBIT

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BY

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CERTIFICATE

This is to certify that the thesis entitled **STUDIES ON THE EFFECT OF MICROBIALLY DEGRADED AGRO-BY-PRODUCT FEEDS ON DIGESTIBILITY AND GROWTH PERFORMANCE IN DOMESTIC RABBIT** submitted by **Mr. R.N. Shanmuga Sundaram** for the award of degree of **Doctor of Philosophy in Botany** is based on the results of investigations carried out by him under my supervision. The thesis or part there of has not been submitted for any other degree or diploma of any University.

Dr. D.J. BHAT
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Place: Goa University

Date: 16 JUNE 1997

STATEMENT AS REQUIRED BY THE UNIVERSITY

1. Statement on originality of thesis document: The work on biodegradation of agricultural wastes aiming at converting them into animal feed was carried out by me with the by-products available in Goa and it does not form part of any other thesis work.

2. Statement on the research contributions towards general advancement of knowledge: Use of agro-wastes as animal feed is an important for livestock development and rural economics. Any developmental work in this field will be beneficial to the low and marginal income group in the rural sector to adopt improved technique for more profit in livestock rearing.

3. Statement on originality of reported research:. The study was carried out as per the approved programme and the data presented in this thesis are collected during the course of the work from 1992 to 1996.

4. Statement on my own individual research contributions: The reported work on the thesis entitled 'Studies on the effect of microbially degraded agro-by-product feeds on digestibility and growth performance in domestic rabbit'.is the result of work carried out by me during the course of this study and no part of this work was associated with any other person..

5. Statement on published work in support of my candidature: Separate list is enclosed.

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Place: Goa University

Date: 16 th June 1997

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LIST OF TABLES

LIST OF GRAPHS

CONTENTS

INTRODUCTION

INTRODUCTION

Higher demand for protein nourishment of the increasingly fast growing world population is partially met by supply of legume and coarse grains and partly accomplished by the produces of livestock sector. The foods of animal origin, viz. milk, meat and egg, have higher biological value and are said to play a major role in meeting the protein demand (McDonald *et al.*, 1977). It has been realized that ruminants such as cattle and sheep and nonruminants such as rabbit, pig and poultry which convert fibrous agricultural by-products and waste into nutritiously rich food will be more beneficial and acceptable if these animals are reared under economically viable feeding system using the available land for grazing and fodder production (Cheeke, 1987).

Unfortunately the scope to increase fodder production is limited due to pressure of land use for human settlement, urbanization and development of industries. At present, availability of dry fodder is said to be 38% less than the actual requirement (Acharya, 1986). Alternate methods to overcome the current feed shortage are use of unconventional feed ingredient, evolving superior breed, selecting small-sized meat animal which require less feed, increasing feed conversion efficiency and improving the nutritive value of poor quality feed and by-products (Vietmeyer, 1985; Gupta, 1986; Punj, 1991).

In animal husbandry, major portion of maintenance expenditure goes in livestock feed management which includes production, procurement and supply of coarse grain and dry fodder. It is in fact a crucial issue in livestock development system. Although efforts are being made to increase coarse grain production, the feed cost always remained high due to socio-economic factors such as competition between men and animals for food and huge marginal-income group population present in the developing countries. Therefore, the scope for rearing livestock as a viable enterprise remained partially uncertain.

It is now known that agro-industrial wastes which are generated in large quantity and often held responsible for causing environmental nuisances, can be better utilized as animal ration after enrichment through appropriate technology. Several physical, chemical and biological methods have been evolved (Sundstol *et al.,* 1978; Rangnekar *et al.,* 1982; Kundu and Chawla, 1986 and Cheeke, 1987), to improve the nutritive value of lignocellulosic agro-by-products and waste. Unfortunately most of these methods are not practiced due to lack of adaptability of technology. Therefore it was found essential that better alternate and appropriate techniques are developed to sustain the precious livestock farming particularly the nonrumiants.

Considerable amount of solar energy is locked up in plants in the form of lignocellulose fibre (Janshekar and Flechter, 1983). These structural carbohydrates constitute the major source of food energy for livestock. However, due to lack of appropriate hydrolytic enzymes in the intestinal tract of animals, the digestibility of fibre is limited. Only 50% of the fibrous feed is generally utilized by the animals and the remaining is voided off as waste (Gupta, 1986). Enzymes known to break down lignocellulose complexes are produced by a number of micro-organisms and several of which are functional in the intestinal tract of ruminants and nonruminants (Gulati, 1991).

Biological conversion of agricultural by-products and waste into animal feed is attempted by several workers (Chahal, 1982; Langar *et al.*, 1989; Zakia Bano and Rajarathnam, 1988; Walli *et al.*, 1991; Gulati, 1991; Chaudhary *et al.*, 1994). Bacteria, fungi and yeast are known to increase the nutritive value of agro-waste and by-products through bioconversion and/or enrichment process (Kiran Singh, 1991; Krishnamoorthy *et al.*, 1996; Rangaswami and Bagyaraj, 1996). Use of filamentous fungi in fermentation of food for human consumption is known to have traditionally practiced in Asia Pacific and East Asian countries for several centuries (Kendrick, 1993; Subramanian, 1995).

Filamentous fungi play an important role in the biodegradation of agro-wastes (Chahal *et al.*, 1979) . The complex lignocellulosic substances are broken down into simpler structures through microbial degradation and thereby the utility of fibrous waste are said to have enhanced (Chahal, 1982; Cheeke, 1987).

Considering various constraints faced in maintaining large-sized animals by marginal farmers in rural sector, it was emphasized in the recent years that the rearing of small animals such as rabbit and poultry which require less housing space, feed and labour is more economical and realistic (Cheeke, 1987).

Rabbit, guinea-pig, poultry and Japanese quail are some of the non-conventional source of meat being popularized in recent times. Rabbit meat is consumed predominantly in Italy, Canada and France. Developing countries such as India, China, Thailand and Philippines in south east Asia and countries in Africa have also commenced rearing rabbit for meat (Cheeke, 1987; Sundaram and Bhattacharya, 1992).

In India, from the point of meat production, rabbit farming was first commenced in 1976 at the Central Sheep and Wool Research Institute, Avikanagar, Rajasthan. Four well known exotic breeds of meat-rabbit, viz. Soviet Chinchilla, New Zealand White, Gray Giant and White Giant, were experimented. The growth performance and suitability of these to Indian agroclimatic conditions have been investigated and the Soviet Chinchilla variety was found to be suitable especially to coastal environment (Sundaram and Bhattacharyya, 1991). Data on its production performance and economics are being gathered and further analyzed from different parts of the country. It is realized in this context that development of low-cost and suitable feeding and management practices applicable for local climatic condition will greatly enhance meat production in the country.

In the present work, fungal biodegradation of three locally available agricultural by-products and waste, viz. coconut coir-dust, cashew fruit-apple and karad grass, has been worked with an aim to formulate a low-cost, economically viable and enriched feed for rabbit.

The objectives of the present work were the following:

1. To select locally available agricultural by-products as substitute for costly feed ingredients.
2. To identify suitable biodegradation technique for enrichment of fibrous wastes and by-products
3. To study changes in chemical composition of agro-wastes on treatment by fungi.
4. To evaluate suitability of the fungus-treated agro-by-products as rabbit feed through digestibility, feed intake and meat quality studies. And,
5. To suggest improved techniques for better utilization of by-products and wastes as animal feed.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Domestic animals have been considered an integral part of farming since the dawn of human civilization. These have provided milk, meat, egg, leather, companionship and labour and greatly contributed to the development of rural stability and an enduring agriculture (Cheeke, 1987).

India has a large livestock population with about 192 million cattle, 69.8 million buffaloe, 48.4 million sheep and 95.4 million goat, besides an unlimited number of non-ruminants (Acharya, 1993). Traditionally, mixed farming is practiced in several parts of rural India where maintenance of livestock has been an integral part of agriculture (Patil *et al.*, 1993). The crop residues are generally used as livestock feed and soil enrichment has been accomplished by addition of farm yard manure.

Increasing human population demanded higher quantum of food production all over the world (Yotopoulos, 1987). Various estimates indicate an increase of 70-90 million people annually, with 87% of this growth occurring in the countries not able to feed themselves (Cheeke, 1987). Since the productivity value of farm animals is very low in India, it was necessary for marginal income-group farmers to maintain a large number to meet the regular requirement of meat and milk. Major portion of crop land has been used for production of cereals and consequently fodder cultivation was grossly neglected in India. Industrial use of roughage for paper- and board-making and domestic burning of agricultural by-products and fibrous waste for cooking is also on the raise. These all together resulted with shortage of fodder without which livestock rearing would be uneconomical.

A. LIVESTOCK FARMING AND FEEDS

a. Livestock farming:

Use of livestock as an efficient instrument to convert fibrous crop residue into nutritious food, viz. milk, meat and egg, has been realized well before (Mudgal *et al.*, 1995). However, the crop residues are poor in providing adequate energy and nitrogen due to the complex structural arrangement of plant cells. Physical degradation methods such as soaking in water, powdering and crushing have been attempted (Mathur and Sharma, 1985). Chemical treatment of fibrous feed has also been tried long before. Alkali-treated straw was fed to cattle in Germany during World War I (Ranjhan, 1983).

In livestock production, with introduction of high yielding animals and nonavailability of enough forages and roughage sources, more emphasis was given on concentrate feeding than roughage in the recent past. An increase in concentrate feeding by 2.6% as against 1.2% for fodder has been recorded

(Agostini, 1987). The past decade also saw an increase of 20% in nonruminant population as against 8% in ruminants and this was attributed mainly to nonavailability of adequate roughage (Agostini, 1987).

Presently, an estimated 700 million people do not get sufficient food around the world. Hunger and malnutrition are said to be on continuous raise in developing countries. It is predicted that there will be a deficit of 208 million ton food by 2000 AD (Paroda, 1996). Of the food grains, cereals are the major source of calorie in-take for people of low income household. It is now well realized that domestic animals are the major competitors of men for food grains. Out of the total world grain production, 47% is consumed as food by humans, 39% as feed by animals and the remaining 14% used for industrial purposes (Yotopoulos, 1987).

Broiler production has increased from 10 million to 200 million in the last two decades (Chadha, 1991). Similarly, population of other meat-animals has also been increased considerably to meet the increasing demand of protein-rich food. Concomitant with this, a 44% deficit in feed and 34% shortage in fodder is anticipated by turn of this century in India (Mudgal *et al.*, 1995). Therefore, there is an urgent demand to identify ways and means by which the competition between man and animal for grains can be reduced. Assuming a

10% growth in layers and 20% increase in broilers, 11 million tons of poultry feed will be required by 2000 AD over the present requirement of 4.5 million tons. In order to meet the demand, the following alternate measures were recommended by Rao and Rakshit (1991) for careful consideration: (i) finding out newer sources of feed ingredients, (ii) use of additives to improve efficiency of utilization of feed and fodder, (iii) reducing the feed wastage, (iv) increased use of agro-industrial by-products and waste as feed and (v) increased use of nonconventional feed ingredients.

b. Search for better feed substitutes:

Rayton and Hall (1979) developed improved feeding technology in poultry farming so as to reduce feed wastage and successfully increased the efficiency of egg production. Various feed resources such as babul seeds and mango kernel were tried as substitute for costly feed ingredients in farm animals and poultry development (Rao *et al.*, 1986; Shukla *et al.,* 1991,).

Efforts were made to identify economic feeding practices in livestock development. Various feed additives were added to improve digestibility of concentrate feeds. On adding yeast culture extract as crude protein source in cattle/poultry diet, improved performance was observed by Wiedmeier *et al.* (1987) and Verma and Shyamsundar (1988). Addition of biodegradable enzymes to feed ration was attempted by Devegowda (1991) and Chen *et al.* (1995) to achieve higher digestibility.

Use of agro-industrial by-products and waste as animal and poultry feed substitute was reported by several workers (Punj 1991; Sawal *et al.*, 1995). Ranjhan (1983) incorporated molasses as an alternate to grains in cattle ration. Waste materials such as rubber seed cake (Anantha subramaniam, 1980), animal waste (Hazarika, 1994), spent tea (Sud and Dogra, 1993) and sugarcane bagasse (Chaudhary *et al.*, 1994) were fed to livestock as substitute to costly feed ingredients.

Although little success was achieved, incorporation of unconventional items such as poultry waste in cattle and sheep feed (Paul *et al.*, 1994; Puntambekar *et al.*, 1991) and cow dung in poultry feed (Saikia *et al.*, 1988) was some of the efforts tried to overcome feed shortage and to improve the feed quality. Chademana and Offer (1990) added yeast culture in feed ration and studied its effect on digestion in sheep. Tegbe and Zimmerman (1977) tried the effect of same feed components in pigs. Water-washed neem seed cake as substitute for de-oiled rice bran in sheep and goat rations was reported by Ramu *et al.* (1994). Cotton seed hull was used as feed for poultry by Reddy and Reddy (1991).

c. Biochemistry of feed substitutes:

In livestock feeding exercises, it is now known that the fibrous feeds such as cereal straw and agricultural by-products are not fully utilized by animals due to complex nature of the substrate. Vast amount of potential energy is locked up in the form of lignocellulose molecules (Basham, 1975). About 3650 million metric ton per annum of cereal straw is available around the world (FAO, 1985).

During photosynthesis, about 95% of solar energy absorbed is fixed in the form of structural carbohydrate in plants. Of this, nearly 40% of energy is in the form of lignin (Kiran Singh, 1991) which forms a complex structure with cellulose and thereby protects the latter from enzymatic degradation by digestive juices of gastro-intestinal tract during herbivore feeding process. The enzymes required for breaking down of lignocellulose are known from a number of micro-organisms present in nature (Kalra and Singh, 1986).

Cellulose present in crystalline and amorphous form is the major nutrient component of fibrous feeds. Digestibility of this nutrient is affected because of its complex structural rearrangement with lignin. Thus, the primary requirement is to break the linkage between cellulose and lignin and thereby improve the digestibility of fibres.

d. Digestion of fibrous feeds:

Various physical, chemical and biological methods have been attempted to disrupt lignocelluloses and digest the fibrous feeds. Simple exercises such as soaking in water, cooking, crushing and microwave heat treatments have been tried.

Rangnekar *et al.* (1982) observed that the digestibility of roughages has increased when the feed source was subjected to high pressure steam treatment. Mahyuddin *et al.* (1994) reported the advantages of pelleting diets in the growth performance of sheep. Banerjee (1988) reported that irradiation of straw had improved its digestibility in sheep.

Chemicals such as sodium hydroxide (Garrett *et al.*, 1979; Berger *et al.*, 1980; Chesson, 1981; Patterson *et al.*, 1983; Moss *et al.*, 1990), calcium hydroxide (Sharma and Verma 1993), ammonium hydroxide (Sundstol *et al.*, 1978) and urea (Agrawal *et al.*, 1989; Prasad *et al.*, 1993; Vinod kumar and Walli, 1994) have been successfully used in the treatment of straw and these resulted with digestibility improvement from 10 to 20%.

Although physical and chemical treatments can improve digestibility up to about 36%, biological treatments were shown to enhance the digestibility to a much greater extent (Kiran Singh, 1991). Several studies have been made on microbial degradation of fibrous feeds and agro by-products (Bisaria *et al.,* 1987; Rajasekhara and Gulati, 1992; Neelakantan and Deodhar, 1993). Further, in view of nonavailability of desired chemicals and poor response of fibres to treatment, reluctance of farmers to adapt chemical treatment for straw digestion has been discussed by Mahendra Singh *et al.* (1993).

e. Role of microorganisms in the digestibility of fibres:

Nature has provided herbivores with a well-developed and microbially enriched digestive system with which the animals can efficiently degrade fibrous crop residues and other lignocellulosic waste and derive energy. Attempts have been made by several workers to take advantage of this biological phenomenon. Role of bacteria in the digestibility of fibrous feed in ruminant digestive system has been well recognized. Hungate (1966) estimated presence of a load of 10^7 million bacteria per ml of rumen fluid.

Two well known species of anaerobic bacteria, viz. *Rumenococcus albus and R. flvofacian,* are said to play a major role in cellulose degradation and transformation into volatile fatty acids in the rumen (Barnett and Reid, 1961).

The role of anaerobic fungi in fibre digestion has also been studied extensively (Gulati, 1991). These organisms are generally active under anaerobic condition at a pH range of 6.4 to 7.0.

Teather (1985) made an attempt on genetic manipulation of rumen micro-organisms through gene cloning technique. The first attempt was to reduce the supply of outside protein to herbivores by increasing the level of production of amino acid by rumen bacteria. The second approach involved improving the rate of fibre degradation by bacteria. However, the work was difficult because several enzymes involved in lignocellulose degradation are produced by a number of organisms both within and outside the rumen. Through gene cloning technique, favourable genes were transferred from *Escherichia coli* to *Rumenococcus albus* in the rumen and the survival of the organism with synthetic gene under the rumen ecosystem was studied (Teather, 1985).

Several workers attempted to grow favourable microorganisms in artificial media and to use the microbial biomass as feed supplement (Moo Young et al., 1979). Some promising species of *Pseudomonas* were grown in methanol and convertion of hydrocarbons into bacterial protein was achived (Zwatanov, 1988). Feeding trials conducted using single cell protein in young pigs and rats (Zimmerman and Tegbe, 1977) showed encouraging results. Kumar *et al.* (1977) grew *Bacillus* in paddy husk and compared the structural carbohydrate changes occurred in the process with that of chemical treatment. Use of *Lactobacilli* as important organisms for enrichment of food has been reported by Rathna *et al* (1994). Schingoethe *et al.* (1984) fed dried cells of *Lactobacillus acidophilus* and *L. bulgaricus* to cattle and reported its effect on milk production. Maize meal fermented with *L. plantarum* when fed to broiler chicken showed no adverse effect on growth performance (Newman and Sands, 1984).

Conversion of carbohydrate into protein-enriched microbial biomass and further use as human food have been practiced for long. Consumption of fermented food product such as 'polu pedro' in south-east Asian countries was known since 18^{th} century (Zadrazil, 1984).

The first attempt to incorporate yeast as food additive was made by Balling in 1865. Development of improved technology for production of food yeast as protein supplement for human consumption was described by Reed and Peppler (1973). Species of *Saccharomyces* and *Candida* were grown in alcohol for production of single cell protein from hydrocarbon . The harvested biomass was added to diet of poultry (Egorov *et al.*, 1986; Bhatt *et al.*, 1995), cattle

(Desai and Shukla, 1988; Kulkarni et al., 1994) and pig (Tegbe and Zimmerman, 1977) as substitute for protein in the ration.

The role of anaerobic fungi in fibre digestion has been extensively studied (Gulati, 1991). Since these organisms are active only under anaerobic condition at a pH range of 6.4 to 7.0, the scope of utilising them in field condition is limited. However, solid state fermentation by aerobic fungi for improving the digestibility has been attempted by several workers (Senez *et al.,* 1980; 1979; Gupta, 1986; Valmaseda *et al.,* 1991).

Brown rot, soft rot and white rot fungi were used in the degradation of lignocelluloses. Cellulose which is a polymer of glucose is degraded by hydrolytic enzymes whereas lignin, a phenolic compound, is degraded by oxidation processes (Kirk and Farrel, 1987). Gulati *et al.* (1986) used *Trichoderma reseii* for bioconversion of cellulose into soluble carbohydrate in sugarcane bagasses. Fifty percent increase in digestibility of bagasses was reported in cattle due to break down of the lignocelluloses during fermentation. Several workers have used species of *Agaricus, Phanerochaete* and *Pleurotus* as lignin degrading organisms (Zadrazil and Brunnert, 1982; Langar *et al.,* 1982; Kakkar *et al.,* 1990; Puniya et al., 1996).

f. Substrate enrichment through microbial fermentation:

Attempt was made by Han (1978) to enrich the wheat straw through microbial fermentation. Hatakka and Pirhonen (1995) cultivated wood-decaying fungi such as species of *Ganoderma* and *Phanerochaeta* on various agricultural wastes and concluded that the decomposed lignocellulosic material enriched with fungal protein may be a vauable feed.

Rai *et al.* (1993) studied effect of fungal growth on cotton straw under submerged culture condition. Santos and Gomez (1977) designed a starch fermentor for production of fungal mycelium in a liquid medium. Rodriquez and Enriquez (1985) used enriched liquid medium to grow appropriate fungi. In all these studies, the fungal mycelium was harvested and used for feeding the animals.

The process of bioconversion technology for agro- by-products are required to be simple so that it can be repeated and practiced at farmers' level. Wheat straw used for production of edible mushroom through solid state fermentation was tried as a possible feed (Langar *et al.*, 1982). The by-product, viz. the spent-straw, was evaluated for its nutritive value (Singh *et al.*, 1990). Gupta (1986) developed a novel method labelled 'Karnal Process' for enriching wheat straw using *Coprinus fimetarious*. Natarajan *et al.* (1992) reported successful use of *Pleurotus citrinopileatus* in the biodegradation paddy straw. Rajsekhara and Gulati (1992) recorded the effect of fungal biodegradation on chemical composition of cotton straw. Choudhary *et al.* (1994) fermented sugarcane bagasse using separately *Pleurotus florida* and *P.cornucopiae* and reported that lignin degradation was higher in *P.florida* inoculated sample. Arneja and Chahal (1992) used *Chetomium cellulolyticum* for fermentation of rice straw, with and without pretreatment, and indicated that pretreatment enhances the process without any adverse effect on chemical compositon of the substrate. Considering these possible advantages, solid state fermentation was favoured for bioconversion of agro by-products using fungal principles.

In order to achieve enhanced rate of biodegradation, straw material was pretreated prior to inoculation by fungi by several workers. Kishan Singh *et al.* (1989) pretreated wheat straw with sodium hydroxide or ammonia and reported that 4% sodium hydroxide treatment gave maximum increase in crude protein content under submerged condition with *Aspergillus terrus*. Walli *et al.* (1991) studied the influence of urea on growth of *Coprinus filamentarius* and observed increased nutrient utilisation in calves. The digestibility of urea-treated straw was more in cattle than in untreated *Coprinus* fermented straw.

Zadrazil and Brunnert (1981) evaluated various physical parameters required for effective biodegradation of lignocelluloses when grown with *Pleurotus* spp. Raman Rao and Naik (1992) studied the influence of moisture level and incubation period for colonisation by *Pleurotus sajor-caju* in paddy straw. Puniya *et al.* (1992) reported that gaseous metabolites accumulated in the substrate during fermentation inhibited degradation by fungi. Saxena and Rai (1992) reported that higher level of nitrogen in the substrate inhibited enzyme production by *P.sajor-caju.*

Choice of suitable fungi for fermentation of agro by-products is important in improving the process of solid state fermentation. In the selection of suitable candidate fungus, Sondhi *et al.* (1988) compared performance of 19 species of filamentous fungi in solid state fermentation of paddy straw. The biomass yield was higher in *Pleurotus sojar-caju* treated substrate than in other treatments. Kundu and Chawla (1986) inoculated different fungal species on wheat straw and reported that *Alternaria tenuis* and *Chaetomium globosa* caused maximum decrease in neutral detergent fibre content. Rai *et al.* (1986) attempted to improve the nutritive value of bagasse by fermentation with *Trichoderma reesei* and observed that both digestibility and crude protein content improved after 30 days of fermentation.

Although several attempts have been made to improve the nutritive value of straw through bioconversion processes, little effort was made on use of other agricultural wastes. Gulati (1991) used agricultural wastes as substrate for bioconversion. Leaves and tuber of tapioca were used as substrate for fungal growth by Alexander(1977). Cassava tubers enriched by nitrogen and inoculated with *Aspergillus niger* fermented into a protein-enriched feed called 'cassapro' (Kompiang, 1995). The feed could be prepared at village level and incorporated in poultry ration at 15% level.

Well over 20000 species of litter degrading fungi are known. A sizable number of these belong to Basidiomycotina (Kendrick, 1993). Among these, species such as *Phanerochaete chrysosporium* has been studied and is known to be highly lignolytic. Several species of edible mushroom fungi undertake lignin degradation. Rai *et al.* (1993) studied the lignolytic activity of 23 species of Basidiomycetous fungi and reported that *Pleurotus sajor-caju* colonised well on the substrate. Kishan Singh *et al.* (1989) reported that, when grown on paddy starw, *P. sajor-caju* and *P. florida* degraded lignin to same extent. Considering the capability of various enzyme production, safety and easiness to handle, *P. florida* has been selected for the present study.

Although several workers have used paddy straw and wheat straw as substrates for feed biodegradation, limited attempts have so far been made to use other agro waste material for conversion into animal feed. Evaluation of fermented banana waste as protein source in poultry development has been reported by Sethi (1983). Susan and Jeannett (1984) used citrus pulp as base for production of single cell protein with *Fusarium* sp. In view of its low investment cost and easy adaptability, these authors had followed solid state fermentation instead of submerged culture. Keeping these possible advantages in mind, degradation of substrate by fungi through solid state fermentation process was attempted in the present study.

B. RABBIT PRODUCTION AND FEEDS:

Rabbits are raised for a variety of reasons, and are found in virtually every country. Production of rabbits for meat has long been known in the European countries such as France, Italy and Spain (Cheeke, 1987).

Rabbit production in commercial livestock farming required only limited land and financial resources. With increased interest in 'urban-farming', rabbits were considered the better choice in the selection of suitable components (Cheeke, 1987). They can be raised in a small place and be fed with vegetable waste and by-products.

a. Advantages of rabbit as meat source:

Compared to other types of livestock animals, rabbits have a rapid growth rate and may reach market weight within 120 days from birth (Sundaram and Bhattacharyya, 1991). Rabbits can be successfully raised on feeds such as forages (e.g. leguminous tree leaves, grass forages, fruit-tree leaves, aquatic weeds, etc.) and grain-milling by-products (e.g. rice bran, corn bran and table scaps) which are noncompetitive with human foods. Being small in body size, rabbits require only small quantities of food. Rabbits have simple housing requirements; they make no noise and produce little odour (Cheeke, 1986). Vietmeyer (1985) termed the rabbits as 'micro-livestock', having great potential as a means of providing protein to the multitudes of low-income people in the developing countries.

However, a few factors currently limit the economic viability of rabbit for meat production. Rabbits are susceptible to many respiratory and enteric diseases due to malnutrition. Feed supply is the major limiting factor in rabbit production. World recognised rabbit expert Cheeke (1987) stated that improvement in feeding and better nutrition should make rabbit husbandry profitable.

b. Present status of rabbit-feeds:

Considering the existing market price of livestock feed commodities, the cost of balanced rabbit diet worked out to be approximately Rs.6.00 per Kg. Assuming that an animal consumes around 5-8% of its body weight feed per day, an adult animal requires about 100 gm of feed for a day (Cheeke, 1987; Sundaram, 1997). This would cost Rs 1.20 per day for feeding an animal.

c. Dietary requirements of rabbits:

Ruminant animals such as cattle and sheep have very simple nutritional requirements because the rumen micro-organisms produce the required amino acids, energy sources and most of the vitamins. Chickens require almost all known nutrients in their diet. Although rabbits are poor digesters of fibres, they are adapted to the utilization of fibrous feeds (Cheeke, 1983).

d. Fibrous feed for rabbits:

Observations on feeding behaviour of wild rabbits revealed that they require a diet of tender leaves and succulent plant parts (Van Soest, 1982). Rabbits are concentrate feeders, selecting high protein and high carbohydrate portions of plant material. However, rabbits are generally adapted to high-fibre containing roughage feed, the digestive strategy being quick elimination of fibres from the gut and consumption of non-fibre constituents of the forage. Fibrous feeds such as alfalfa, clover, grass, etc. are typical rabbit diet. Alfalfa is 20-25% fibre and 75-80% non-fibre components. Separation of fibre from nonfibre in the feed takes place in the colon, with the fluids and small particles are utilized for fermentation in the cecum. The fibres are excreted as 'hard faeces' (De Blas *et al.*, 1986).

Rabbits are hind-gut fermenters, the specific site of digestion being the cecum. All processes of digestion occuring in ruminants take place in the rabbit (Cheeke, 1987). Copropagy (eating of 'soft faeces'), consumption of cecal contents, a process comparable to remastication in cattle, takes place in rabbits and aids in the complete absorption and digestion of fibre containing herbaceous feeds (Robinson *et al.*, 1985; Cheeke, 1987).

Various researches have shown that even though rabbits do not digest fibre very effectively they require a fairly high level of fibre in their diet (Cheeke, 1983). On studying the dietary effect on rabbits, De Blas *et al.* (1986) concluded that the growth rate was optimal with a low-energy and high-fibre (15-20%) diet. A high-fibre containing diet had less influence on reducing the protein availability to animals since cecotrophy is known to have increased the nitrogen retaining capacity in rabbits (Hornicke and Bjornhag, 1982). High-fibre containing pelleted diet reduced enteritis and fur-chewing in rabbits (Harris *et al.*, 1983; Cheeke, 1987).

It has become therefore necessary and important to identify alternate, nutritious, low-cost and balanced diet for rabbits using available fibrous agro-waste and other natural resources.

MATERIALS AND METHODS

MATERIALS AND METHODS

I. Survey, selection and evaluation of suitable agricultural by-products as feed ingredient for the present study

1.1. Survey and selection of suitable agricultural by-product/wastes as substitute feed base

In order to evaluate the current value of domastic animal feeds and to plan for suitable low-cost feed ingradient substitute, the cost of various presently available animal feeds was ascertained from the prevailing market price in the state of Goa and computed for the past ten years (Table 1). Annual increase in the price index of conventional feed ingredients was worked out and the changes observed in the cost are presented in Fig. 1-3.

A field survey, on the availability and continuous supply of common agro-waste and by-products for preparation of low-cost animal feed ingredient, carried out earlier (Sundaram, 1986) by obtaining informative data from local agro-industrial units, indicated that coconut coir dust, cashew fruit-apple and karad-grass are available in abundance all over in the state of Goa and neighbouring districts of Maharashtra and Karnataka and may be tried as substitute feed bases.

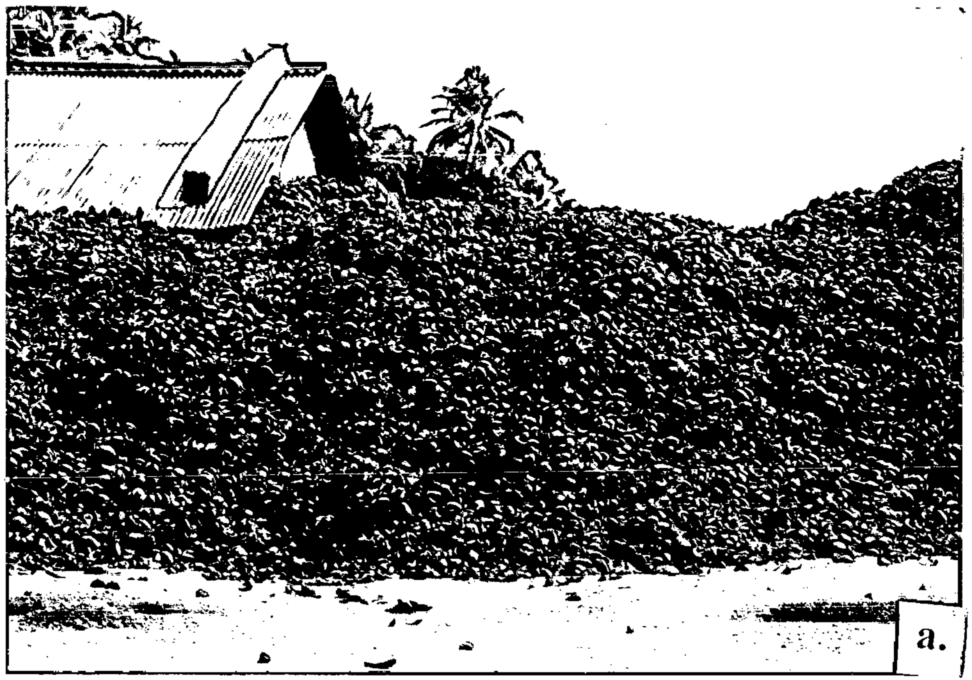
The Annual Statistical Report of the Department of Agriculture, Government of Goa (1991), was used as source material to predict the status and quantum of availability of various agricultural by-products and waste in the State. Information on land area under coconut and cashew cultivation, yield per annum and present-status of utilization of produces were obtained from the Annual Report of the Directorate of Planning and Statistics, Government of Goa (1989-1993) and the Proceedings of the ICAR Research Station, Old Goa (1989).

Chemical composition of the agro-waste/by-product materials, viz. coir dust, cashew fruit-apple, and karad grass were analyzed following the procedure outlined in the Manual of AOAC (1975) and Van Soest (1963). Based on the analyses, and considering their plentiful availability and limited use for other industrial/domestic purposes, these lignocellulosic wastes were tested as possible animal feed-ingradient substrates in the present study.

1.1.1. Coconut coir dust:

Coconut (*Coccus nucifera*) coir dust used in the present study was obtained from a coir production unit of the Department of Industries, Government of Goa, located in the rural industrial estate, Kundaim, Goa. The coconut husk generally heaped up near the factory (Pl. I,a) is otherwise used to a limited extent as domestic fuel by the local inhabitants or as a soil moisture retainer in the plantation crop fields. The average weight of the nut and available husk were

Plate - 1


a.


b.

estimated for dried coconuts. The percentage availability of coir-dust was calculated at the rate of 4.5% of the husk weight (per. comm).

On subjecting through roller drums, fibre component of the coconut husk was separated (Pl. I,b) and dust particles were collected by sieving the powder waste through an iron mesh of 20 mm # size (Pl.II,a). Moisture content of the coir-dust was estimated by drying it in a hot-air oven and calculating the weight loss. The bulk dust was sun-dried for seven days and stored in polythene bags for further analysis and for solid state fermentation.

1.1.1.Cashew fruit-apple:

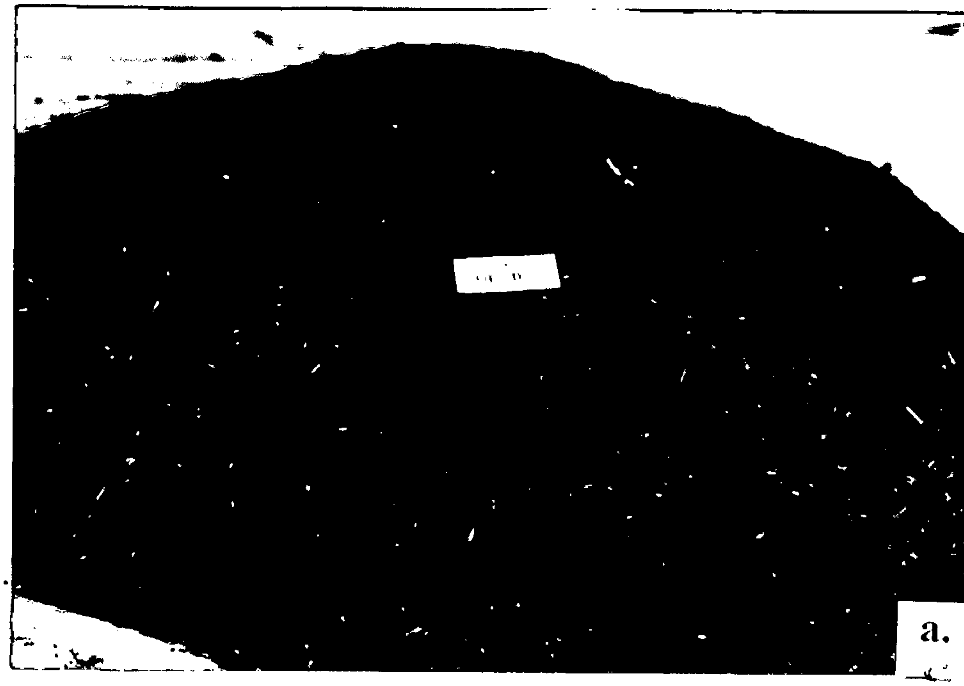
Cashew (Anacardium occidentale) fruit-apple material used for this study was collected at random from the experimental plantation sites of ICAR Research complex, Old Goa (Pl. III,a,b) and gross weight of fruit and nut was estimated using Metler analytical balance. Moisture holding capacity of the fruit apple was determined by crushing the ripe fruits manually or with electrically operated crushers as shown in Pl. IV,a (Sundaram, 1986). Crushed fruit-apple discarded as waste (Pl.IV,b) contains about 70% moisture. The apple waste was sun-dried 8 hr per day for one week, powdered into grits and stored in sterile polythene bags for further analysis.

PLATE - 2

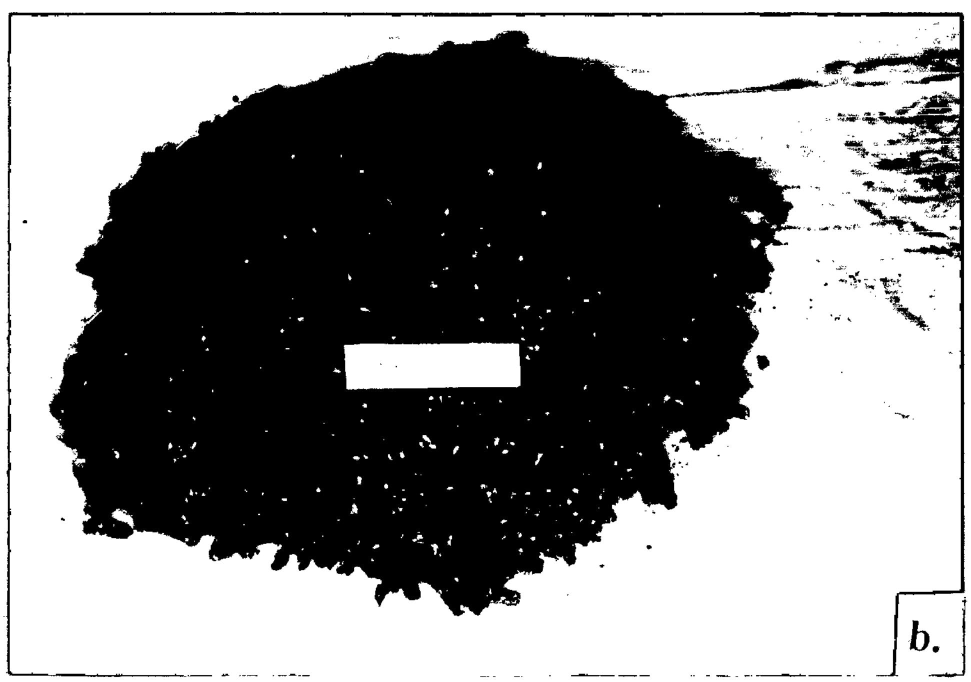
a. Coir dust rejected from coir pith as waste.

b. Compounded pelleted feed formulated with coir dust.

Plate - 2



a.



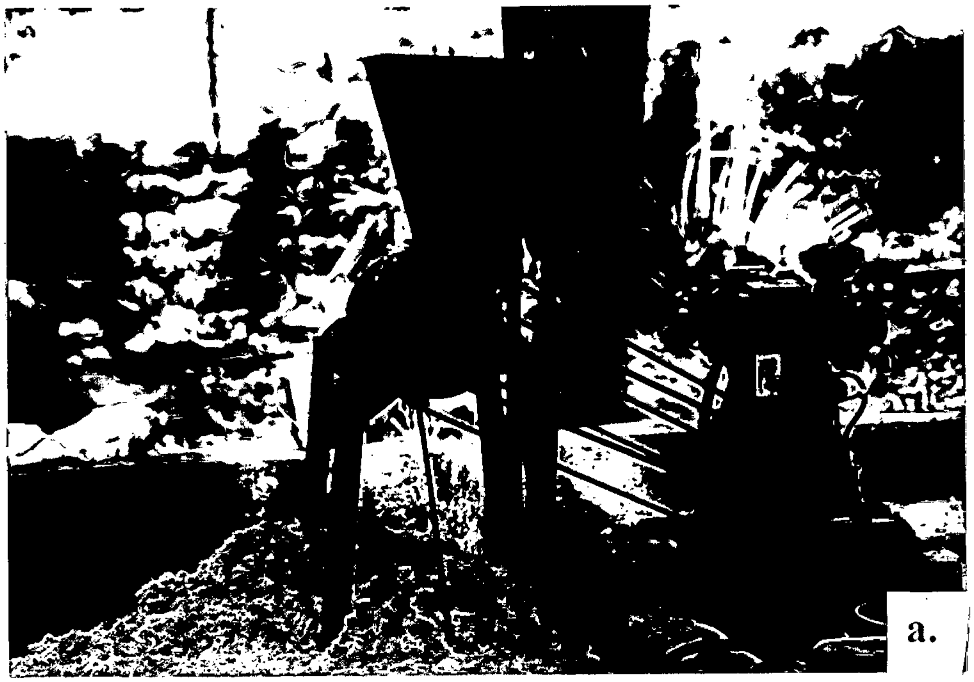
b.

Plate - 3

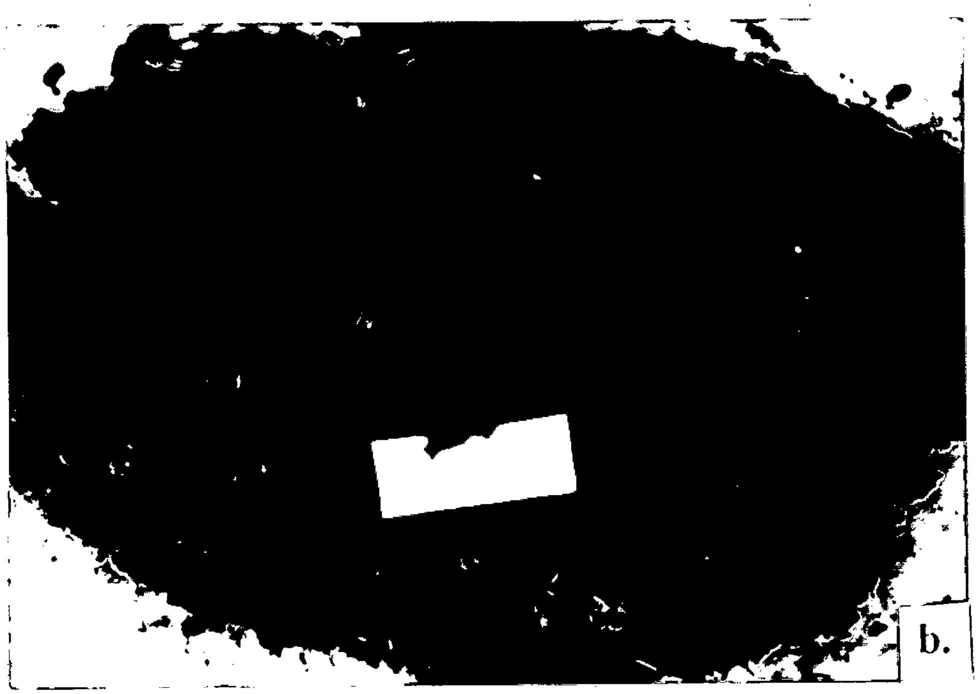
a.

b.

Plate - 4



a.



b.

1.1.3. Karad grass:

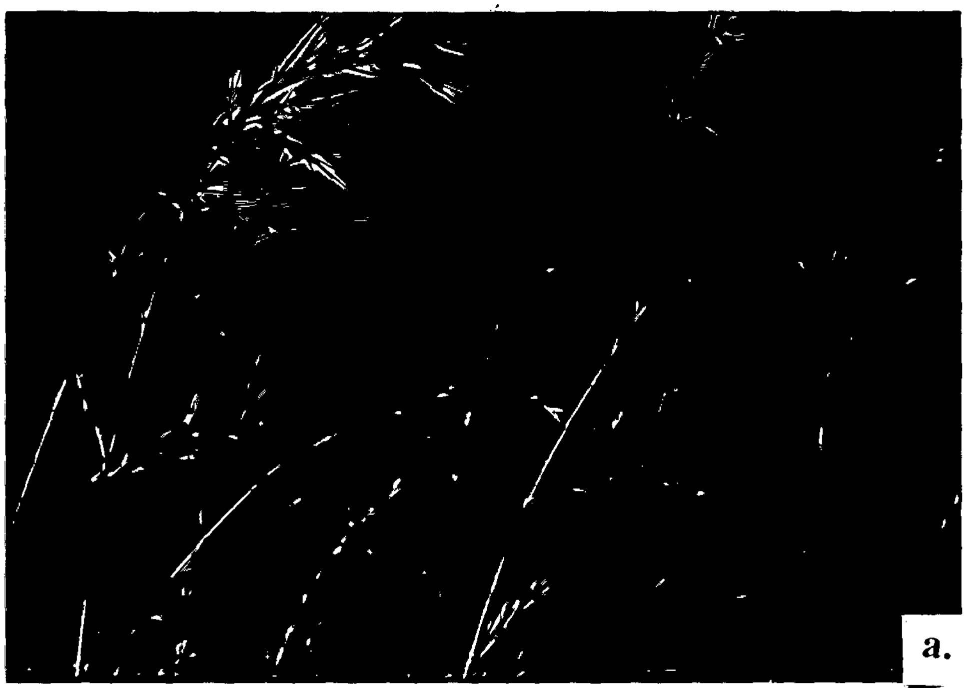
The karad-grass (*Themeda quadrivalis*), growing wild on the plateau and hilly terrains (Pl. V,a,b), is available in large quantity in Goa. These are annuals appearing with the onset of monsoon rain in June and drying out in October every year (Pl. VI,a). The fresh biomass yield was estimated by harvesting the grass at random per unit area. Dry matter content of the grass was analyzed following the standard procedure outlined by AOAC (1975). The grass was harvested during its early flowering stage (Pl. VI,b) and sun-dried, at the rate of 8 hr per day, for seven days to remove the moisture. The hay was cut into small pieces of 2 to 4 inches and stored in polythene bags for further treatment.

II. Evaluation by substrate fermentation.

2.1. Microbial (fungal) inoculants used in the study

Pure cultures of *Pleurotus florida, Ganoderma lucidum* and *Trichoderma viride* were obtained from the culture collections of the Indian Institute of Horticulture Research, Bangalore, Indian Agriculture Research Institute, New Delhi, and Tamilnadu Agricultural University, Coimbatore, respectively. The cultures were grown in malt extract agar and potato dextrose agar media and maintained at the Fungus Culture Collection of Department of Botany, Goa University. These fungi were inoculated separately into boiled and autoclaved wheat grains and maintained in sterile saline bottles. After two weeks of mycelial

Plate - 5



a.

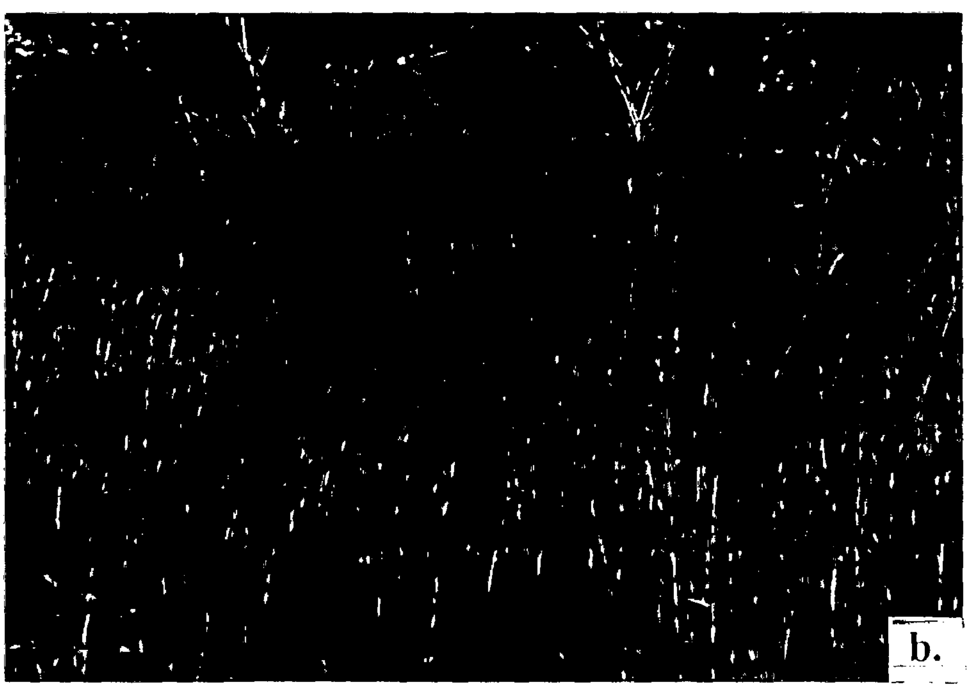


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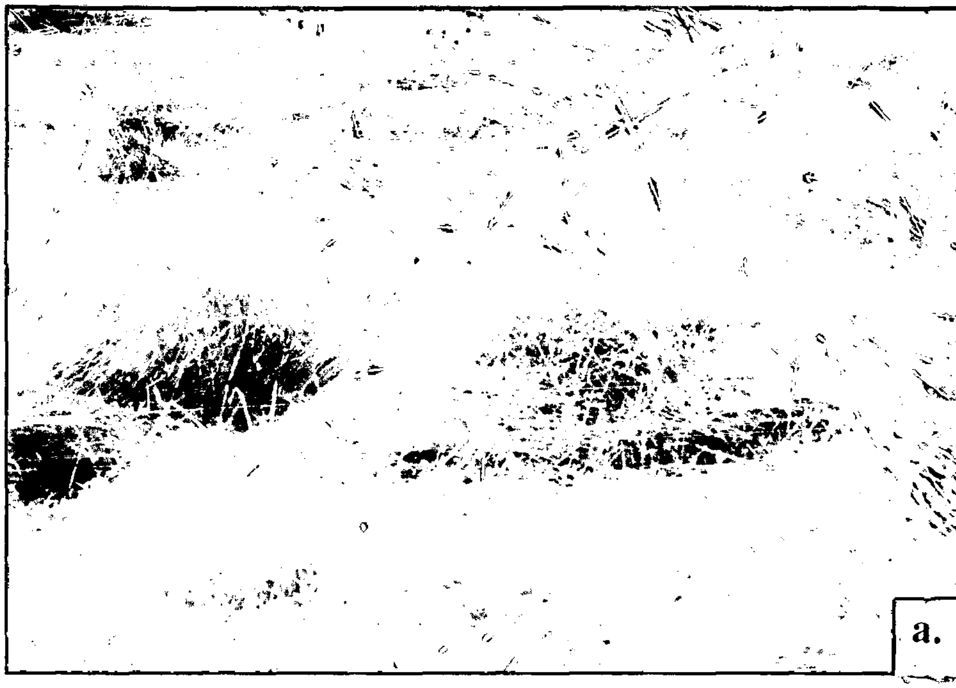
Plate - 6



a.

b.

growth, the spawn was used as inoculant for solid state fermentation of the selected substrate.

2.2. Fermentation of sample substrate

One hundred gram of substrate was placed in each polypropylene bag of 12 x 8 cm size and maintained in triplicate sets. The substrate was moistened with deionized distilled water and autoclaved in a steam sterilizer for 20 minutes at 15 psi. Approximately 5 g of well grown spawn was spread over the substrate in each bag and the bags were sealed and maintained in a BOD incubator at 30^{0}c for a required duration of incubation period. Fermented sample bags were tear-opened and placed in a hot-air oven maintained at a temperature of 60°C for about 3 days until the moisture is completely evaporated.

As outlined in Savoie *et al.* (1992), pH of the substrate was measured as follows. About 0.5 g sample was taken in 10 ml water and allowed to stand for two hours in a 50 ml beaker. The decanted supernatant fluid was used for estimation of pH.

2.3. Bulk fermentation of substrate

The experiment on bulk production of fermented substrate was undertaken as follows:

Five kg of substrate was placed in a 45 x 35 cm size polypropylene bag. The substrate was soaked in deionized distilled water to attain 100% humidity and autoclaved in a steam sterilizer for 20 min at 15 psi. The bulk substrate was inoculated by appropriate fungal spawn culture. The bags were sealed and maintained in a BOD incubator at 30^0c. After thirty days of incubation, substrate was opened and oven-dried at 60^0C for 3 days. The dried shreds of fermented substrate were stored in sealed and maintained in polythene bags for several months and mixed with the feed as and when required prior to feeding trials.

III. Evaluation by feeding trials.

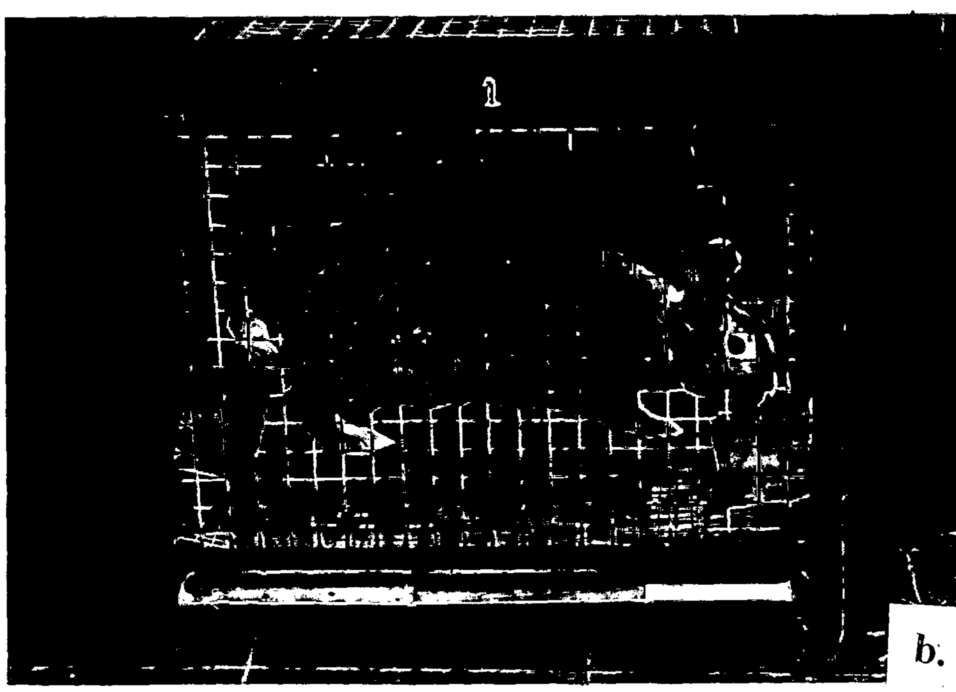
3.1. Test animals

Cross bred variety of adult Soviet Chinchilla rabbit (*Orictologus cuniculos*) used in the present investigation as test animal to evaluate the suitability and value of feed ingredients were obtained from the lot maintained at the experimental animal unit of ICAR Research Complex, Old goa (Pl. VII,a).

3.2. Formulation and administer of trial feed

The nutrient requirement of adult rabbit was estimated as per the standard recommended by Cheeke (1987). The minimum standard digestible energy requirement was taken as 2600 kcal/kg feed and crude protein requirement as 16% of the feed (Cheeke, 1987).


a.


b.

The commonly used rabbit feeds such as wheat, wheat-bran and groundnut oil-cake were selected as feed ingredient bases. The experimental diet for test animal was formulated and prepared by proportionately replacing the wheat bran with the fermented by-products by w/w ratio as indicated in Table 1-3. The replacement was maintained for wheat bran alone since it had high lignocellulosic content and low digestibility value. The standard feed served as the control.

As the rabbits have a tendency to refuse uncommon ingredients, the experimental feed mixture was prepared in the form of pellets of 4 mm diam (Pl. VIII).

3.3. <u>Setting up of test animals for trial feed</u>

3.3.1. Selection of animals:

Eight Soviet Chinchilla cross bred rabbits of sixteen week old with an average body weight of 2-2.5 kg were selected and divided into two groups of four animals each. These were housed individually in separate metabolism cages (Pl: VII,b). A switch-over feed trial was conducted for a preliminary period of 10 days and an experimental digestion trial for an additional seven days. All the animals were individually fed *ad libitum* everyday.

Table 1. Ingredient composition of experimental diet with coir dust.

	Control	CD			CDPL		
		10	20	25	10	20	25
Wheat	50	50	50	50	50	50	50
Ground nutcake	25	25	25	25	25	25	25
Wheat bran	25	15	5	-	15	5	-
Coir dust	-	10	20	25	-	-	-
Coir dust fermented	-	-	-	-	10	20	25
Crude protein	18.00	17.27	17.00	16.18	17.15	17.35	17.67
DE KcalKg	2675	2660	2655	2650	2645	2615	2600

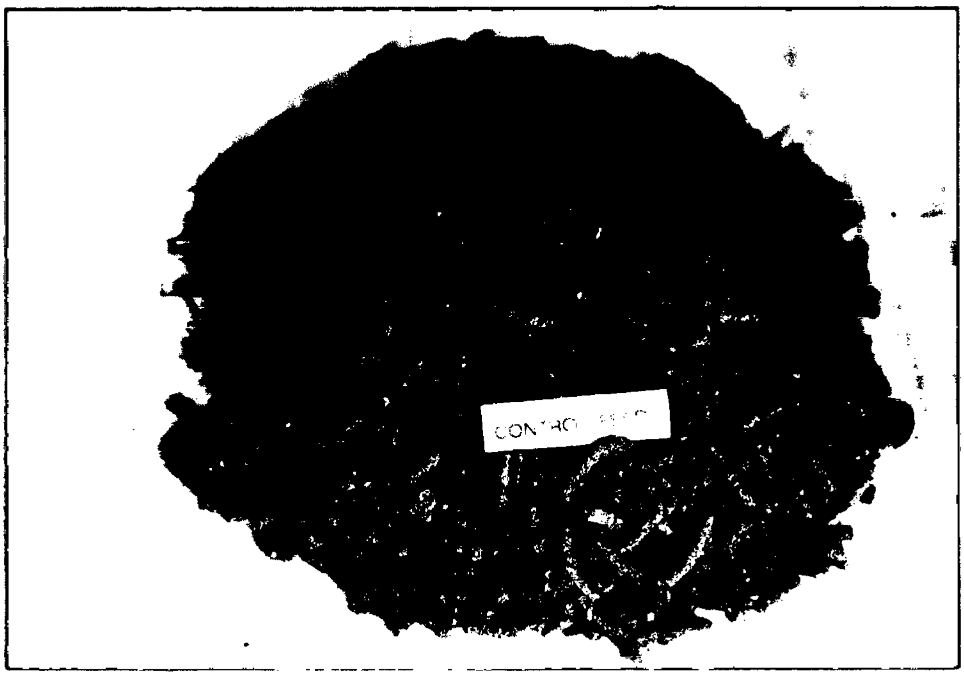
Table 2 . Ingredient composition of experimental diet with cashew apple waste.

	Control	CAW			CAWPL		
		10	20	25	10	20	25
Wheat	50	50	50	50	50	50	50
Ground nutcake	25	25	25	25	25	25	25
Wheat bran	25	15	5	-	15	5	-
Cashew waste	-	10	20	25	-	-	-
Cashew waste fermented	-	-	-	-	10	20	25
Crude protein	18.00	18.05	18.10	18.12	18.40	18.80	19.00
DE Kcal/Kg	2890	2775	2790	2850	2760	2800	2820

Table 3. Ingredient composition of experimental diet with karad hay.

	Control	KRD			KRDPL		
		10	20	25	10	20	25
Wheat	50	50	50	50	50	50	50
Ground nutcake	25	25	25	25	25	25	25
Wheat bran	25	15	5	-	15	5	-
Karad hay	-	10	20	25	-	-	-
Karad hay fermented	-	-	-	-	10	20	25
Crude protein	18.00	17.47	16.95	16.68	17.77	17.55	17.43
DE KcalKg	2725	2705	2675	2675	2685	2645	2600

Plate - 8



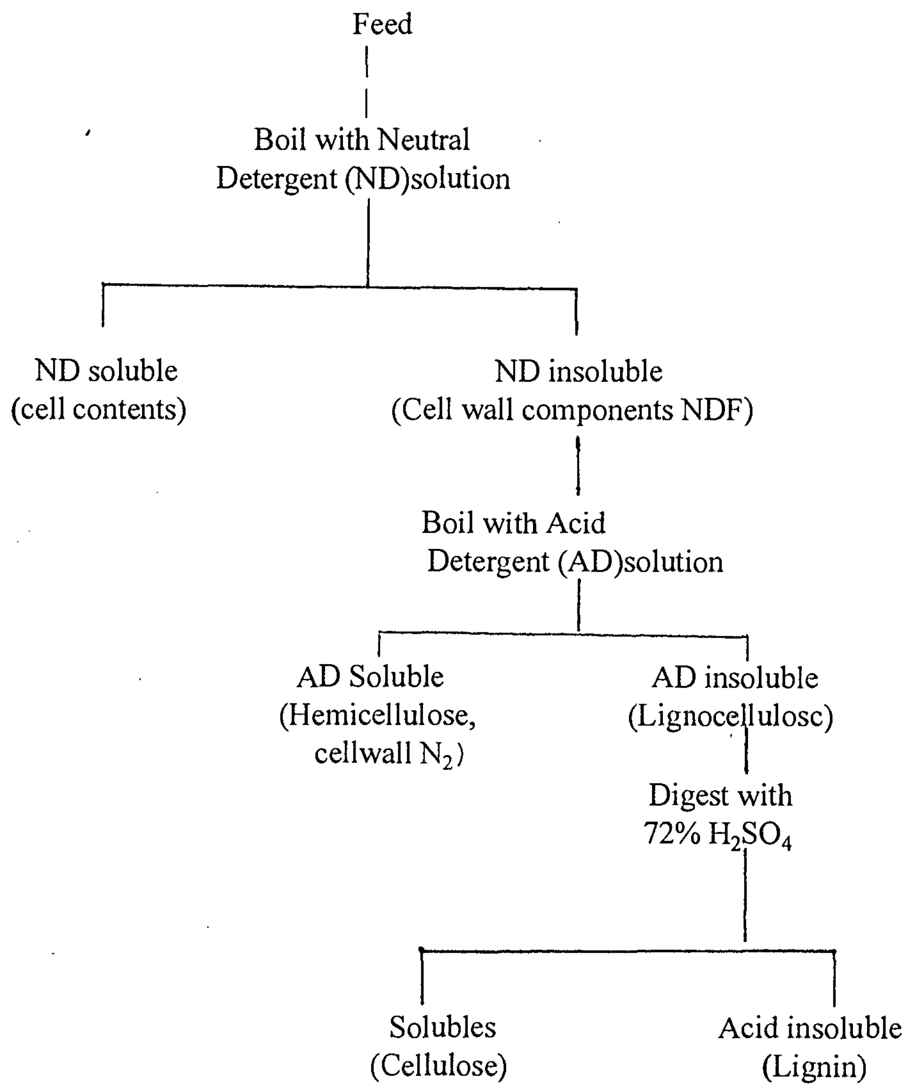
3.3.2. Feeding trials:

Weight of consumed and leftover feed and dung output were recorded for all individuals at 24 h intervals. These materials, collected during the feeding period, were oven-dried at 60^0 c for three days, powdered using a blender and stored for further analysis. The initial and final body weight were recorded for each animal in all experiments. The feeding trials were repeated thrice for each feed. Daily growth rate and average body weight gain were calculated by dividing the overall weight gain from the total number of days of feeding trial experiments.

IV. Chemical analysis.

The cell wall components of the lignocellulosic feed were analyzed as per the scheme of Crompton and Harris (1969) shown in flow-diagram given below. Desired aliquot of experimental and control feed was taken, powdered in a blender and analyzed as per the method of Goering and Van Soest (1970).

Scheme for analysis of cellwall components of lignocellulosic substances (Crompton and Harris, 1969)



4.1. Neutral Detergent Fibre (NDF)

4.1.1. Preparation of stock solution:

Neutral detergent solution was prepared by dissolving the following in 1 litre distilled water.

Sodium lauryl sulphate	30.00 g
EDTA (Disodium ethylene diamine tetraacetate)	18.61 g
Sodium borate decahydrate	6.81 g
Disodium hydrogen phosphate anhydrous	4.56 g
2-ethoxy-ethanol(ethylene glycol monoethyl ether)	10.00 ml

The pH of the solution was adjusted to the range between 6.9 to 7.1.

4.1.2. Estimation:

One gram of the sample was ground to pass through a 1 mm # size sieve and placed in a tall-form, spoutless, 500 ml beaker for refluxing. 100 ml of cold neutral detergent solution, 2 ml dekalin and 0.5 g sodium sulphite were added to the sample and heated to boil for 5-10 min. Thereafter, the heat was reduced to avoid foaming. Refluxing was continued for 60 min from the onset of boiling. The digested sample was transferred to a previously weighed sintered crucible kept on a filtering apparatus and washed with a minimum of hot water (80^0c). The washing with water was repeated thrice to remove the residual chemicals and finally twice with acetone. The crucible with residue was dried at 105^0c overnight, cooled and weighed.

4.1.3. Estimation:

$$NDF\% = \frac{\text{Wt.of crucible+ residue - Wt.of crucible}}{\text{Wt.of sample on dry matter basis}} \times 100$$

The lignocellulose content of the feed was estimated as acid detergent fibre following the procedure outlined by Goering and Van Soest (1970).

4.2. <u>Acid Detergent Fibre</u> (ADF)

4.2.1. Preparation of Acid detergent solution :

1N H_2SO_4 standard solution was prepared by adding 49.04 g of Sulphuric acid to 1 litre of distilled water. To this solution 20 g of cetyl trimethylammonium bromide (technical grade) was added, stirred well and dissolved.

4.2.2. Estimation:

One g of sample was placed into a tall form beaker. To this, 100 ml of acid detergent solution and 2 ml of decahydronaphthalene were added and refluxed for 60 minutes from the onset of boiling. Initial heating for boiling was continued for 5 to 10 min and further the heat was adjusted for boiling at slow and even level to avoid foaming.

The digested sample was filtered through a crucible, fixed over a filtering apparatus fitted with light suction, and washed twice with hot water (90^0c). Washing was repeated with acetone (reagent grade) until it removed all colours, followed by washing twice with hexane. The residue was dried at 105^0c for overnight, cooled to room temperature and weighed. Acid detergent fibre was calculated as follows.

$$\text{ADF \%} = \frac{\text{Wt.of crucible + fibre - crucible wt}}{\text{Wt.of sample on dry matter basis}} \times 100$$

4.3. Lignin

4.3.1. Reagent:

72% solution of Sulphuric acid was prepared by dissolving con. H_2SO_4 in distilled water by weight.

4.3.2. Estimation:

The acid detergent fibre residue obtained was placed in a previously weighed sintered crucible. The crucible was placed in a glass tray with one end of the tray kept at 2 cm higher than the other end in order to felicitate the draining of acid. Contents of the crucible was covered with cooled 72% H_2SO_4 stirred with a glass rod to break the clumps. When the acid was completely drained, the crucible was refilled again with acid to half the level and allowed for further draining. The washing was repeated thrice. The acid was filtered off and finally rinsed again with 72% acid and allowed for complete draining. The content was washed with hot water (80^0c) until free from acid, dried overnight, cooled and weighed. The weighed crucible was ignited in a muffle furnace at 500^0c for three hours, cooled to room temperature and weighed. Loss of weight on ignition was estimated and the lignin content was calulated as follows.

$$\text{Lignin}(\%) = \frac{\text{Wt.of crucible+residue-Wt.of crucible+ash}}{\text{Wt.of sample on dry matter}} \times 100$$

4.4. Cellulose

The cellulose component was estimated by the method of Cline *et al.* (1966)

4.4.1. Reagents:

Glacial acetic acid (Reagent grade)

Con. Nitric acid (Reagent grade)

4.4.2. Estimation:

One g of sample was treated with 10 ml of glacial aetic acid and 1.5 ml of conc. Nitric acid for 20 min in flat-bottom flask. The digested material was transferred to a sintered crucible of grade 4 and washed with hot benzene, hot alcohol and diethyl ether successively. The crucible with residue was dried in a hot-air oven at 105^{o}c overnight and weighed. The sample was subjected for ashing at 500^{0}c for three hours. Loss of weight on ashing was taken as cellulose.

4.5. Gross energy

Energy value of the fermented by-product and the experimental diet was estimated using a adiabatic bomb calorimeter (Gopalkrishna and Ranjhan, 1980).

4.5.1. Estimation:

One gram of sample compressed to a tablet with the help of a pelleting machine was placed in a platinum crucible. The crucible was fixed inside the bomb and connected to the ignition wire through a cotton thread. The bomb was closed air-tight and charged with oxygen at 25 lb atmospheric pressure. The bomb was kept immersed in the inner vessel. The two electric terminals of the bomb were connected to the terminals in the ignition control unit. The inner water vessel with the bomb was placed inside the external water jacket. The temperature of the inner vessel was recorded with using a thermometer graduated to read 0.01^0c. The sample was ignited electrically and the temperature raise in every 30 sec was recorded for 15 min. The maximum rise in temperature was taken as the final reading.

The gross energy of the sample was calculated by multiplying the raise in temperature with the water equivalent of the calorimeter, less heat deduction for ignition wire and cotton thread. Eighty percent of the gross energy was taken as digestible energy value in computing for feed rations (Maynard and Loosly, 1983).

4.6. Total Nitrogen

4.6.1. Reagents used:

1. Conc. H_2SO_4
2. N H_2SO_4 (prepared by diluting 2.85 ml of H_2SO_4 to one litre with water)
3. N NaOH (prepared by dissolving 4.2 g of NaOH pellets in one litre of water)
4. Catalyst (95 g of anydrous sodium sulphate, 5 g of $CuSO_4$ and 1 g of selenium were mixed and stored for use as catalyst)
5. Phenolphthlene indicator soln.
6. Methyl red indicator soln.

4.6.2.Estimation:

Two g of sample was carefully transferred into a Kjeldhal flask. Five g of catalyst and 10 ml of H2SO4 were added to the sample. The digestion flask was kept in a tilted position over a heater. Initially heat was applied to the boiling temperature of the acid. After 15 min, the temperature was raised for vigorous boiling and continued for 2 hours or till the acid became colourless. The flask was allowed to cool and the contents were transferred to a clean 100 ml volumetric flask kept in an ice bath. The Kjeldhal flask was washed with 15 to 20 ml of water and the washings were transferred to the volumetric flask. The volume was made up to 100 ml by adding water.Five ml aliquot of the digest was taken in a pipette and poured into a distillation unit. Phenolthalene indicator and 5 ml of 40% NaOH were added to make it alkaline (pink colour). In a 50 ml beaker, 10 ml of 0.1N H_2SO_4 was taken with 2 drops of methyl red indicator and kept at the distillation end of the condenser. Steam was allowed to pass through the sample. The nitrogen released was collected in a 50 ml beaker for 10 minutes. The distillate was titrated against 0.1N NaOH and the volume of 0.1N H_2SO_4 utilized by N_2 was calculated. Using the following formula crude protein content of the sample was calculated.

$$CP = \frac{v \times 0.0014 \times 100 \times 100 \times 6.25}{2 \times 10}$$

where v is the volume of 0.1N H_2SO_4 consumed

4.7. Organic carbon

The carbon content was estimated following Jackson (1973). Finely ground organic material was subjected to wet oxidation using dichromate mixture. The unused dichromate mixture was back-titrated with standard ferrous ammonium sulphate solution and the organic carbon was calculated.

4.7.1. Reagents used:

1. The standard dichromate mixture was prepared by adding 19.86 g of $K_2Cr_2O_7$ and 200 ml of H_3PO_4 to 400 ml of con.H_2SO_4 and dilute to one litre.

2. Ferrous ammonium sulphate solution: 156.86 g of ferrous ammonium sulphate $\{(NH_4)_2SO_4.FeSO_4.6H_2O\}$ was dissolved in distilled water and 20 ml of con.H_2SO_4 was added and the final volume was made upto one litre with water.

3. Indicator solution: 5 g of barium chloride and 0.3 g of barium diphenyl amine sulphonate were dissolved in 100 ml water

4.7.2.Estimation :

Fifty mg of sample was transferred to a 250 ml conical flask. 25 ml of dichromate mixture was added and boiled for 60 min using a condenser fitted to the neck of the flask. The contents of the flask was allowed to cool and 100 ml water was added. 5 ml of indicator solution was added and the excess dichromate mixture was back-titrated with ferrous ammonium sulphate solution till mixture turned into dark blue. Further, 2.5 ml of dichromate mixture was added and the titration was continued till the appearance of a dark blue colour. Blank determination was carried out simultaneously. The organic carbon content was calculated as follows

$$C = \frac{(27.5 - T)\text{ml} \times 0.12}{\text{Sample weight (g)}} \times 100$$

where T is the quantity of 0.4M ferrous ammonium sulphate used for the titration and C is the percentage of organic carbon in the sample. The Carbon/nitrogen ratio was estimated for all feed ingredients.

V. Meat quality and carcass yield estimation.

Two experimental animals from each group maintained in the cage were slaughtered for carcass yield and meat quality studies.

The animals ready for estimation were kept off feeding for 24 hr, weighed and slaughtered. Immediately after the slaughter, the content of gastro-intestinal tract was removed and the carcass yield by weight was recorded. The meat was stored at -20^{0}c in a deep freezer. The frozen carcass was cut into small pieces using a clean and sterlie hand saw and ground to fine paste with a meat mincer.

The minced meat was subjected to chemical analysis. The dry matter content was determined by drying 25 g of sample in a forced draught oven at 105^{0}c to constant weight. Ash content was determined using a muffle furnace at 600^{0}c (Campbell *et al.*, 1984). Protein content was estimated using kjeldhal apparatus as described in 4.6.

VI. *In vitro* estimation of digestion.

In the present study, technique standardised by Tilly and Terry (1963) was followed for estimation of digestion. The method involves fermentation of 1 g of substrate in a mixture of 30 ml of nutrient solution with 25 ml of rumen inoculum.

Freshly slaughtered cattle from a slaughter house located on the outskirts of city of Panaji was the source of rumen liquor for the experiment. The rumen fluid was collected in a sterile, thermostatic (37°c) and air-tight container and brought to the laboratory. It was further strained through a four-layered sterile cheese cloth (Baumgardt *et al.*, 1962) into a clean, sterile and pre-warmed conical flask. The liquid portion was used as inoculum. The pH of the inoculum fluid was estimated using a Elico pH meter.

The nutrient solution for *in vitro* digestion studies was prepared following the composition given by Cheng *et al.* (1955).

CHEMICALS	G/2 LITTER
Na_2HPO_4	0.631
KH_2PO_4	0.303
$NaHCO_3$	5.250
KCl	0.750
NaCl	0.750
$MgSO_4$	0.225
$CaCl_2$	0.075
$FeSO_4.7H_2O$	0.015
$MnSO_4$	0.008
$ZnSO_4.7H_20$	0.008
$CuSO_4.5H_2O$	0.004
$CoCl_2$	0.002
Urea	2.000

A 175 ml size fermentation flask was fitted with a double-holed rubber stopper; one hole served as an inlet and the other as an outlet for CO_2. A continuous and steady jet of CO_2 was passed through the nutrient solution for about 20 minutes so as to bring down the pH to 6.5. The 2-holed stopper was subsequently removed and the flask was capped with a single-holed rubber stopper. To each flask, 25ml of rumen inoculum and 1 g of substrate were added. Where the pH of nutrient solution was low, saturated solution of Na_2CO_3 was added to bring it to 6.5 (Johnson, 1969). The flask was subsequently filled with CO_2 and kept in a water-bath at a constant temperature of 39°C. The overall digestion was allowed for a duration of 96 hours which included 48 hours microbial and 48 hours pepsin digestion.

At the end of digestion process, content of the flask was centrifuged at 2000 rpm for 10 min. The liquid component was discarded and the residue was transferred onto a weighed silica dish using 5 ml distilled water and dried overnight at 105°C. The dry residue was weighed using an analytical balance. The dry matter weight in fresh inoculum was also estimated as described above.

The *in vitro* dry matter digestibility was calculated as described in the following formula.

$$IVDMD = \frac{\text{substrate dm+inoculum dm-residual dm}}{\text{Substrate dm+inoculum dm}} \times 100$$

where IVDMD is *in vitro* dry matter digestibility and dm is the dry matter content on percentage basis.

VII. Statistical analysis

Data obtained from chemical analyses of test feed ingradients, diet, feed intake, dropping and other pertinent parameters were statistically analysed for treatment difference and significance as per Snedecor and Cochran (1967).

RESULTS AND DISCUSSIONS

RESULTS AND DISCUSSION

PART I

Identification of suitable fungal species for biodegradation of agro-waste

1. Selection and evaluation of available feed and by-product resources in Goa for biodegradation studies:

1.1. Cost of ingredients

In the absence of enough locally grown forages, the feeding exercise of domesticated ruminants, viz. dairy cattle, buffaloe and goat and nonruminants such as poultry, piggery and rabbitry, with substituted feed ingredients has impacted about 70% of the maintenance cost to rural farmers in the state of Goa. The conventionally used livestock feed ingredients such as groundnut cake, wheat bran and maize, are regularly brought to Goan market mainly from the states of Maharashtra and Karnataka. Transportation of these ingredients from distant region and seasonal higher demand have resulted with undue price escalation of the animal feeds. It was always realized that cost of feed ingredients has greater influence on the final consumable livestock products, viz. milk, meat and egg.

An attempt was made to study the trend of feed price increase and, as a standard, status of the last ten years price index of feeds such as wheat,

wheat bran, maize and groundnut cake was reviewed. Data gathered from the retail traders in Goa was analysed and the feed cost during the past ten years is presented in Table 4.

It can be seen from the analysis that the cost of feed ingredient was increased by 10% every year for all feed stuffs (Fig. 1, 2, 3 and 4). On a scale, steep price hike of feed was observed mainly with wheat and wheat bran followed by groundnut cake and maize. All these are essential feed ingredients for livestock development but not grown or produced in the State of Goa.

In view of the comparatively high maintenance cost of domestic animals, several workers elsewhere have attempted to make use of some of the locally available agricultural by-products as animal feed substitute, although the nutritive value of such stuffs are comparatively poor or of low quality (Gupta, 1986; Prasad *et al.*, 1993). Efforts were also made earlier to incorporate some of the waste by-products such as water hyacinth (Chakraborty *et al.,* 1991; Ahmed *et al.,*1995), sugarcane bagasse (Rangnekar *et al.*, 1982), rice bran (Sundaram *et al.*, 1987), spent tea (Punj, 1991) and fruit waste (Geoffroy, 1987) in animal feed and to bring the feed cost low.

In order to choose nutritionally acceptable feed substitutes, chemical composition of some of the locally available fibrous agro-wastes, viz.

Table 4 . Cost of feed ingredients during the past ten years (1986-1996).

Year	Wheat	Maize	Groundnut cake	Wheat bran	Poultry feed
1986	2.20	2.21	3.50	1.46	2.71
1987	2.40	2.30	4.20	1.70	2.71
1988	2.59	3.00	4.50	1.90	2.84
1989	3.50	4.00	4.25	2.10	2.92
1990	4.20	4.00	4.50	2.40	3.17
1991	4.25	4.50	4.75	3.00	3.35
1992	4.75	4.70	5.20	3.50	4.34
1993	5.00	5.00	5.50	4.00	4.55
1994	5.90	5.29	7.08	4.00	5.25
1995	7.24	5.50	7.20	4.30	5.90
1996	7.70	6.18	9.71	4.22	6.20

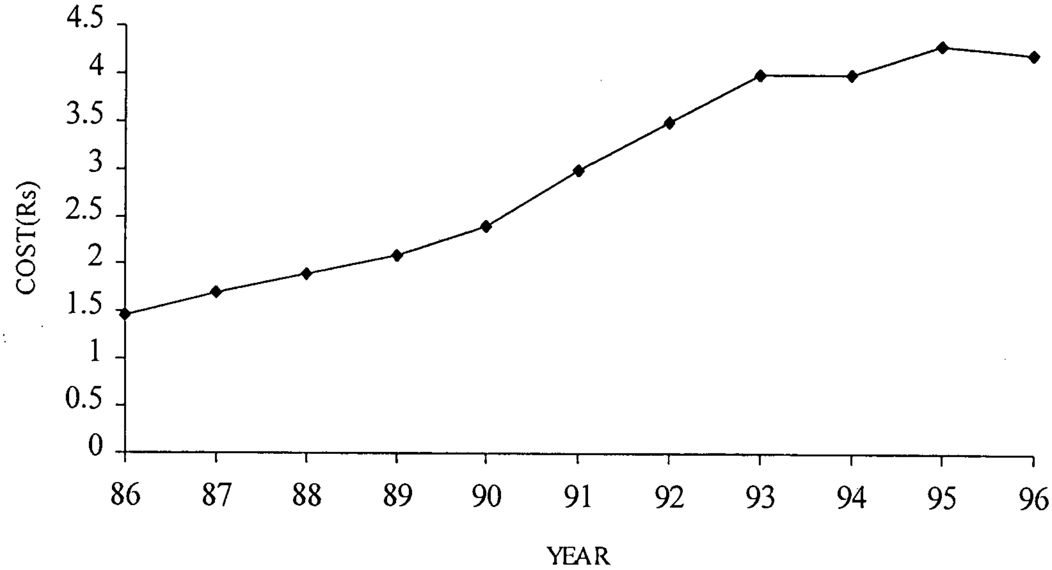


Fig 1 : Cost of wheat bran during the past 10 years

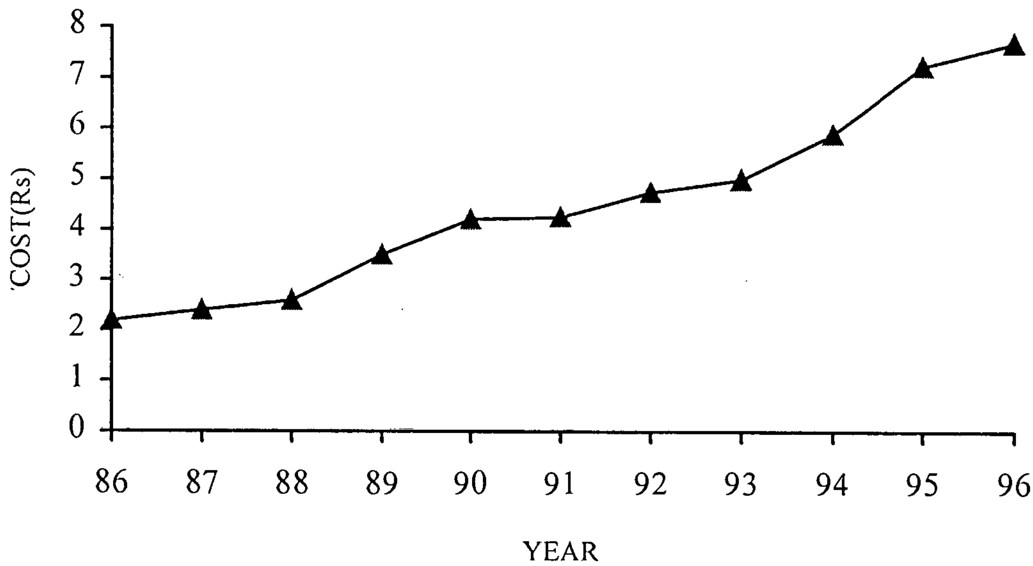


Fig 2 : Cost escalation of wheat for the past 10 years

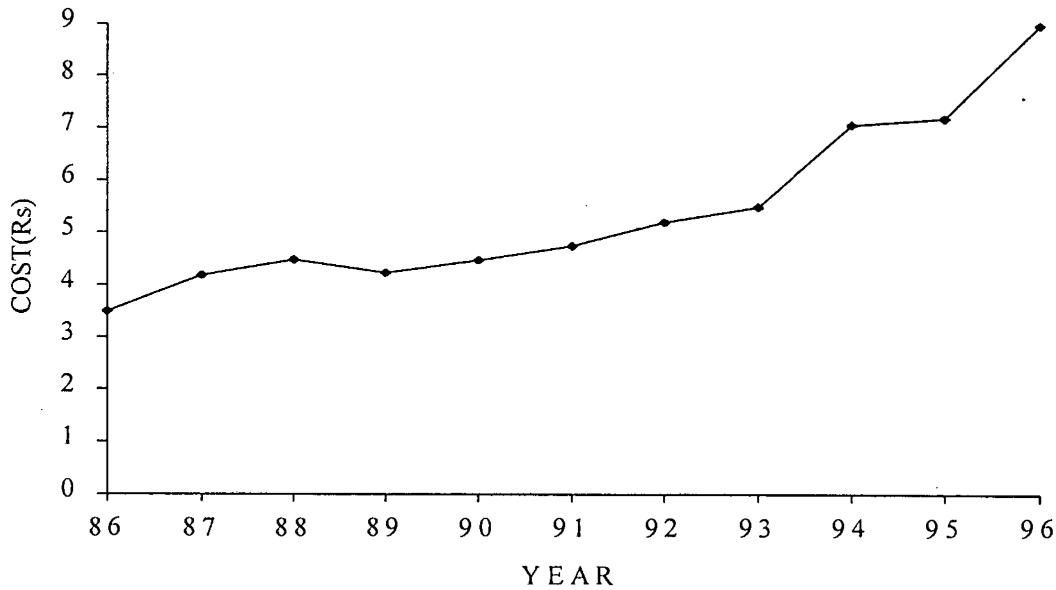


Fig 3. Cost escalation in Groundnut cake for the past 10 years

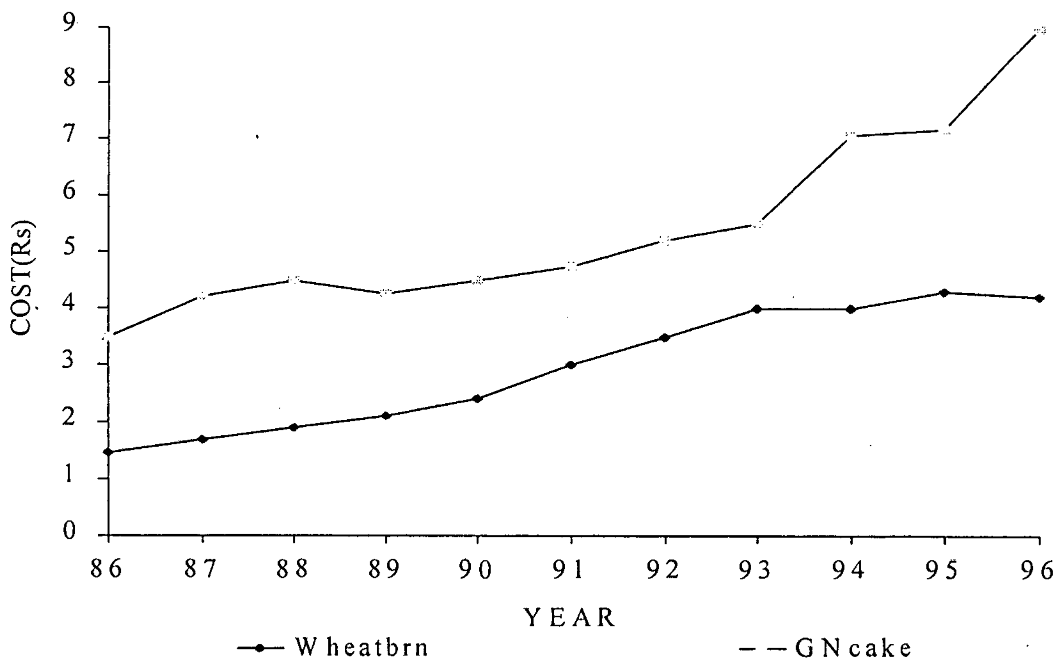


Fig 4. Comparative cost rise in wheat bran and groundnut cake

coir-dust, cashew fruit apple, sugarcane bagasse, rice bran and karad grass, were analysed and presented in Table 5. So far, very few attempts were made to make use of the locally available agricultural waste materials as unconventional feed substitute (Sundaram and Bhattacharyya, 1986). The quantum and availability of the agro-waste in Goa are presented in Table 7, 8 and 9.

1.2. Selection of suitable agro-by-products for biodegradation:

1.2.1. Coir dust

On a conservative estimate, 6000 million coconuts are available in India per annum (Nagarajan *et al.,* 1988). In Goa alone 24,200 ha of land is under coconut cultivation and annual production is around 16 million nuts (ICAR, 1996).

From a local coir-extracting unit in Kundaim industrial area, it was found out that 4.5% of the husk by weight is coir dust. Nagarajan *et al.* (1988) reported that 10% of the total nut weight is its coir dust component. Considering these, it was estimated that about 5,600 metric ton per annum of coir dust may be available as agro-waste in this region of the country. One can always see the coir dust heaped out as a waste in the close proximity of fibre extracting units (Pl. I, a and b).

Table 5. Chemical composition of various feed ingredients (% Dry matter basis):

Ingredient	Crude fibre	NDF	ADF	CELL	LIG	Crude protein
Coir waste	38.43	78.30	69.44	19.50	39.91	1.75
Cashew waste	18.78	63.05	45.82	17.23	12.43	9.65
Karad hay	28.47	64.76	46.92	33.75	14.62	3.75
Rice bran	18.43	76.32	42.44	19.57	20.47	6.24
Wheat bran	10.15	66.45	12.10	14.32	2.45	8.35
Maize	1.87	50.16	4.35	12.56	1.36	7.43
Forage grass	32.27	71.82	39.43	24.87	8.12	6.78
Sugarcane bagasse	36.42	67.86	43.54	38.28	10.71	5.75

Table 6. Chemical composition of common forages and karad hay.(% Dry matter basis)(Adapted from Chakrabarti *et al* 1988)

Common name	Botanical name	CP	NDF	ADF	Cellulose	Permanganate lignin
Maize	*Zea mays*	8.92	68.70	41.24	30.28	8.40
Jowar	*Sorghum vulgare*	8.38	59.00	40.00	36.02	7.58
Anjan grass	*Cenchrus cilliaris*	7.07	67.40	36.08	28.96	5.54
Hybrid Napier NB-21 grass	*Pennisetum sp*	10.10	62.40	42.40	32.60	4.80
Dub grass	*Cynodon dactylon*	7.39	51.00	27.00	16.50	7.20
Guinea grass Var Riverside	*Panicum maximum*	8.20	61.00	56.09	32.00	13.50
Karad hay	*Themada quadrivalis*	3.75	64.76	46.92	33.75	14.62

Table 7. Annual coconut production and availability of coir dust in Goa.

Area under coconut production	:	24000 ha.
Coconut production per annum	:	116 million nuts
Av.Dry nut yield per unit	:	550 g
Av.Weight of husk per unit	:	300 g
Yield of husk per million nuts	:	30 m.ton
Total availability of husk	:	3480 m.ton
Yield of coir dust @ 5%	:	174 m.ton

Table 8. Annual cashew nut production and availability of cashew apple waste in Goa.

Area under cashew cultivation	:	49000 ha
Av.weight of fresh apple	:	74.93 g
Av.weight of cashew nut	:	8.50 g
Av.weight of dry apple	:	7.57 g
Total yield of fresh apple	:	80,000 ton
Dry matter percent in apple	:	10.22
Total apple waste available	:	8176 m.ton

Table9. Annual karad hay availability in the forest land of Goa and paddy straw from cultivable land

Area of waste land	:	12000 ha
Av.yield of dry matter	:	1.5 m.ton/ha
Av.annual yield	:	18000 m.ton
Paddy cultivation	:	4000 ha
Straw yield per annum	:	40000 m.ton

From an analysis (Table 5), it has been found out that the coir-dust has 78.30% NDF, 69.91% ADF and 20.25% cellulose and the chemical composition is almost similar to that of sugarcane bagasse. Several workers have attempted for degradation of sugarcane bagasse using fungi and achieved success in improving its nutritive value (Gulati *et al.*, 1986; Rai *et al.*, 1986). Substantially high quantity of lignin, i.e. 39.91% by weight, has been observed in coir-dust and this is comparable to the reported values of Theradimani and Marimuthu (1992) who evaluated and also tried the coir-pith as a fertilizar compost. The digestibility of woody materials containing high lignin content has been found enhanced on treatment with white rot fungi such as *Lentinus edodes* (Suzuki, 1995). This indicated that although a significantly high lignin content is present in coir dust, it can be tried as a substrate for fungal degradation.

1.2.2. Cashew apple waste:

Cashew crop is cultivated in 49,750 ha of land in the state of Goa (ICAR, 1996). About 80,000 metric ton per annum of cashew apple is available during the season. The fruit apple, after extraction of juice, is generally discarded as a waste (Pl. II, a and b). The mean dry matter content of the fruit estimated is 10.11% and comparable to that reported by Ogunmoyela (1983). Taking the total fresh fruit production into consideration, it is estimated that about 8,600 metric ton of dried apple waste may be available every year in Goa.

Chemical composition of the dried cashew apple by-product is presented in Table 5. The cashew apple crude protein (CP) and ADF content are 9.65 and 45.82% respectively as against 8.35% and 12% for wheat bran and 6.24% and 42.44 % for rice bran (Table 5) indicating that the cashew apple waste could also be a suitable or better trial substitute than other by-products. Sawal *et al.* (1995) reported incorporation of dried apple pomace in rabbit feed at 10% level and tested its suitability as a feed substitute. Fruit wastes such as pineapple waste, citrus pulp and banana waste have been subjected to fermentation and successfully fed to animals (Geoffroy, 1987). Considering the plentiful availability and chemical composition almost similar to other fruit wastes, it was thought that cashew apple waste can be tried as a possible substrate for fermentation.

1.2.3. Karad hay:

Karad hay is a naturally grown grass available in abundance in Goa (Pl. III and IV). It grows well in laterite soil. It was observed that about 10,000 ha of waste land in Goa is under karad coverage in the post-monsoon period and the yield is estimated to be about 1.5 metric ton per ha per annum in the State.

The ADF and NDF content of dry karad is 45.32% and 64.76% whereas that of rice bran and sugarcane bagasse were 42.44% and 76.32% and 77.34% and 65.35% respectively. The karad hay is highly lignocellulosic with 33.75% cellulose and 14.62% lignin (Table 5). Nutritive value of the hay is said to be poor.

The chemical composition and nutritive value of the karad roughage was estimated and reported earlier by Sundaram *et al.* (1987). The lignocellulosic bagasse having similar chemical composition has been used earlier as an animal feed (Rangnekar *et al.*, 1982). Chakrabarti *et al.* (1988) reported the comparative proximate values of several graminaceous forages from India. The karad hay is compared with other rougages (Table 6).

Successful degradation and enrichment of bagasse by *Trichoderma* spp. has been reported by Rai *et al.* (1986). Lignocellulosic cotton stalk has been fermented and improvement in its nutritive value was reported earlier (Rajashekara and Gulati, 1991). It is now realized that by improving the nutritive value of agro-by-products through microbial degradation, low-cost feed ingredients can be developed and expenditure on animal feeding may be brought down.

1.3 Identification of suitable microbial (fungal) species for biodegradation:

The extent of degrdation of organic substrate by fungi depends on several factors such as substrate quality, growth condition and decomposing organism (Savoie *et al.,* 1992). Influence of physical factors such as moisture, temperature and pH on solid state fermentation of straw has been investgated and reported by Zadrazil and Brunnert (1981). These indicated that most of the tested organisms performed well at a temperature range of 25 to 30^{0}C and pH between 6.5 to 6.8.

It has been observed earlier that the substrate degradation, in which several fungal enzymes involved, is species specific (Rai *et al.*, 1993). As it has been referred earlier, white rot fungi are generally preferred for lignin degradation (Hatakka, 1994) and cellulolytic anamorphic ascomycetous species are used for breaking down lignocelluloses. Some of these fungi were tried in the present work for substrate fermentation. Keeping the safety of feeding animals in mind, two lignolytic edible basidiomycetous fungi, *Ganoderma lucidum* and *Pleurotus florida* and a nonpathogenic cellulolytic fungus, *Trichoderma viride* were used in the present study.

<u>Cultural description of the fungi used in the study</u>:

1.3.1 *Ganoderma lucidum* (Leyss. ex Fr.) Karst

Basidiomycetous ,Colony on malt extract agar fast growing, whitish to cream-coloured, attaining 8.5 cm diam in 7 days when grown at 25^0C. Mycelium with repeatedly branched hyphae of 2-4.5 um wide and with distantly located clamps, often the mycelium forming threads or chords of varying diam. Aged cultures are tan-coloured

1.3.2. *Pleurotus florida* Eger

Basidiomycetous, Colony on malt extract agar fast growing, whitish, attaining 8.0 cm diam in 7 days when grown at 25^0C. Prostrate mycelium with repeatedly branched hyphae possessing clamps, often forming threads or chords of varying diam. Aged cultures retain whitish colour.

1.3.3.*Trichoderma viride* Pers. ex S.F.Gray

Hyphomycetous, Colony on malt extract agar fast growing, whitish to dark green, attaining a diam of 7-8.5 cm in 7 days when maintained at 25-27^0C. Mycelium prostrate, with repeatedly branched, 1.5-4.5 um wide hyphae. Conidiophores branched, with ampuloid metuhe or conidiogenous cells, developing at right angles to main hyphae. Conidia slimy, globoid, in mass green-coloured, rough-walled, in broken chains or clumps, 3.5-4.6 um diam.

1.3.4. Effect on coir dust.

The extent of substrate degradation by the fungi used was ascertained through chemical analysis for ADF, lignin, cellulose and crude protein content in the degraded substrate and *in vitro* dry matter digestibility. The results are presented in Table 10A-10C and described below.

In coir dust treatment, ADF was reduced by 9.67%, 6.77% and 3.39% in *Pleurotus florida*, *Trichoderma viride* and *Ganoderma lucidum* inoculated samples (Fig. 5). The reduction in lignin content was 16.86%, 2.18% and 3.88% for *Pleurotus florida*, Trichodrma viride and *Ganoderma lucidum* inoculated samples (Table 10C). Cellulose degradation was highest with *Trichoderma viride* (26.91%) as against 11.01% and 4.74% in the *Pleurotus florida* and *Ganoderma lucidum* inoculated samples. As observed in this study, Kirk (1983) reported a high cellulolytic activity in *Trichoderma viride* compared to other species.

Kundu and Chawla (1988) made a comparative study on biodegradation of wheat straw by 12 species of fungi including *Trichoderma viride* and *Pleurotus sajor-caju* and reported a maximum decrease in cell wall

Table 10 A. Effect of fungal degradation on the chemical composition of coir dust (% Dry matter basis).

	Control	Treatment		
Nutrient	CD	CD+Pl f	CD+Tr v	CD+Gn l
NDF	80.62 ±1.63	72.98 ±1.24	77.81 ±1.00	78.18 ±0.91
ADF	69.91 ±1.30	63.15 ±1.01	65.18 ±0.83	67.54 ±1.36
HCEL	10.71 ±0.90	9.45 ±1.08	9.06 ±1.40	9.27 ±1.16
CEL	20.25[a] ±1.28	18.02 ±0.56	14.80 ±1.44	19.29[a] ±1.05
LIG	39.91[a] ±1.12	33.18 ±1.25	39.04[a] ±1.85	38.36 ±1.11
CP	1.75 ±0.23	6.75 ±0.56	4.12 ±0.57	3.76 ±0.43
OM	97.21 ±0.93	81.46 ±2.15	88.09 ±0.66	87.24 ±1.39
C2	40.17[a] ±1.24	35.32 ±0.93	37.83 ±1.02	39.15[a] ±0.65

Mean values in rows followed by superscript 'a' are not significantly different ($P < 0.05$)

CD - Coir dust

Trv - *Trichoderma viride*

Plf - *Pleurotus florida*

Gnl - *Ganoderma lucidum*

Table10 B. Reduction in structural carbohydrate and organic matter of coir dust (% Dry matter basis).

Nutrient	Treatment		
	CD+Plf	CD+Trv	CD+Gnl
NDF	7.66	2.81	2.44
ADF	6.76	4.73	2.37
HCEL	1.26	1.65	1.44
CEL	2.23	5.45	0.96
LIG	6.73	0.87	1.55
CP	5.00	2.37	2.01
OM	15.75	9.12	9.97
C2	4.85	2.34	1.02

Table 10 C. Percent reduction in structural carbohydrate and organic matter of coir dust.

Nutrient	Treatment		
	CD+Plf	CD+Trv	CD+Gnl
NDF	9.50	3.49	3.03
ADF	9.67	6.77	3.39
HCEL	11.76	15.41	13.45
CEL	11.01	26.91	4.74
LIG	16.86	2.18	3.88
CP	5.00	2.37	2.01
OM	16.20	9.38	10.26
C2	12.07	5.83	2.54

CD - Coir dust Trv -*Trichoderma viride*

Plf - *Pleurotus florida* Gnl - *Ganoderma lucidum*

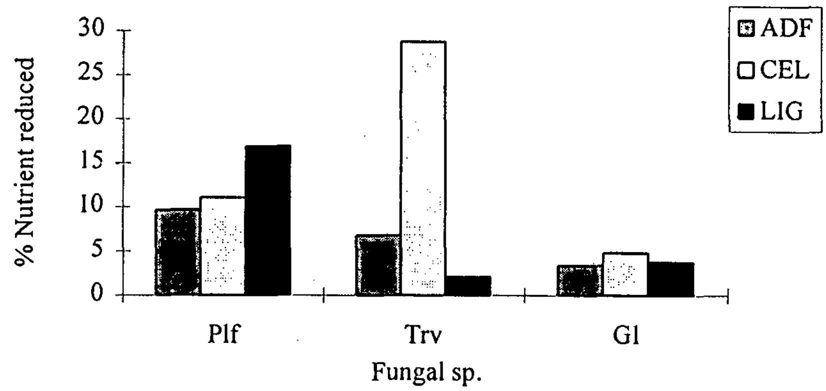


Fig 5: Effect of fermentation with different fungal species on the structural carbohydrate in coir dust.

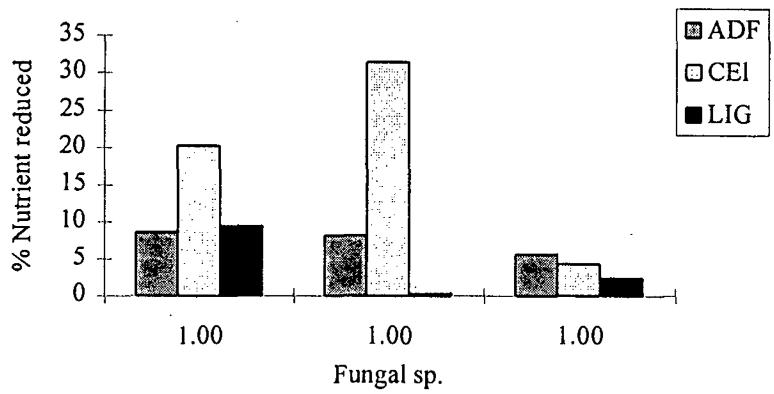


Fig 6: Effect of fermentation with different fungal species on the structural carbohydrate in cashew apple waste.

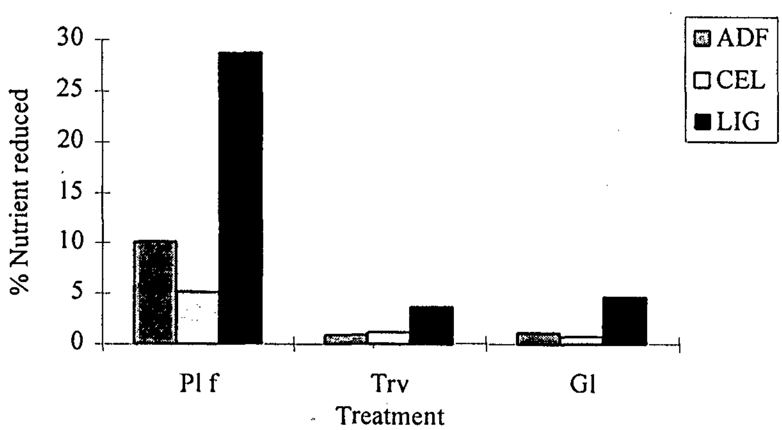


Fig 7: Effect of fermentation with different fungal species on the structural carbohydrate in karad hay.

contents (NDF) by *Alternaria tenuis* and *Chaetomium globosum*. Kahlon and Kalra (1989) screened four nontoxic fungi including *Pleurotus ostreatus* and *Phanerochaetae chrysosporium* aimed at improving the nutritive value of wheat straw and reported a high cellulolytic activity in *P.chrysosporium*. The crude protein content was increased to 6.75% in *Pleurotus florida* fermented samples whereas it was only 1.75%, 3.76%,and 4.12% in the untreated control, *Ganoderma lucidum* and *Trichoderma viride* treated samples (Table 10A).

1.3.5 Effect on cashew apple waste

In cashew apple waste treatment, the growth of *Pleurotus florida* and *Trichoderma viride* were prominant (Fig. 6; Table 11A). However, the percent loss in ADF was 8.66%, 8.23% and 5.65% for *Pleurotus florida*, *Trichoderma viride*, and *Ganoderma lucidum* fermented samples respectively (Table 11C). Lignin degradation was more prominent in *Pleurotus florida* fermented samples. It was reduced from 12.43 to 11.25% in the fermented cashew apple (Table 11A). Only a marginal reduction in lignin (0.3%) was observed in *Ganoderma lucidum* and *Trichoderma viride* (0.37%) inoculated samples (Table 11B).

Singh *et al.* (1989) reported 14% reduction in ADF content of paddy straw after 28 days of fermentation by *Pleurotus florida*. Reduction in

ADF and cellulose content was observed in the present study after degradation by the same fungal species. Rai *et al.* (1986) reported an increase of 6.3 % in crude protein value in sugar cane bagasse when treated with *Trichoderma* spp. whereas in the present study only 2.37% increase in the nutrient was observed with T.virideon coir dust. These observations indicate that the nature of substrate could influence the extent of degradation.

The cellulose content of cashew apple waste was reduced from 12.35 % to 8.47% in *Trichoderma viride* treatment, whereas it was reduced to 9.85% by *Pleurotus florida*. Insignificant reduction was observed in *Ganoderma lucidum* inoculated samples (Table 11A).

Rai *et al.* (1993) described cellulolytic activity of *Trichoderma viride* as superior to other fungi. Tsao and Cheng (1983) reported the mode of cellulose degradation by cellulolytic fungi. Although lignolytic activity is expected to be more prominent in *Ganoderma lucidum*, appreciable effect was not seen in a short duration of 30 days treatment (Table 11B). A higher reduction of lignin with restricted cellulose degradation by *Pleurotus florida* was observed in this study and this is in conformation with an earlier report (Zakia Bano and Rajarathnam, 1988).

Table 11 A . Effect of fungal degradation on the chemical composition of cashew apple waste (% Dry matter basis).

	Control	Treatment		
Nutrient	CAW	CAW+Plf	CAW +Tr v	CAW + Gnl
NDF	63.05	61.06	59.97	61.58
	±1.61	±0.00	±1.57	±1.86
ADF	45.82	41.85	42.05	43.23
	±2.08	±1.01	±0.97	±1.34
HCEL	17.23	19.21	17.92	18.35
	±1.21	±0.83	±1.17	±0.93
CEL	12.35	9.85	8.47	11.82
	±1.43	±0.97	±0.66	±0.72
LIG	12.43	11.25	12.06	12.13
	±0.85	±1.10	±0.77	±0.81
CP	9.65	10.75	11.20	9.75
	±1.17	±0.88	±1.03	±0.47
OM	97.25	91.56	89.72	94.18
	±1.58	±1.32	±2.41	±1.85
C2	37.53	35.28	34.71	36.60
	±0.85	±1.12	±0.68	±1.26

CAW - Cashew apple waste

Trv - *Trichoderma viride*

Plf - *Pleurotus florida*

Gnl - *Ganoderma lucidum*

* Mean values of six analyses

Table 11 B . Reduction in structural carbohydrate and organic matter of cashew apple waste (% Dry matter basis).

Nutrient	Treatment		
	CAW+Plf	CAW+Trv	CAW+Gnl
NDF	1.99	3.08	1.47
ADF	3.97	3.77	2.59
HCEL	1.98	0.69	1.12
CEL	2.50	3.88	0.53
LIG	1.18	0.37	0.30
CP	1.10	1.55	0.10
OM	5.69	7.53	3.07
C2	2.25	2.82	0.93

Table 11 C. Percent reduction in structural carbohydrate and organic matter of cashew apple waste.

Nutrient	Treatment		
	CAW+Plf	CAW+Trv	CAW+Gnl
NDF	3.16	4.89	2.33
ADF	8.66	8.23	5.65
HCEL	11.49	4.00	6.50
CEL	20.24	31.42	4.29
LIG	9.49	2.98	2.41
CP	1.10	1.55	0.10
OM	5.85	7.74	3.16
C2	6.00	7.51	2.48

The crude protein content of cashew apple waste was increased from 9.65% of the control to 10.75% in *Pleurotus florida* treated sample as compared to 11.2% and 9.75% in *Trichoderma viride* and *Ganoderma lucidum* inoculated samples. The dry matter loss was also observed to be more in both *Pleurotus florida* and *Trichoderma viride* treated materials (see Table 11C). As it has been observed in the present study, Nagra *et al.* (1994) an increased crude protein level with corresponding decrease in soluble carbohydrate and crude fibre in guar meal treated with *Aspergillus niger.*

1.3.6. Effect on karad hay.

In the case of karad hay, reduction in ADF was prominent in *Pleurotus florida* treated sample (Table 12A-12C). The ADF content was reduced from 46.92% to 41.93% (Fig. 7). The lignin was reduced from 14.62% to 10.41% whereas cellulose content was reduced from 33.75% to 30.02%. The performance of *Ganoderma lucidum* and *Trichoderma viride* was found to be very poor, especially with degradation of ADF and lignin (Table 12A).

Several, agro-by-products, such as paddy straw and a few other grass substrates have been tried earlier as substrate for cultivation of Pleurotus spp. and these proved to be performing well (Nair, 1993; Chander Rao, 1992)). It has been reported that at least three enzymes, viz. lignin peroxidase, laccase and Mn peroxidase produced by these fungi are involved in the degradation of lignin component (Hatakka, 1994). The apparent absence of these enzymes together may be the reason for poor degradation of karad hay by *Trichoderma viride* and *Ganoderma lucidum*.

In the present study, growth of *Pleurotus florida* was more prominent in karad hay than in other agro by-products(Fig 7). Wide variability in lignin structure (Punj and Jakhmola, 1986), nature of lignocellulose complex, enzyme system of the fungi used and the physical parameters adopted for solid state fermentation could be the possible reasons for the preferential growth of *Pleurotus florida* in all the by-product bases and more so in the dry roughage karad hay. In cashew apple waste, cellulose was reduced more than in other substrates when treated with *Pleurotus spp.* Patil *et al.* (1989) compared the performance of *Pleurotus sajor caju* on different substrates and reported a higher performance of the fungus in cotton straw.

Table12 A . Effect of fungal degradation on the chemical composition of karad hay (% Dry matter basis).

	Control	Treatment		
Nutrient	KRD	KRD+Plf	KRD + Trv	KRD + Gnl
NDF	64.76 ±1.63	59.04 ±2.04	63.81 ±0.85	64.65 ±0.76
ADF	46.92 ±0.87	41.93 ±1.03	47.07 ±1.58	46.11 ±1.72
HCEL	17.84 ±0.75	17.11 ±1.03	16.74 ±1.58	18.54 ±1.72
CEL	33.75 ±0.85	32.02 ±0.68	33.36 ±1.12	33.51 ±0.97
LIG	14.62 ±0.65	10.41 ±0.44	14.08 ±0.83	13.94 ±0.72
CP	3.75 ±0.50	7.36 ±0.75	4.78 ±0.25	4.12 ±0.50
OM	96.37 ±1.56	84.37 ±2.38	91.27 ±1.06	94.25 ±1.72
C2	40.35 ±0.82	35.86 ±0.64	37.41 ±1.06	38.60 ±1.23

KRD - Karad hay

Trv - *Trichoderma viride*

Plf - *Pleurotus florida*

Gnl - *Ganoderma lucidum*

* Mean values of six analyses

Table 12 B . Reduction in structural carbohydrate and organic matter of karad hay (% Dry matter basis).

Nutrient	Treatment		
	KRD+Plf	KRD+Trv	KRD+Gnl
NDF	5.72	0.95	0.11
ADF	4.99	0.15	0.81
HCEL	0.73	1.10	0.70
CEL	1.73	0.39	0.24
LIG	4.21	0.54	0.68
CP	3.61	1.03	0.37
OM	12.00	5.10	2.12
C2	4.49	2.94	1.75

Table 12 C . Percent reduction in the structural cabohydrate and organic matter of karad hay.

Nutrient	Treatment		
	KRD+Plf	KRD+Trv	KRD+Gnl
NDF	8.83	1.47	0.17
ADF	10.64	0.32	1.73
HCEL	4.09	6.17	3.92
CEL	5.13	1.16	0.71
LIG	28.80	3.69	4.65
CP	3.61	1.03	0.37
OM	12.45	5.29	2.20
C2	11.13	7.29	4.34

KRD - Karad hay Trv - *Trichoderma viride*

Plf - *Pleurotus florida* Gnl - *Ganoderma lucidum*

PART II

II Standardisation of fermentation techniques

2.1. <u>Effect of moisture regime</u>:

2.1.1. Coir dust.

Pleurotus florida was inoculated onto coir dust at different moisture level ranging from 0 to 100%. In view of its roughness, wettable texture was achieved only at 80% moisture level rather than the standard 75% recommended by Zadrazil and Brunnert (1981).

Lignocellulolytic activity of the fungus was estimated through chemical analysis for structural carbhohydrates after 30 days of inoculation. Changes observed in the substrate during fermentation at various moisture level are presented in Table 13. Maximum reduction in organic matter and nutrient content in coir dust was observed at 80% moisture level in coir dust (Table13 A; Pl. 9b). Zadrazil and Brunnert (1981) reported an optimum level of 75% moisture for wheat straw degradation. In the present study, the ADF content was reduced from 69.91 to 63.11% at 0 and 80% moisture level whereas at 70 and 100% level it was 65.87% and 65.71% respectively. Reduction in lignin was higher at 80% moisture (17.21%) as shown in Table 13C. At 70% moisture

Table 13. A. Effect of moisture on degradation of coir dust by *Pleurotus florida* (Nutrient on % dry matter basis).

	Moisture level in %						
Nutrient	0	20	40	60	70	80	100
NDF	80.62 ±1.63	79.06 ±1.33	77.38 ±0.33	76.21 ±1.42	73.57 ±1.03	71.86 ±1.02	70.25 ±0.80
ADF	69.91 ±1.30	69.36[a] ±0.68	68.52[a] ±0.65	66.08 ±1.55	65.87 ±0.71	63.11 ±0.99	65.71 ±0.32
HCEL	10.71 ±0.90	9.70 ±0.62	08.86 ±1.27	10.13 ±1.05	7.70 ±0.58	8.75 ±1.04	4.54 ±0.93
CEL	20.25 ±1.28	19.77[a] ±0.58	19.14[a] ±0.42	18.95 ±0.72	18.02 ±0.62	17.43 ±0.72	17.56 ±0.69
LIG	39.91 ±1.12	39.12 ±0.43	38.40 ±0.98	36.74 ±1.20	34.14 ±0.56	33.04 ±0.80	36.93 ±0.71
CP	1.75 ±0.23	1.75 ±0.13	2.25 ±0.80	3.75 ±0.55	5.25 ±0.45	6.25 ±0.86	6.50 ±0.27
OM	97.21 ±0.93	95.52 ±2.37	95.70 ±1.43	94.56 ±0.73	92.45 ±0.74	88.43 ±1.72	87.05 ±1.19
C2	40.17 ±1.24	39.88 ±0.86	39.15 ±1.14	37.56 ±0.79	36.24 ±1.37	35.47 ±0.52	34.06 ±0.49

Mean values in rows followed by superscript 'a' are not significantly different ($P < 0.05$)

Table 13 B. Reduction in structural carbohydrate and organic matter content of coir dust fermented at different moisture level (% Dry matter basis).

Nutrient	Moisture level in %					
	20	40	60	70	80	100
NDF	1.56	3.24	4.41	7.05	8.76	10.37
ADF	0.55	1.39	3.83	4.04	6.80	4.20
HCEL	1.01	1.85	0.58	3.01	1.96	6.17
CEL	0.48	1.11	1.30	2.23	2.82	2.69
LIG	0.79	1.51	3.17	5.77	6.87	2.98
CP	0.00	0.50	2.00	3.50	4.50	4.75
OM	1.69	1.51	2.65	4.76	8.78	10.16
C2	0.29	1.02	2.61	3.93	4.70	6.11

Table 13 C. Percent reduction in structural carbohydrate and organic matter of coir dust (% Dry matter basis).

Nutrient	Moisture level in %					
	20	40	60	70	80	100
NDF	1.94	4.02	5.47	8.74	10.87	12.86
ADF	0.79	1.99	5.48	5.78	9.73	6.01
HCEL	9.43	17.27	5.42	28.10	18.30	57.61
CEL	2.37	5.48	6.42	11.01	13.93	13.28
LIG	1.98	3.78	7.94	14.46	17.21	7.47
CP	0.00	0.50	2.00	3.50	4.50	4.75
OM	1.74	1.55	2.73	4.90	9.03	10.45
C2	0.72	2.54	6.50	9.78	11.70	15.21

Plate - 9

a.

b.

level, it was only 14.46% and as can be seen (Fig. 8a), there was significant difference in cellulose content between 70% and 80% moisture range. However, the percent reduction of lignin was comparatively more than cellulose (Fig 8b). Preferential reduction of lignin than cellulose by Pleurotus spp. has also been reported by other authors (Valmaseda *et al.*, 1991; Martinez *et al.*, 1994).

2.1.2. Cashew apple waste.

With cashew apple waste, when water was added from 0% upward, reasonable wet texture was achived at 50% moisture level. Beyond this regime, the fruit base became sticky and compact and appreciable growth of fungi was not observed. Zadrazil and Brunnert (1981) described the importance of optimum level of moisture in the substrate for solid state fermentation and indicated that very high moisture content may interfere with the gaseous exchange in the substrate during fermentation. Adequate supply of air or oxygen is essential for mycelial growth (Rothschild *et al.*, 1995). The cashew apple fermentation by *Pleurotus florida* was highest at 50% moisture (Pl. 10a) and at this level, the substrate apparently has a texture which would permit the exchange of air with gaseous metabolites. The adverse effect of accumulation of gaseous metabolites during solid state fermentation has been repoted by Puniya *et al.* (1992). Reduction in ADF and lignin content was significantly higher at

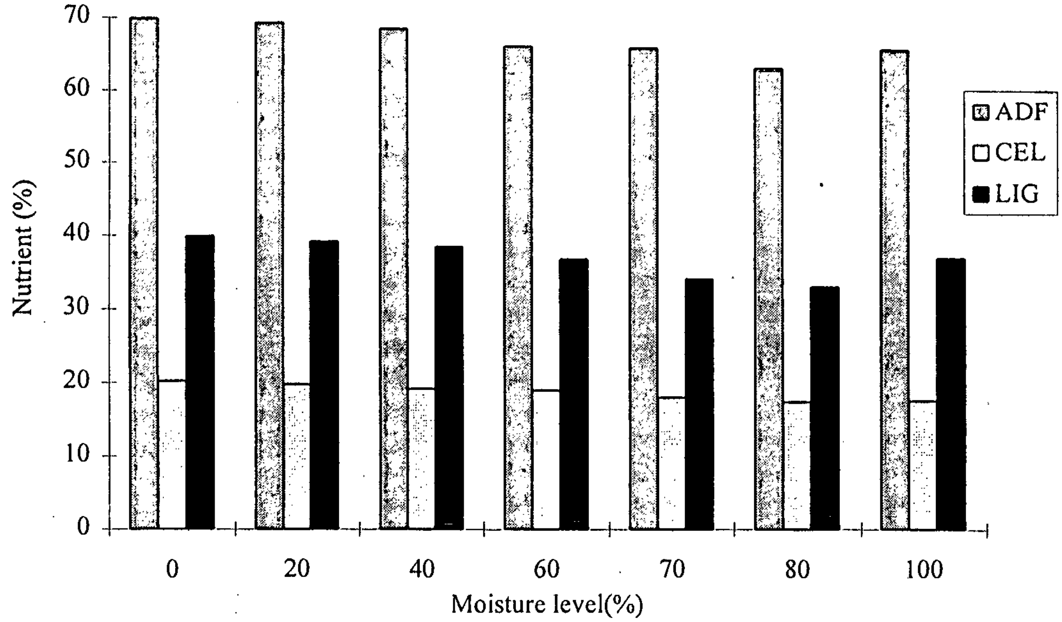


Fig 8 a: Effect of moisture level on the structural carbohydrate of coir dust during fermentation

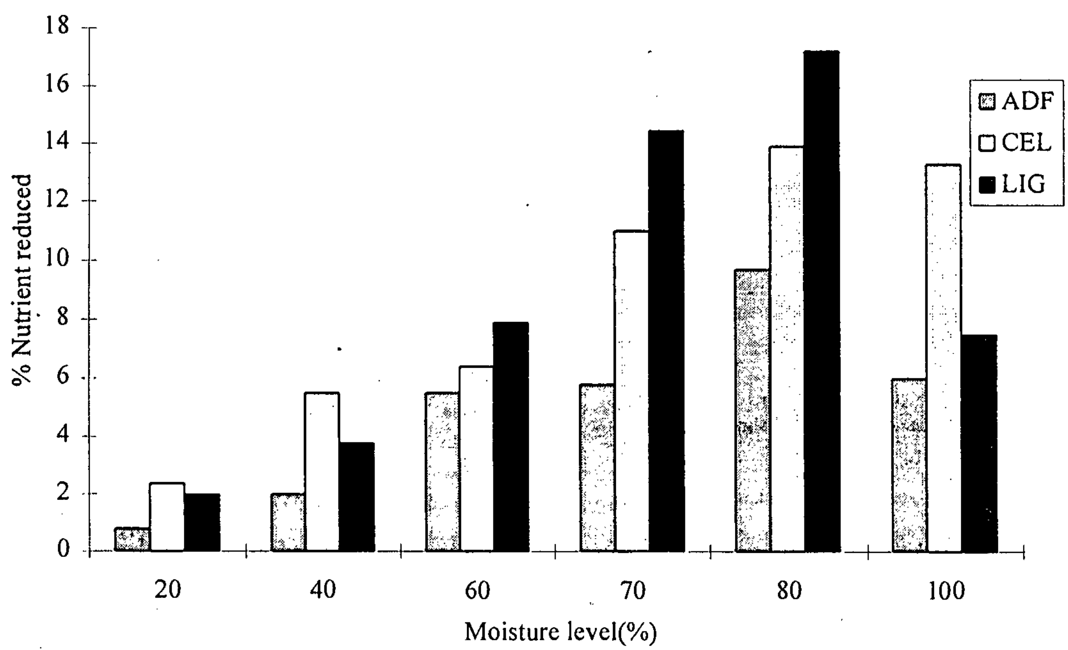


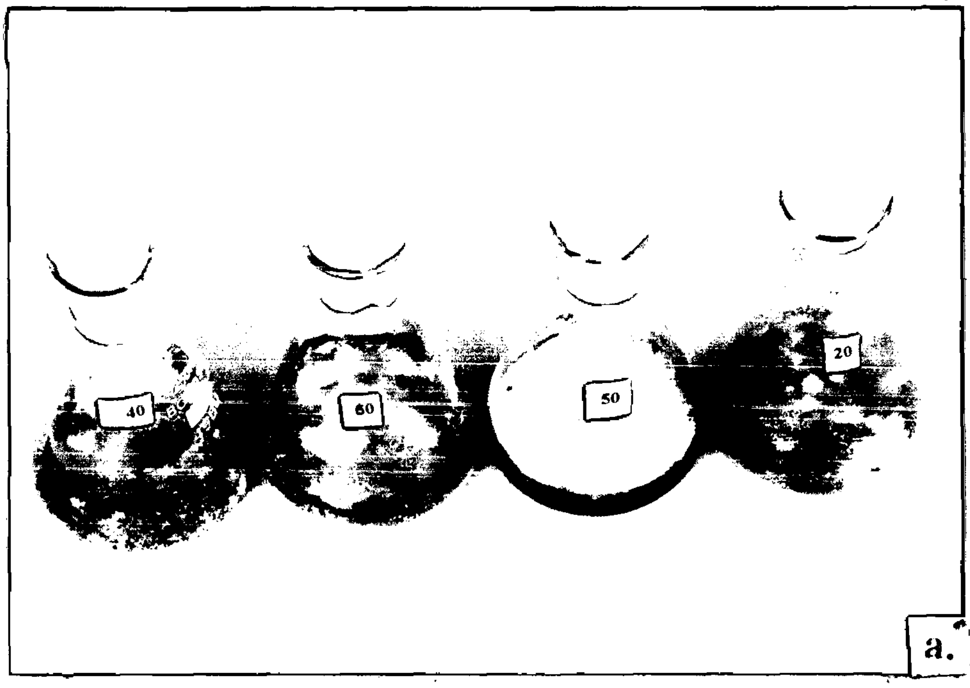
Fig 8 b : Percent reduction in structural carbohydrate in solid state fermentationat different moisture level

PLATE - 10

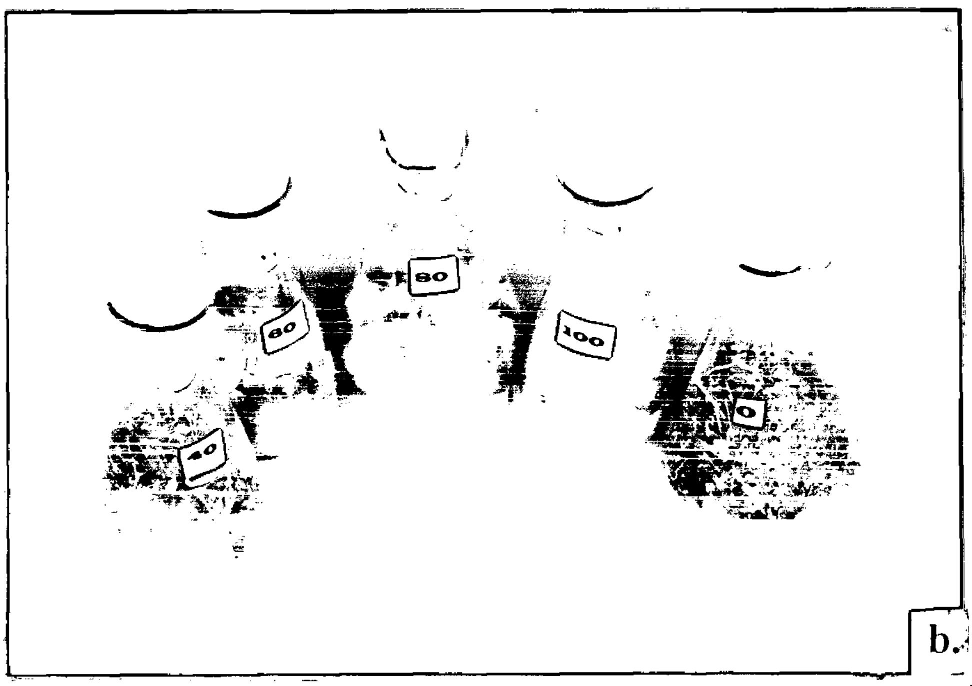
a. Cashew apple waste fermented with *Pleurotus florida* at different moisture level.

b. Karad grass fermented with *Pleurotus florida* at different moisture level.

Plate - 10

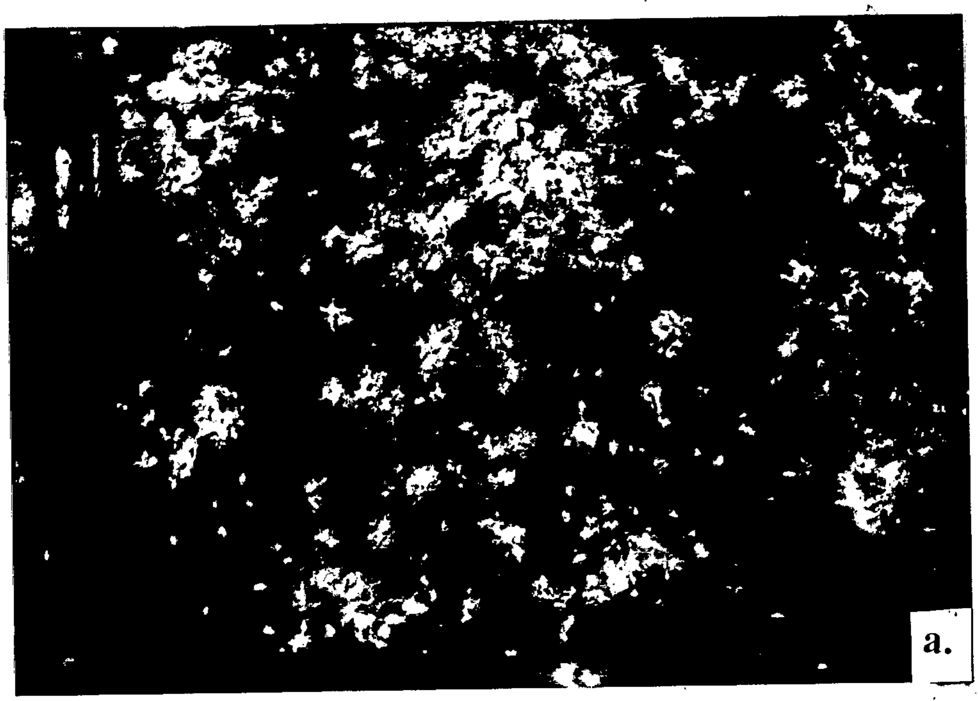


a.



b.

Plate - 11



a.

b.

c.

50 % moisture than at 40% and 60% level (Table 14C). In the initial stage, the percentage reduction of cellulose and organic carbon were higher than lignin indicating that the fungus might have utilised the soluble carbohydrates and cellulose for its own growth (Fig. 9b). Dosoretz *et al.*, (1993) also observed and reported that the glucose consumption was high at the early stage of the fermentation with *Phanerochaete chrysosporium* under unlimiting nutrient level. The IVDMD was 54.08% in control and 64.12% at 50% moisture containing cashew apple waste samples.

2.1.3. Karad hay.

In karad hay, the ADF and lignin reduction were almost similar as it can be seen in the Table 15A. Reduction in cellulose was significantly higher at 60% moisture than at 70% moisture level (Fig. 10 a, b). The ADF and lignin were reduced by 30.88% and 22.64 % at 80 % moisture (Table 15C). Kakkar *et al.* (1990) investigated the effect of moisture level on biodegradation of wheat straw by *Pleurotus florida* and reported a maximum reduction of ADF at 70% moisture level. However, Zadrazil and Brunnert (1981) reported an optimum moisture level for wheat straw as 75%. He also reported that satisfactory growth can be observed at a wide range of moisture content of the substrate. Moreover, the difference in the optimum moisture level could be due to the nature of the

Table 14 A. Effect of moisture on degradation of cashew apple waste by *Pleurotus florida* (Nutrient on % dry matter basis).

Nutrient	Moisture level in %					
	0	20	30	40	50	60
NDF	63.05 ±1.61	62.37 ±0.68	60.56 ±0.65	60.18 ±2.44	57.58 ±1.07	58.32 ±0.84
ADF	45.82 ±2.08	45.61[a] ±0.53	44.92[a] ±0.92	43.86 ±1.20	43.17 ±2.63	44.73 ±1.77
HCEL	17.23 ±1.21	16.76 ±0.68	15.64 ±0.72	16.32 ±0.53	14.41 ±0.49	13.59 ±0.78
CEL	12.35 ±1.43	12.90[a] ±0.70	11.58 ±0.43	10.23 ±0.90	09.51 ±0.91	09.78 ±1.30
LIG	12.43 ±0.85	12.63[a] ±0.37	12.04[a] ±0.48	11.82 ±0.59	11.26 ±1.31	11.43 ±0.74
CP	09.65 ±1.17	10.75 ±0.74	10.75 ±0.57	11.25 ±0.68	12.75 ±0.61	12.75 ±0.83
OM	97.25 ±1.58	93.48 ±0.76	89.87 ±0.57	87.50 ±0.13	88.24 ±1.58	87.19 ±1.05
C2	37.53 ±0.85	38.22 ±0.57	38.04 ±0.28	37.15 ±0.16	35.97 ±0.76	35.33 ±0.68

Mean values in rows followed by superscript 'a' are not significantly different ($P < 0.05$)

Table 14 B. Reduction in structural carbohydrate and organic matter content of cashew apple waste (% Dry matter basis).

Nutrient	Moisture level in %				
	20	30	40	50	60
NDF	0.68	2.49	2.87	5.47	4.73
ADF	0.21	0.90	1.96	2.65	1.09
HCEL	0.47	1.59	0.91	2.82	3.64
CEL	0.55	0.77	2.12	2.84	2.57
LIG	0.20	0.39	0.61	1.17	1.00
CP	1.10	1.10	1.60	3.10	3.10
OM	3.77	7.38	9.75	9.01	10.06
C2	0.69	0.51	0.38	1.56	2.20

Table 14 C. Percent reduction in structural carbohydrate and organic matter of cashew apple waste.

Nutrient	Moisture level in %				
	20	30	40	50	60
NDF	1.08	3.95	4.55	8.68	7.50
ADF	0.46	1.96	4.28	5.78	2.38
HCEL	2.73	9.23	5.28	16.37	21.13
CEL	4.45	6.23	17.17	23.00	20.81
LIG	1.61	3.14	4.91	9.41	8.05
CP	1.10	1.10	1.60	3.10	3.10
OM	3.88	7.59	10.03	9.26	10.34
C2	1.84	1.36	1.01	4.16	5.86

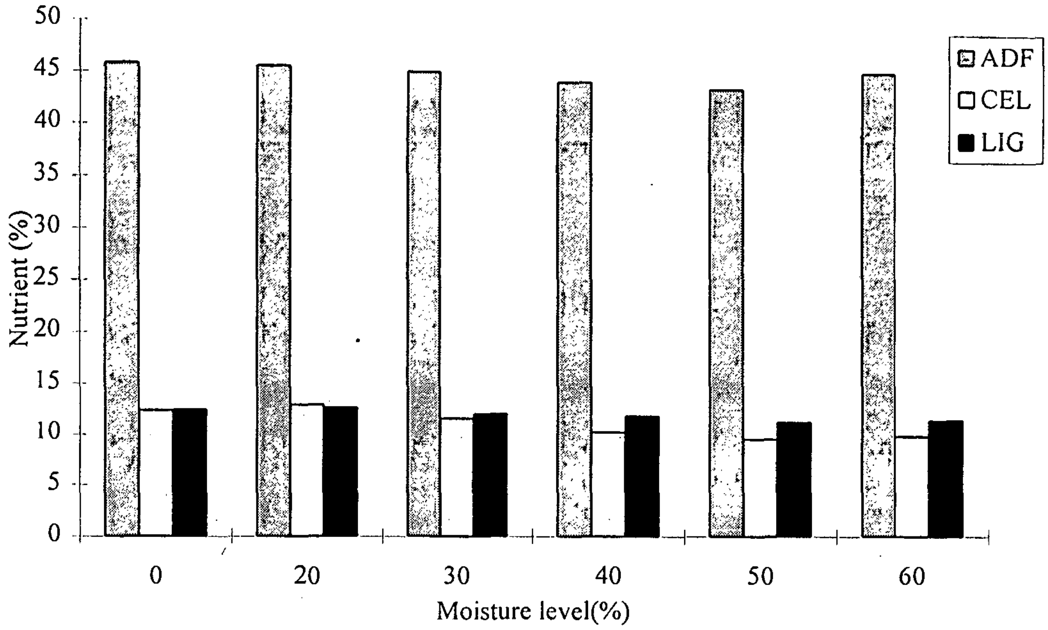


Fig 9 a: Effect of moisture level on the structural carbohydrate content of cashew apple waste after fermentation

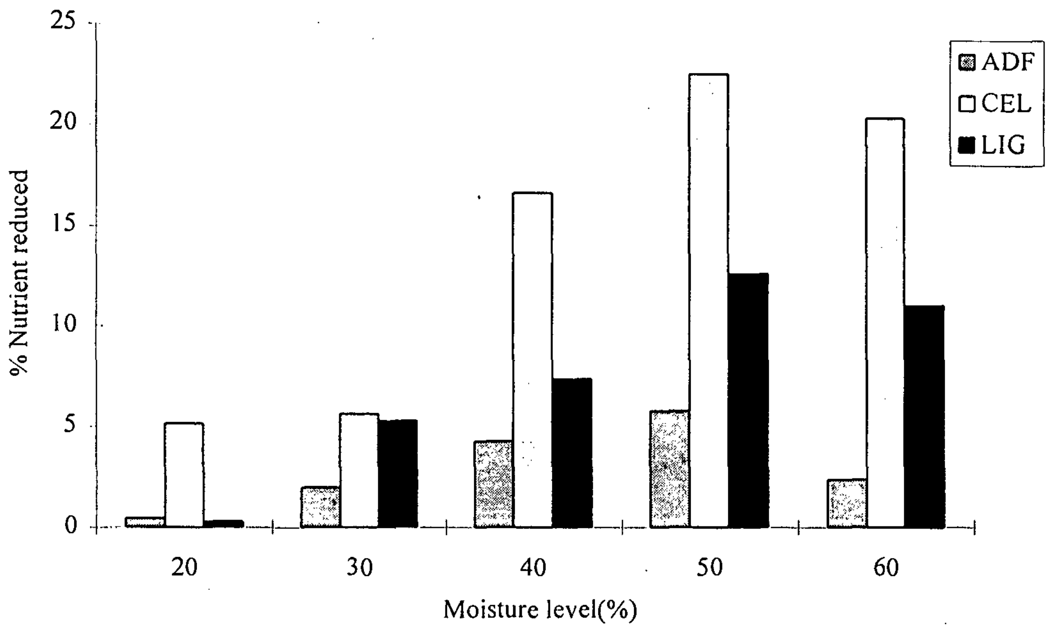


Fig 9 b: Percent reduction in structural carbohydrate in cashew apple waste during solid state fermentationat different moisture level

Table 15 A. Effect of moisture on degradation of karad hay by *Pleurotus florida* (Nutrient on % dry matter basis).

Nutrient	Moisture level in %						
	0	20	40	60	70	80	100
NDF	64.76 ±1.63	62.47 ±1.63	59.42 ±1.15	58.93 ±1.06	54.96 ±1.27	54.41 ±0.51	58.16 ±0.56
ADF	46.92 ±0.87	42.75 ±0.56	37.18 ±0.46	35.67 ±0.65	34.31 ±0.79	32.43 ±0.71	34.16 ±0.37
HCEL	17.84 ±0.75	19.72 ±0.85	22.24 ±1.32	23.26 ±1.05	20.65 ±0.96	21.98 ±1.21	24.00 ±0.86
CEL	33.75 ±0.85	32.86 ±0.39	31.14 ±0.63	30.79 ±0.52	28.51 ±0.47	28.46 ±0.83	31.67 ±0.27
LIG	14.62 ±0.65	15.11 ±0.90	14.05 ±0.24	13.57 ±0.31	11.65 ±0.43	11.31 ±0.42	12.33 ±0.38
CP	3.75 ±0.50	3.75 ±0.31	4.25 ±0.32	5.25 ±0.32	5.75 ±0.45	5.75 ±0.31	4.75 ±0.45
OM	96.37 ±1.56	96.12 ±0.82	96.41 ±0.79	91.04 ±0.89	87.83 ±1.24	88.02 ±0.84	89.15 ±0.45
C2	40.35 ±0.82	44.38 ±0.67	43.61 ±0.65	42.08 ±0.72	40.74 ±1.90	39.83 ±0.55	39.16 ±0.50

* Mean values of six analyses

Table 15 B. Reduction in structural carbohydrate and organic matter of karad hay (% Dry matter basis).

Nutrient	Moisture level in %					
	20	40	60	70	80	100
NDF	2.21	5.26	5.75	9.72	10.27	6.52
ADF	4.17	9.74	11.25	12.61	14.49	12.76
HCEL	1.96	4.48	5.50	2.89	4.22	6.24
CEL	0.89	2.61	2.96	5.24	5.29	2.08
LIG	0.49	0.57	1.05	2.97	3.31	2.29
CP	0.00	0.50	1.50	2.00	2.00	1.00
OM	2.22	1.93	7.30	10.51	10.32	9.19
C2	0.15	0.92	2.45	3.79	4.70	5.37

Table 15 C. Percent reduction in structural carbohydrate and organic matter of karad hay.

Nutrient	Moisture level in %					
	20	40	60	70	80	100
NDF	1.98	9.52	12.31	18.10	18.63	12.99
ADF	8.89	20.76	23.98	26.88	30.88	27.20
HCEL	11.04	25.23	30.97	16.27	23.76	35.14
CEL	2.64	7.73	8.77	15.53	15.67	6.16
LIG	3.35	3.90	7.18	20.31	22.64	15.66
CP	0.00	0.50	1.50	2.00	2.00	1.00
OM	2.26	1.96	7.42	10.69	10.49	9.35
C2	0.34	2.07	5.50	8.51	56.82	12.06

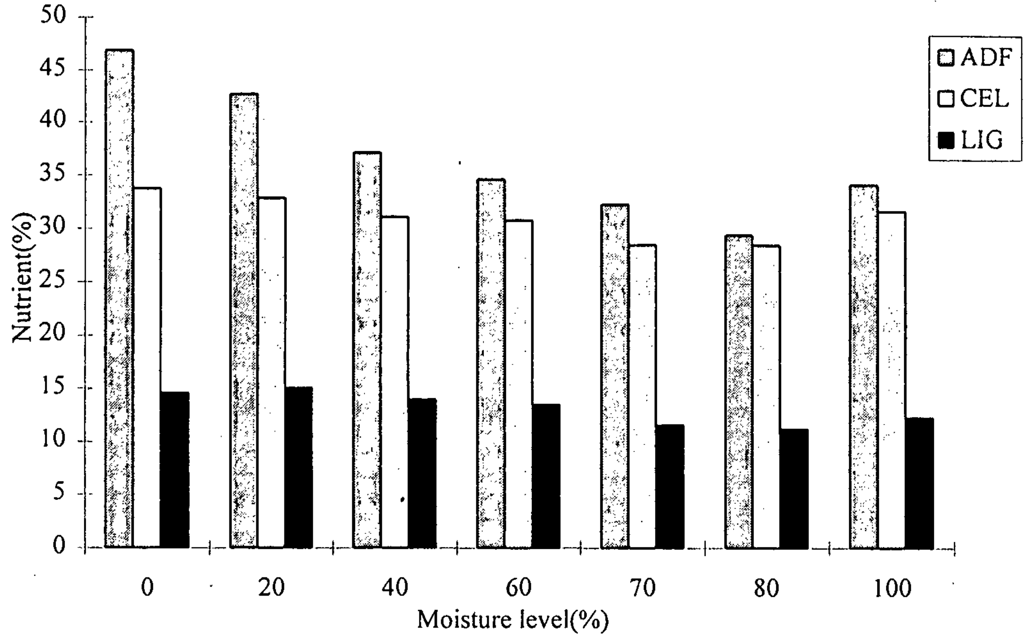


Fig 10 a: Effect of moisture level on the structural carbohydrate of karad hay during fermentation

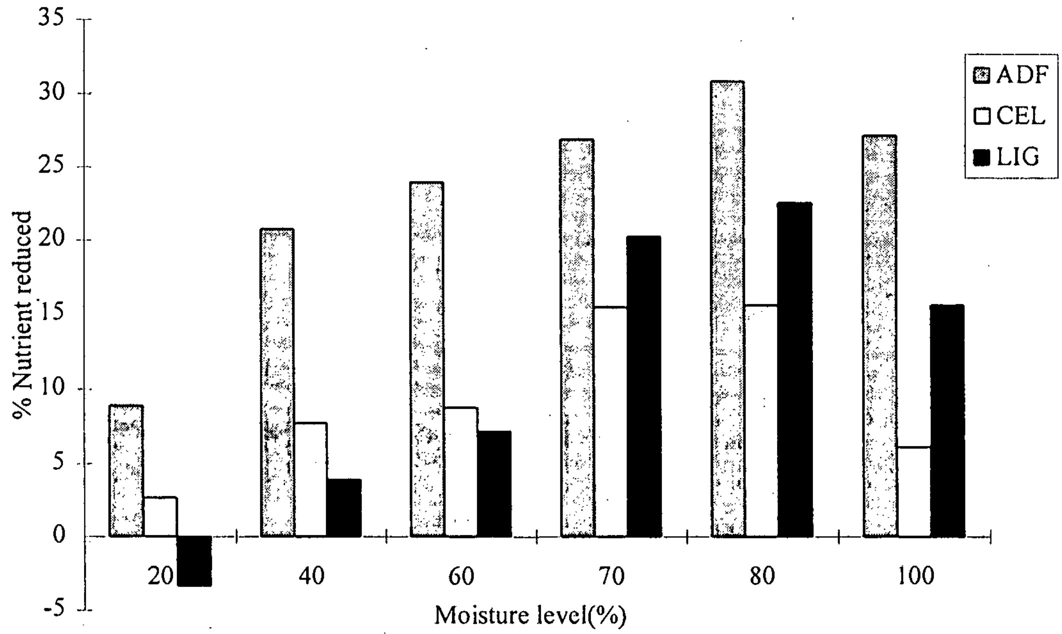


Fig 10 b: Percent reduction in structural carbohydrate in karad hay during solid state fermentationat different moisture level

karad hay, which is slender but hard as compared to paddy straw. Percent reduction of lignin was higher than cellulose at 80% moisture as it has been observed with coir dust in this study (Fig. 10b; Pl. 10b).

2.2. Effect of duration of fermentation on the substrate:

In the initial phase of fermentation, of the substrate, fungi generally utilise easily available carbohydrates such as glucose and other simple sugars from the substrate for growth. When these nutrients are not available, the other complex carbohydrates are degraded and used (Martinez *et al.*, 1994). Since the primary objective of the study was to improve nutritive value of the substrate by degradation of lignocellulose complex which otherwise is difficult to get utilised by the animals, the process of fermentation was allowed to continue for a period of up to 90 days. The rate of degradation of structural components at different duration was monitored so as to understand the optimum peroid for biodegradation of the selected substrate. The fermented by-product was analysed for various nutrients and loss of organic matter and crude protein content at different duration of fermentation.

2.2.1. Effect on coir dust

In coir dust, percentage reduction of lignin and ADF was higher at 15 and 30 days when compared to 60 and 90 days (Table 16 B). Although the

Table 16 A. Effect of duration of fermentation on degradation of coir dust by *Pleurotus florida* (Nutrient on % dry matter basis).

Nutrient	Control	Duration in days			
	0	15	30	60	90
NDF	80.62 ±1.63	75.62 ±0.54	72.48 ±0.53	71.37 ±0.68	69.81 ±0.37
ADF	69.91 ±1.30	65.06 ±0.41	62.73 ±0.54	62.17 ±0.57	60.86 ±0.40
HCEL	10.71 ±0.90	10.56 ±1.12	9.75 ±0.87	9.20 ±1.05	8.95 ±0.73
CELL	20.25 ±1.28	17.80 ±0.40	17.41 ±0.45	16.92 ±0.34	16.77 ±0.35
LIG	39.91 ±1.12	35.42 ±0.62	32.63 ±0.53	31.48 ±0.78	30.65 ±0.57
CP	1.75 ±0.23	3.75 ±0.40	6.25 ±0.45	6.75 ±0.45	6.75 ±0.45
OM	97.21 ±0.93	84.93 ±0.72	79.40 ±2.91	78.60 ±0.62	78.52 ±0.78
C2	40.17 ±1.24	37.84 ±1.24	35.47 ±0.58	34.66 ±0.59	33.92 ±0.38

* Mean values of six analyses

Table 16 B. Reduction in structural carbohydrate and organic matter of coir dust (% Dry matter basis).

Nutrient	Duration in days			
	15	30	60	90
NDF	5.00	8.14	9.25	10.81
ADF	4.85	7.18	7.74	9.05
HCEL	0.15	0.96	1.51	1.76
CELL	2.45	2.84	3.33	3.48
LIG	4.49	7.28	8.43	9.26
CP	2.00	4.50	5.00	5.00
OM	12.28	17.81	18.61	18.69
C2	2.33	4.70	5.51	6.25

Table 16 C. Percent reduction in the structural carbohydrate and organic matter of coir dust.

Nutrient	Duration in days			
	15	30	60	90
NDF	6.20	10.10	11.47	13.41
ADF	6.94	10.27	11.07	12.95
HCEL	1.40	8.96	14.10	16.43
CEL	12.10	14.02	16.44	17.19
LIG	11.25	18.24	21.12	23.20
CP	2.00	4.50	5.00	5.00
OM	12.63	18.32	19.14	19.23
C2	5.80	11.70	13.72	15.56

Fig 11 c.

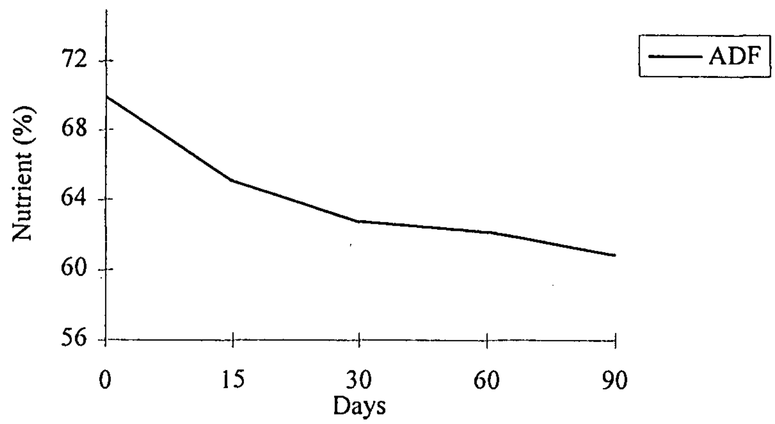


Fig 11 d.

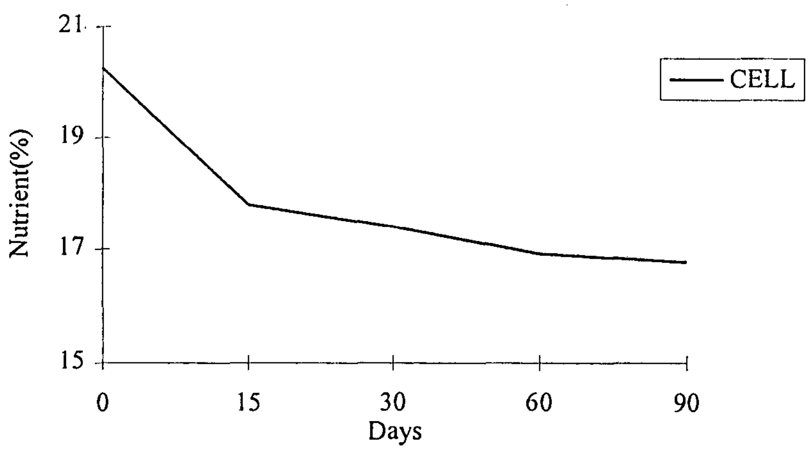


Fig 11 e.

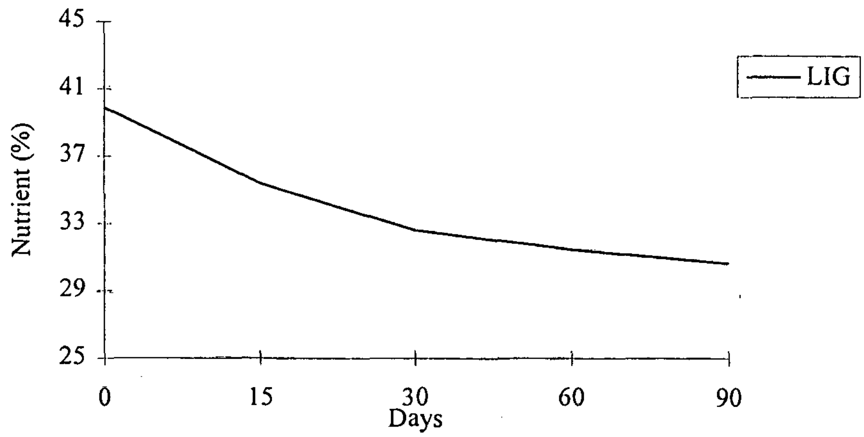


Fig 11 c-e: Reduction in structural components of coir dust at different duration of fermentation with *Pleurotus florida*.

total reduction in ADF was 7.18 % and in lignin 7.28%, when evaluated the percent reduction of the initial content it was 10.27% in ADF and 18.24% in lignin after 30 days of fermentation (Fig. 11 a, b). These observations indicate that maximum degradation has taken place in lignin content. Cellulose was also affected although it is reduced to lesser extent than lignin due to fermentation by *Pleurotus* spp. It was reduced from 20.25% to 17.41% in 30 days and to 16.77% in 90 days. Both the dry matter content and nuterient reduction were higher in the initial stage of fermentation (Fig. 11 c, d, e). The organic matter loss was 18.32% after 30 days of fermentation whereas it was only 19.23% after 90 days. The crude protein content increased by 4.5% after 30 days.

2.2.2. Effect on cashew apple waste

In cashew apple waste, ADF content was 45.82% and 44.60% for 0 and 30 days fermented samples. The lignin content decreased from 12.43% to 11.65% in 30 days (Fig. 12a). Cellulose was reduced from 12.35% to 9.63% in 30 days (Table 17A). As seen in Table 17A, the higher values of lignin and ADF in the early stage of fermentation up to 15 days could be due to utilization of soluble sugars by the fungus for it's initial growth during fermentation. This trend was also seen in the loss of organic matter which is 5.9 % (Table 17B).

Table 17 A. Effect of duration of fermentation on degradation of cashew apple waste by *Pleurotus florida* (Nutrient on % dry matter basis)

	Control	Duration in days			
Nutrient	0	15	30	60	90
NDF	63.05	60.33	61.13	60.42[a]	60.83[a]
	±1.61	±0.49	±0.22	±0.54	±0.59
ADF	45.82	46.05	44.60	44.03	43.25
	±2.08	±0.27	±0.41	±0.74	±0.47
HCEL	17.23	14.28	16.53	16.39	17.58
	±1.21	±0.93	±0.74	±0.93	±1.38
CEL	12.35	10.49	09.63	09.03	08.81
	±1.43	±0.22	±0.24	±0.24	±0.60
LIG	12.43[a]	12.72[a]	11.65	10.85	09.51
	±0.85	±0.49	±0.57	±0.52	±1.18
CP	09.65	10.14	11.25	11.87[a]	11.87[a]
	±1.17	±0.51	±0.39	±0.50	±0.91
OM	97.25	91.35	86.29	82.07	79.26
	±1.58	±0.49	±0.30	±0.70	±0.64
C2	42.96	39.60	39.16	38.88	37.36
	±0.85	±0.35	±0.36	±0.47	±0.38

Mean values in rows followed by superscript 'a' are not significantly different ($P < 0.05$)

* Mean values of six analyses

Table 17 B. Reduction in structural carbohydrate and organic matter of cashew apple waste (% Dry matter basis).

Nutrient	Duration in days			
	15	30	60	90
NDF	2.72	1.92	2.63	2.22
ADF	0.23	1.22	1.79	2.57
HCEL	2.95	0.70	0.84	0.35
CEL	1.86	2.72	3.32	3.54
LIG	0.29	0.78	1.58	2.92
CP	0.49	1.60	2.22	2.22
OM	5.90	10.96	15.18	17.99
C2	2.07	1.63	1.35	0.17

Table 17 C. Percent reduction in the strucrural carbohydrate and organic matter of cashew apple waste.

Nutrient	Duration in days			
	15	30	60	90
NDF	4.31	3.05	4.17	3.52
ADF	0.50	2.66	3.91	5.61
HCEL	17.12	4.06	4.88	2.03
CEL	15.06	22.02	26.88	28.66
LIG	2.33	6.28	12.71	23.49
CP	0.49	1.60	2.22	2.22
OM	6.07	11.27	15.61	18.50
C2	5.52	4.34	3.60	0.45

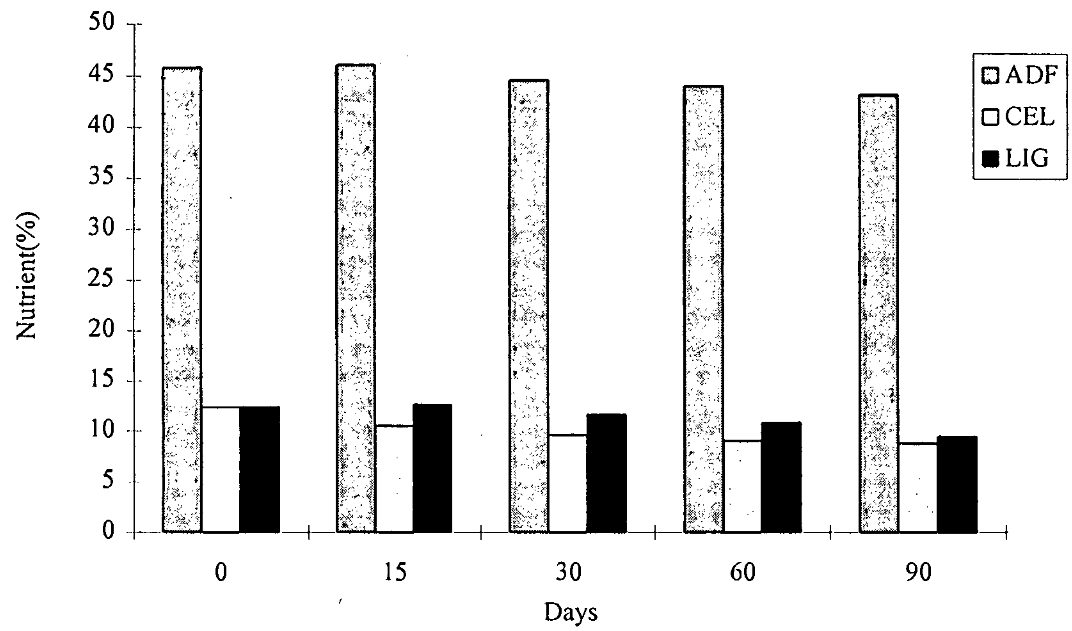


Fig 12 a: Effect of durartion of fermentation on the structural components of Cashew apple waste

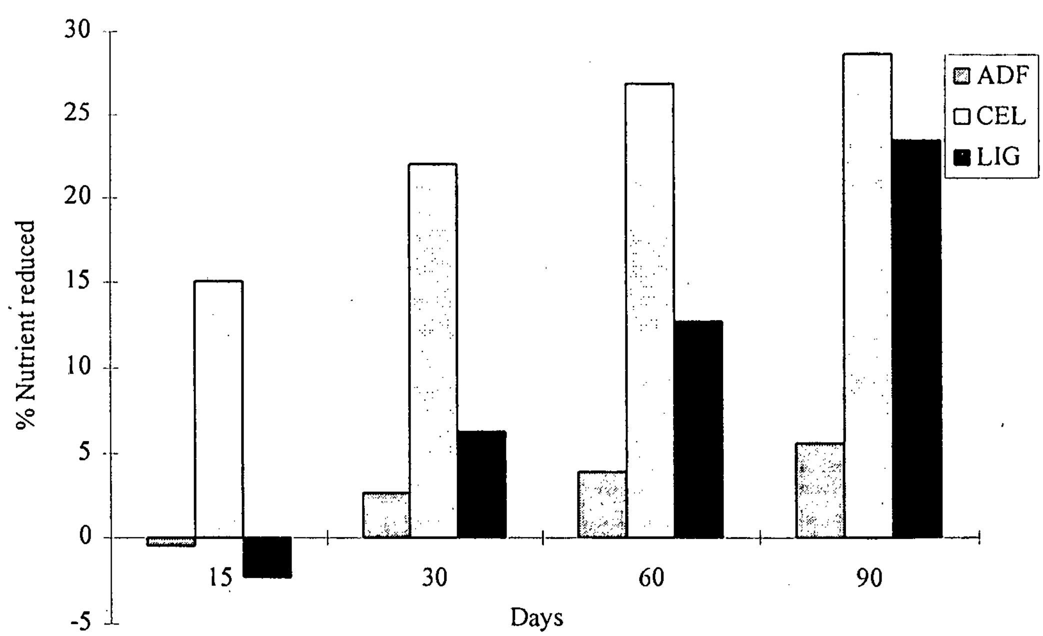


Fig 12 b: Percent reduction in the structural components of Cashew apple waste on different duration of fermentation

Fig 12 c.

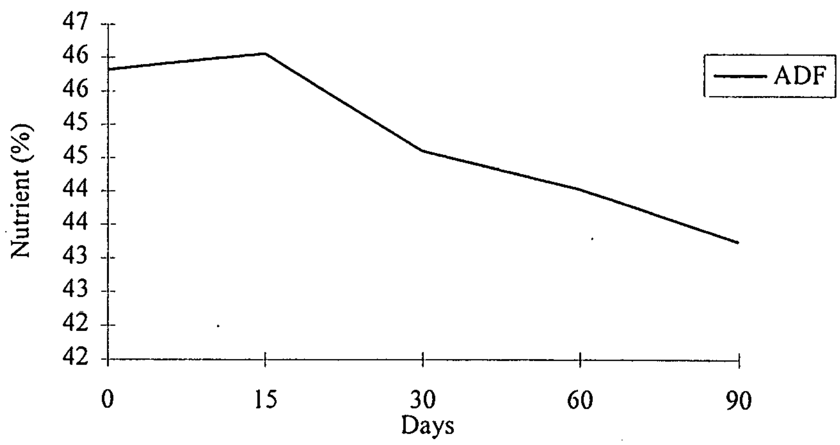


Fig 12 d.

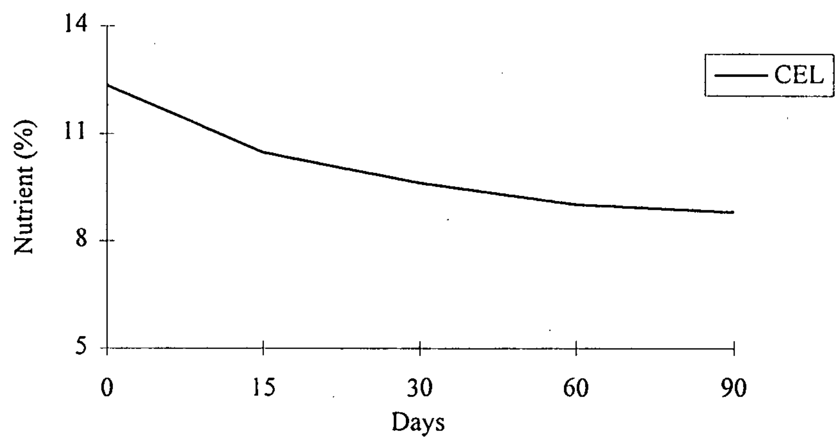


Fig 12 e.

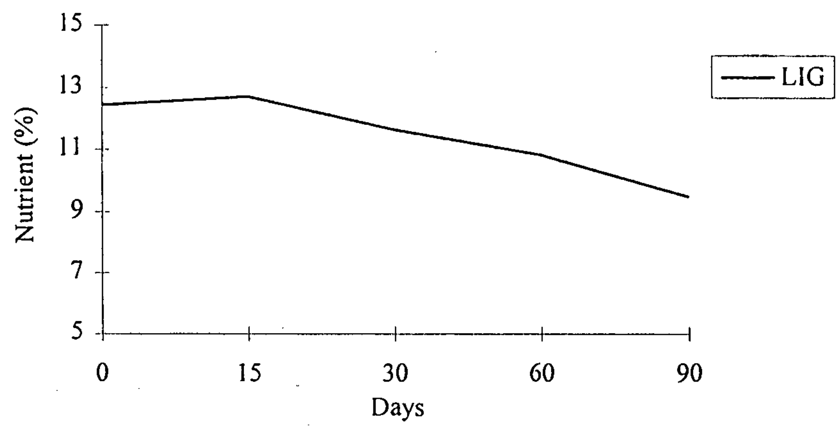


Fig 12 c-e: Reduction in structural components of cashew apple waste at different duration of fermentation with *Pleurotus florida*.

The reduction in cellulose was higher up to 30 days duration. There after, the percent reduction in lignin was higher as can be seen from the Table 17B.

The carbon content was reduced from 42.96 to 39.16% on 30 days of fermentation which indicated a moderate loss in organic matter. The crude protein content was increased from 9.65% to 11.25%. The latter observations indicate significant improvement in the nutrient content of the substrate in 30 days of fermentation over the control. The increase in crude protein content was not an appreciable amount as compared to that in coir dust and karad hay. From the overall assesment of the nutrient content before and after fermentation of cashew apple waste, it can be said that the cellulose has been utilised by the fungi more prominently than the other nutrients (Fig. 12b).

2.2.3. Effect on karad hay.

In karad hay the percent reduction in ADF was 12.25%, 23.17% and 29.11% after 15, 30 and 60 days of fermentation respectively (Table 18C). Lignin was reduced by 12.31%, 22.37% and 25.72% during the same period. Cellulose reduction was lower when compared to lignin (Fig. 13 a, b). It was reduced by 7.2%, 12.09% and 16.62% after 15, 30 and 60 days duration. Increase in crude protein content was more prominent up to 30 days. It was improved from 3.75% in the control to 5.65% in the fermented sample after 30

Table 18 A. Effect of duration of fermentation on degradation of karad hay by *Pleurotus florida* (Nutrient on % dry matter basis)

	Control	Duration in days			
Nutrient*	0	15	30	60	90
NDF	64.76	62.23	58.41	56.17	55.72
	±1.63	±0.35	±1.02	±0.70	±0.65
ADF	46.92	41.17	36.05	33.26	31.83
	±0.87	±0.52	±0.48	±2.46	±0.62
HCEL	17.84	21.06	22.36	22.91	23.89
	±0.75	±0.35	±1.17	±1.04	±0.81
CEL	33.75	31.32	29.67	28.14	27.53
	±0.85	±1.10	±0.60	±0.72	±0.74
LIG	14.62	12.82	11.35	10.86	9.74
	±0.65	±0.47	±1.06	±0.54	±0.40
CP	3.75	4.37	5.65	5.75	6.25
	±0.50	±0.38	±0.41	±0.45	±0.45
OM	96.37	85.20	81.55	78.58	76.37
	±1.56	±1.35	±1.03	±0.92	±0.66
C2	40.35	37.27	35.49	34.83	33.74
	±0.82	±0.30	±0.62	±0.63	±0.57

* Mean values of six analyses

Table 18 B. Reduction in structural carbohydrate and organic matter of karad hay (% Dry matter basis).

Nutrient	Duration in days			
	15	30	60	90
NDF	2.53	6.35	8.59	9.04
ADF	5.75	10.87	13.66	15.09
HCEL	3.22	4.52	5.07	6.05
CEL	2.43	4.08	5.61	6.22
LIG	1.80	3.27	3.76	4.88
CP	0.62	1.90	2.00	2.50
OM	11.17	14.82	17.59	20.00
C2	3.08	4.86	5.52	6.61

Table 18 C. Percent reduction in the structural carbohydrate and organic matter of karad hay.

Nutrient	Duration in days			
	15	30	60	90
NDF	3.91	9.81	13.26	13.96
ADF	12.25	23.17	29.11	32.16
HCEL	18.05	25.34	28.42	33.91
CEL	7.20	12.09	16.62	18.43
LIG	12.31	22.37	25.72	33.38
CP	0.62	1.90	2.00	2.50
OM	11.59	15.38	18.25	20.75
C2	7.63	12.04	13.68	16.38

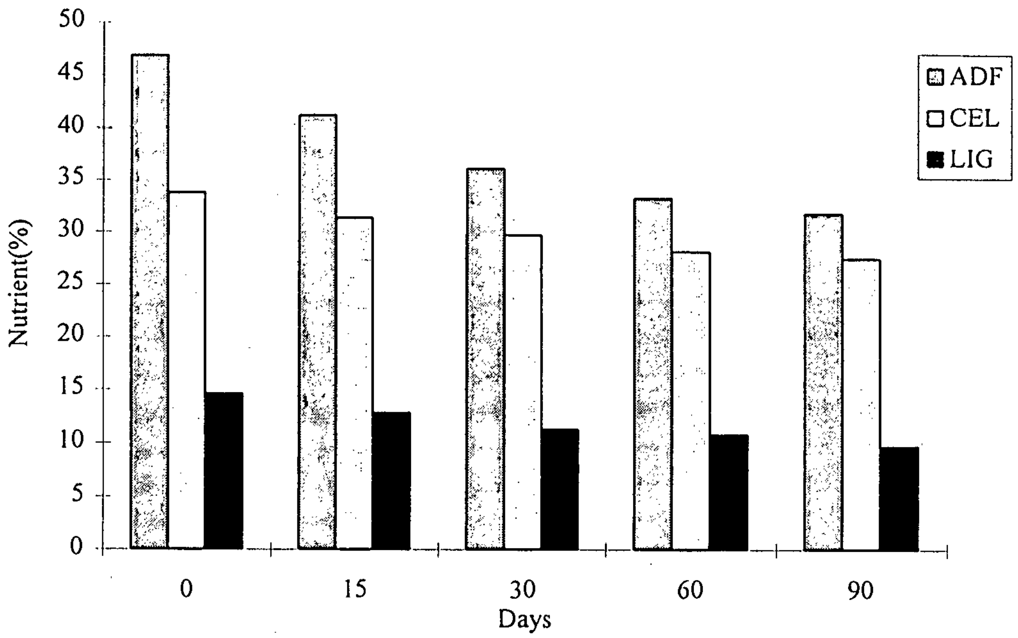


Fig 13 a: Effect of durartion of fermentation on the structural components of Karad hay

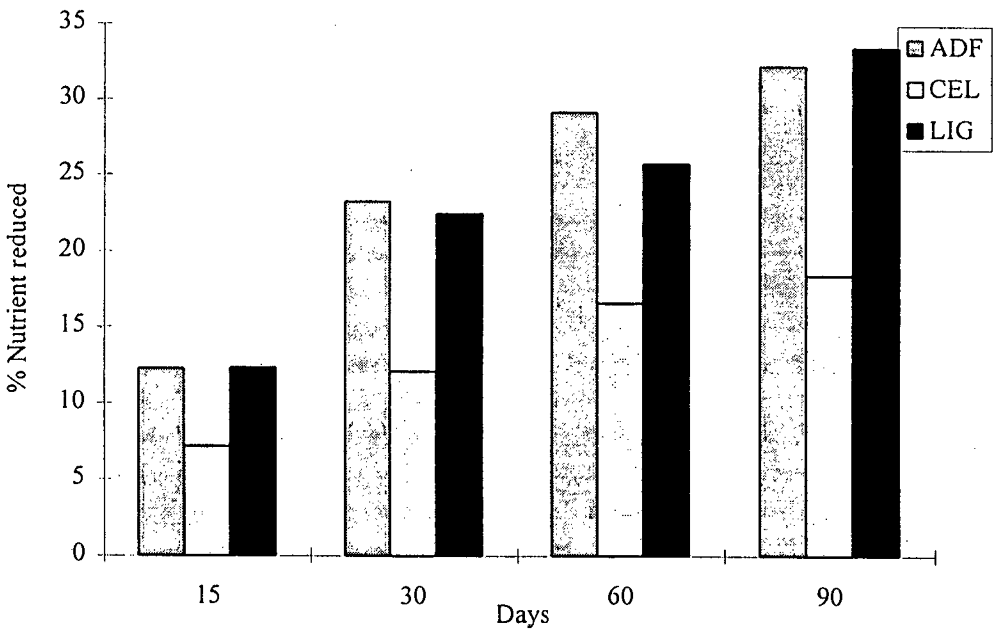


Fig 13 b: Percent reduction in the structural components of karad hay on different duration of fermentation

Fig 13 c

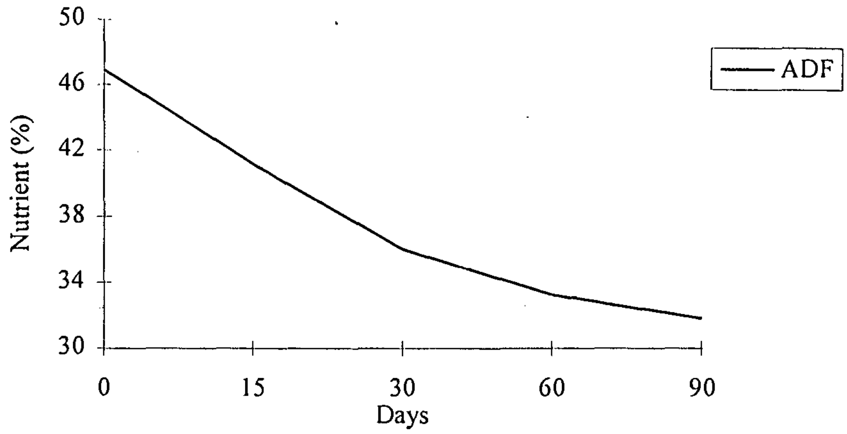


Fig 13 d

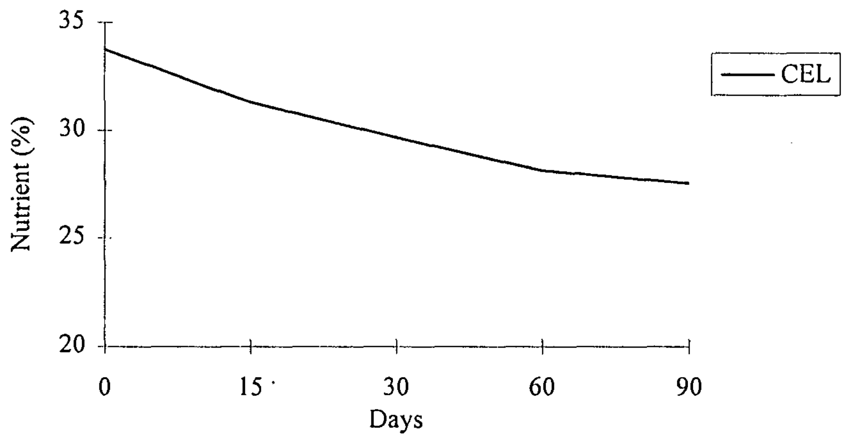


Fig 13 e

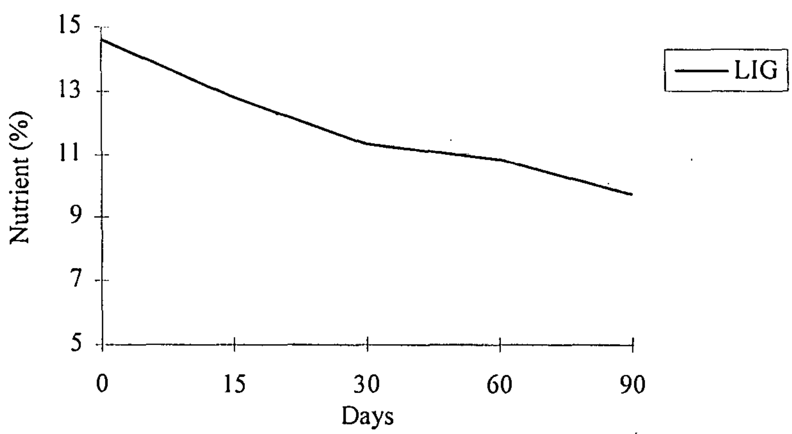


Fig 13 c-e: Reduction in structural components of karad hay at different duration of fermentation with *Pleurotus florida*.

days. The organic matter loss was 11.17% and 20% on 30 and 90 days treatment (Table 18B).

The percent reduction of lignin was more in coir dust (18.24%) than in cashew apple waste (6.28%). However reduction in cellulose content was more in cashew apple waste (22.02%) than in coir dust (14.02%) indicating that the cellulose was more utilised by fungi in cashew apple waste than in coir dust. Perhaps the structural arrangement and nature of the substrate could be the posible reasons for the preferential use of cellulose and soluble carbohydrates by the fungus in cashew waste. The organic matter loss was 18.32% in coir dust and 11.27% in cashew apple whereas in karad hay it was 11.59%. The digestibility under *in vitro* condition was 48.69% for cashew apple waste and 38.76% for coir dust after 30 days fermentation. Maximum loss of lignin, ADF and organic matter was observed in karad hay than coir dust and cashew apple waste.

Part III

III. Effect of added substrate on fibrous waste degradation:

Lignin appears to be a difficult proposition to digest unless a readily available high energy diet is substituted in animal feeds (Harkin, 1978). With a similar view Savoie *et al.* (1992) added corn steep liquor to straw and enhanced biodegradation with *Agaricus bisporus*. This observation indicated that degradation of structural carbohydrate will be at a faster rate if a simple polysaccharide is made available in the substrate. Rai *et al.* (1993) reported that the fungus generally required an easily assimilable additional carbohydrate for its initial growth in the substrate.

Considering the above observations, in the present study, common feed ingradients, viz. rice bran, wheat bran and maize were added to by-products to test and evaluate their associative effect on the degradation of less digestible components of the substrate. Keeping the eventual cost effect in mind, the substrate addition was fixed to 25% level in oder to provide cellulose and simple carbohydrates for fungal growth.

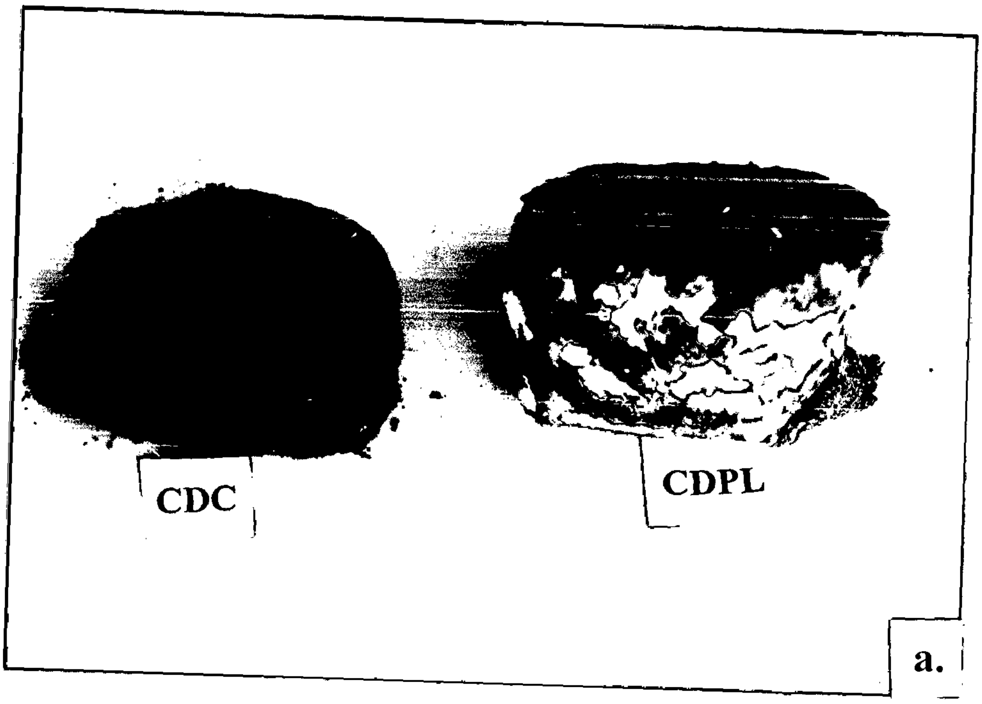
The by product base material together with added substrate was fermented for a duration of 30 days and anlysed for proximate components in order to evaluate the effect of added substrate on degradation of the structural carbohydrates. The results of chemical analysis are presented in Table 19.

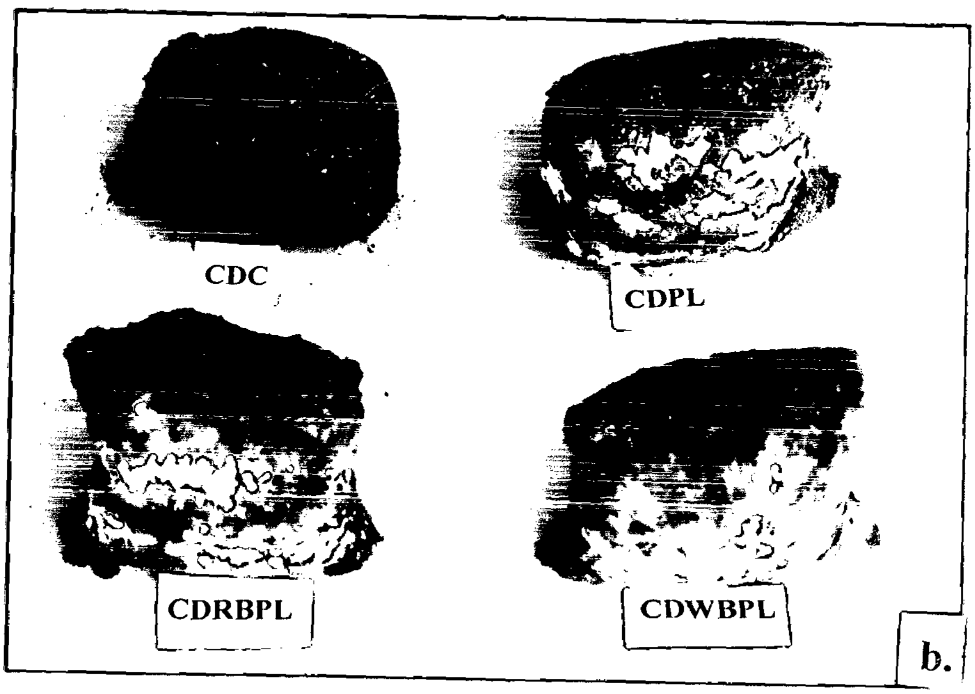
3.1. Effect of enrichment on coir dust degradation :

In coir dust, on visual examination of the inoculated samples, it was observed that growth of the fungi appeared to be more prominent in the control group than in substrate enriched coir dust (Pl. 12 a, b). However, on chemical analysis, it was observed that the ADF content was reduced by 23.64 % in rice bran incorporated samples as against 10.10% in control, i.e. coir dust alone (Fig. 14 b, e). The reduction in ADF was apparently due to the loss of cellulose and lignin of the by product material (Table 19A).

Among all the structural cabohydrate components, maximum reduction was observed in lignin content in all treatments (Fig. 14e). It was reduced from 27.04 to 18.06% in coir dust enriched with rice bran (Table 19B). The percent reduction of lignin in the control, wheat bran and maize added sample was 18.24%, 13.97% and 19.49% respectively (Table 19E). Since a substantially high amount of lignin has been degraded in control group when compared to maize and wheat bran added samples it is evident that *Pleurotus florida* has its preference for lignin degradation in this substrate.

Plate - 12





Cellulose was reduced by 16.31% in control and 5.28% in maize added sample (Table 19E). Higher utilisation of cellulose in the control group, i.e. coir dust, was due to non availability of other cabohydrates as energy source. In maize added sample any available simple carbohydrates might have been utilized as the primary source of nutrient and therefore the cellulose was apparently utilised only to a limited extent.

The crude protein content of coir dust was increased from 1.75% to 5.75% in *Pleurotus florida* treated samples whereas in coir dust enriched with rice bran, it was increased from 2.83% to 6.12% (Table 19B).

The loss of organic matter was16.42% in coir dust added with rice bran treatment whereas it was 20.9% with maize-enriched fermentation (Table 19E). Although higher loss of organic matter was estimated in maize added sample, the growth of fungal mycelium was found to be quite extensive in this treatment. The increase of protein content from 2.98% to 9.76% observed on the substrate is attributed to growth of fungal biomass (Table 19D). The IVDMD was lower in maize treated sample than in coir dust treated with rice bran and wheat bran treatments.

Table 19 A. Effect of fermentation with *Pleurotus florida* on the nutrient content of coir dust (% Dry matter basis).

Nutrient	CD	CDPL	Difference	% Difference
NDF	78.94 ±1.37	64.03 ±1.04	14.91	18.89
ADF	69.91 ±2.22	62.85 ±1.17	7.06	10.10
HCEL	9.03 ±1.88	1.18 ±1.78	7.85	86.93
CEL	20.85 ±1.53	17.45 ±0.90	3.40	16.31
LIG	39.91 ±0.77	32.63 ±0.80	7.28	18.24
CP	1.75 ±0.16	5.75 ±0.66	4.00	228.57
OM	96.85 ±2.10	88.61 ±1.60	8.24	8.51
C2	40.23 ±0.67	35.18 ±1.42	5.05	12.55
IVDMD	38.76 ±1.76	47.34 ±1.40	8.58	22.14

Table 19 B . Effect of Rice bran enrichment on the nutrient composition of coir dust after 30 days of fermentation (% Dry matter basis)

Nutrient	CDRB	CDRBPL	Difference	% Difference
NDF	68.53 ±0.98	62.36 ±0.82	6.18	9.01
ADF	55.47 ±0.53	42.35 ±0.60	13.12	23.64
HCEL	13.07 ±0.75	20.01 ±0.68	6.94	53.10
CEL	20.37 ±0.54	18.61 ±0.63	1.77	8.66
LIG	27.04 ±1.27	18.06 ±0.61	8.98	33.21
CP	2.83 ±0.34	6.12 ±0.54	3.29	116.00
OM	96.40 ±0.45	80.56 ±1.08	15.84	16.42
C2	41.61 ±0.87	34.15 ±0.44	7.46	17.92
IVDMD	44.91 ±0.65	50.40 ±0.74	5.50	12.23

CD - Coir dust

CDPL - Coir dust +*Pleurotus*

CDRB - Coir dust 75% +Rice bran 25%

CDRBPL - Coir dust 75% +Rice bran 25%+*Pleurotus florida*

* Mean values of six analyses

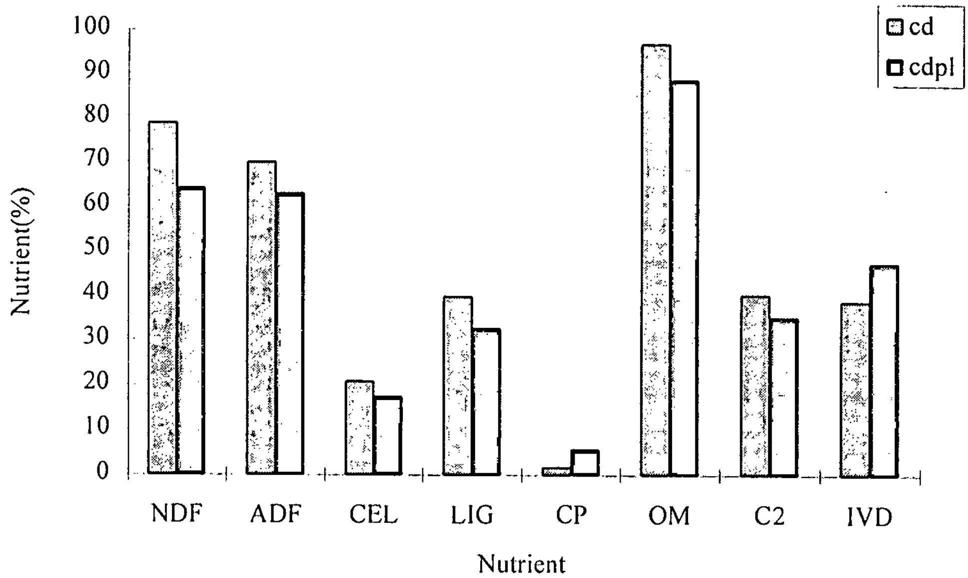


Fig 14 a: Effect of fermentation with *Pleurotus florida* on the nutrient content of coir dust

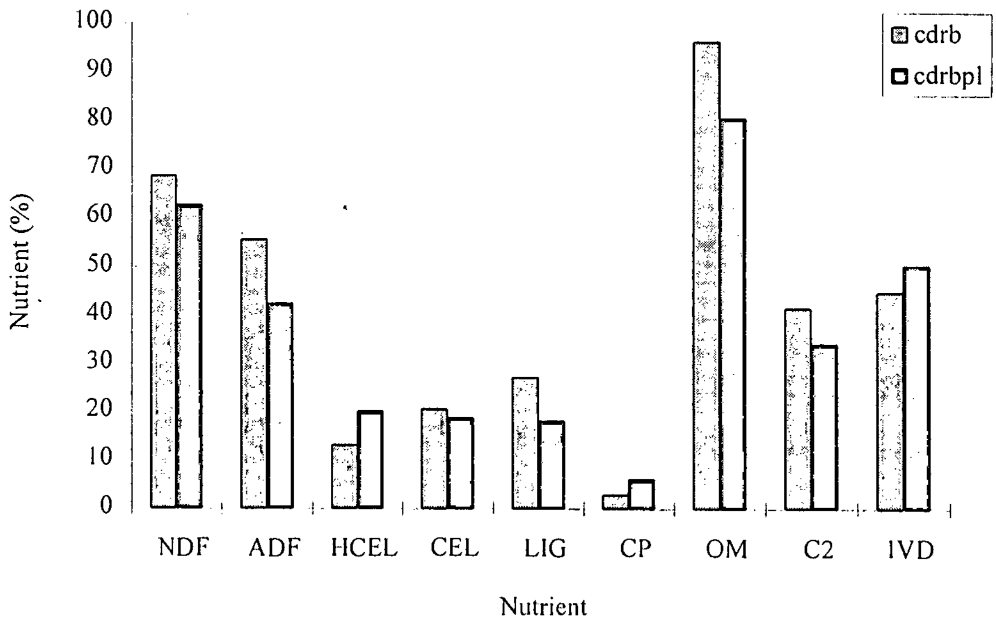


Fig 14 b: Effect of rice bran enrichment on degradation of coir dust by *Pleurotus florida*

R/Exam/UMIC/95/75 11-3-1998

To,

The Secretary to Governor,
Raj Bhavan,
Dona Paula,
Goa - 403 004.

Sir,

With reference to the order of the Visitor dated 4-3-1998 passed in connection with the appeal filed by Shri S.R. Phal, I am to forward herewith the written submissions of the University, in reply to the written submissions filed by Shri Phal on 4-3-1998.

Kindly acknowledge receipt.

Yours faithfully,

(PROF.D.V. BORKAR)
Registrar

Encl: as above.

Table 19 C. Effect of wheat bran enrichment on the nutrient composition of coir dust after 30 days of fermentation (% Dry matter basis).

Nutrient	CDWB	CDWBPL	Difference	% Difference
NDF	64.71 ±0.68	62.95 ±1.60	1.76	2.71
ADF	52.45 ±0.53	45.24 ±0.84	7.21	13.73
HCEL	12.26 ±0.15	17.71 ±0.75	5.45	44.45
CEL	20.44 ±0.68	17.33 ±0.72	3.11	15.19
LIG	25.62 ±0.56	22.04 ±0.44	3.58	13.97
CP	4.83 ±0.26	7.46 ±0.60	2.63	2.63
OM	97.31 ±0.71	74.73 ±0.84	22.58	23.20
C2	39.41 ±1.01	35.56 ±0.56	3.85	9.77
IVDMD	49.12 ±0.42	54.28 ±0.77	5.16	10.50

Table 19 D. Effect of maize enrichment on the nutrient composition of coir dust after 30 days of fermentation (% Dry matter basis).

Nutrient	CDM	CDMPL	Difference	% Difference
NDF	63.84 ±0.65	54.50 ±0.54	9.34	14.62
ADF	52.15 ±0.77	49.27 ±0.80	2.88	5.52
HCEL	11.68 ±0.62	5.23 ±0.83	6.45	55.22
CEL	17.36 ±0.89	16.44 ±0.46	0.92	5.28
LIG	15.78 ±0.60	12.70 ±0.55	3.08	19.49
CP	2.98 ±0.23	9.76 ±0.46	6.78	6.78
OM	97.63 ±0.49	77.23 ±0.66	20.41	20.90
C2	43.71 ±0.55	36.28 ±0.67	7.44	17.01
IVDMD	51.62 ±0.93	56.11 ±1.08	4.49	8.69

CD - Coir dust

CDPL - Coir dust +*Pleurotus florida*

CDM - Coir dust 75% +Maize 25%

CDMPL - Coir dust 75% +Maize 25% +*Pleurotus florida*

* Mean values of six analyses

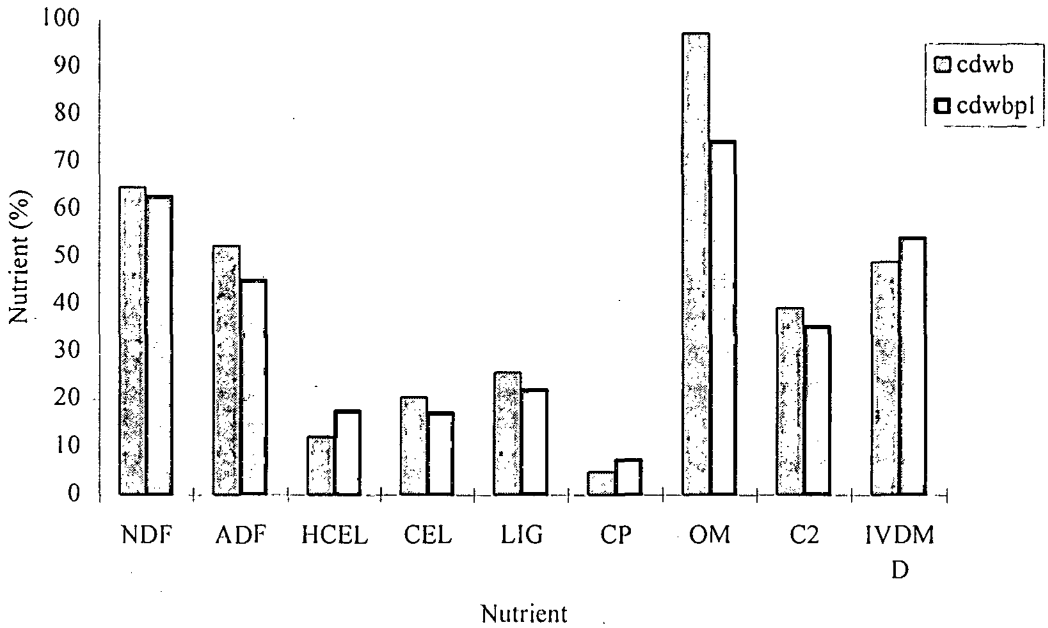


Fig 14 c: Effect of wheat bran enrichment on degradation of coir dust by by *Pleurotus florida*

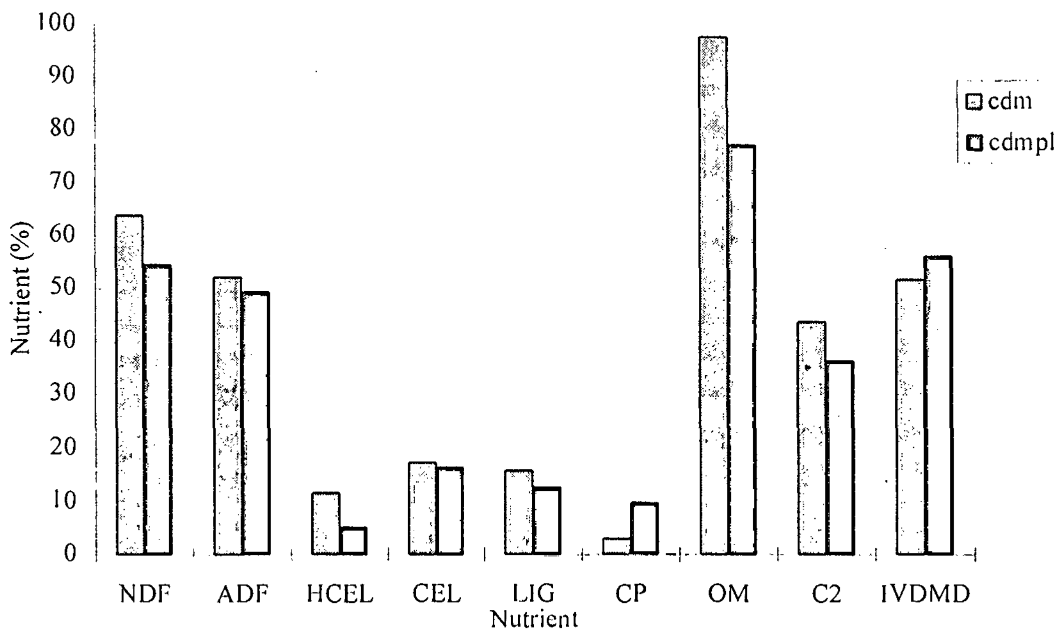


Fig 14 d : Effect of maize enrichment on the degradation of coir dust by *Pleurotus florida*

Table 19 E. Comparative performance of added substrate on the biodegradation of coir dust (percent nutrient degraded)*.

Nutrient	CDPL	CDRBPL	CDWBPL	CDMPL
NDF	18.89	9.01	2.71	14.62
ADF	10.10	23.64	13.73	5.52
HCEL	8.79	53.10	11.02	9.10
CEL	16.31	8.66	15.19	5.28
LIG	18.24	33.21	13.97	19.49
CP	228.57	116.00	54.31	227.80
OM	8.51	16.42	23.28	20.90
C2	12.55	17.92	9.77	17.01
IVDMD	22.14	12.23	10.50	8.69

CDPL - Coir dust + *Pleurotus florida*

CDRBPL - Coir dust 75% + Rice bran 25% + *Pleurotus florida*

CDWBPL - Coir dust 75% + Wheat bran 25% + *Pleurotus florida*

CAWMPL - Coir dust 75% + Maize 25% + *Pleurotus florida*

* Mean value of six analyses

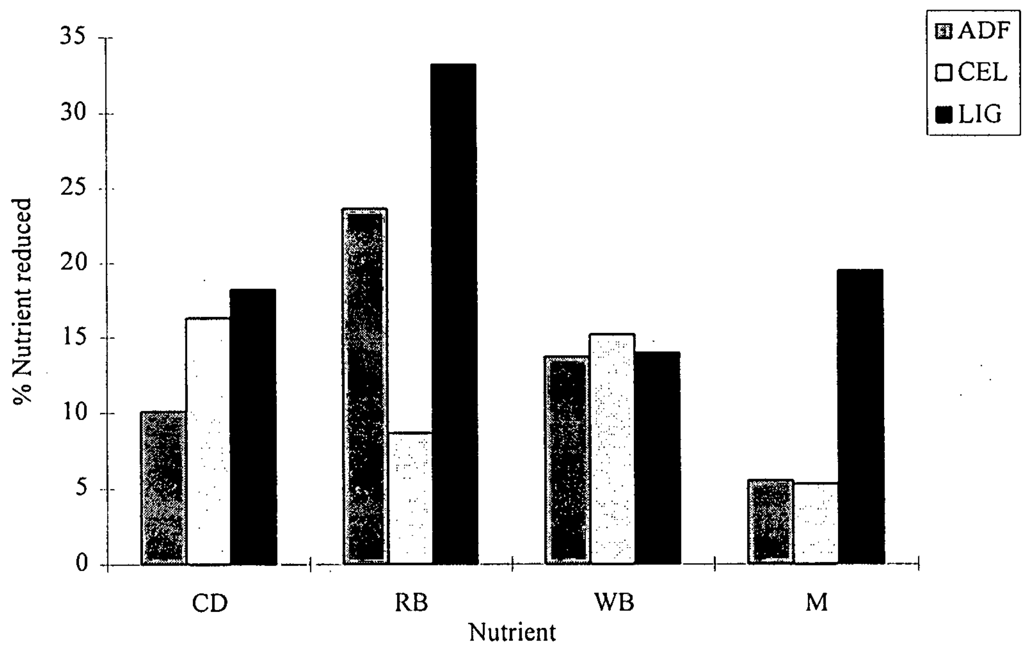


Fig 14 e: Comparative performance of added substrates on coir dust degradation (Percent nutrient reduced)

3.2. Effect of enrichment on cashew apple waste.

In cashew apple waste, maximum reduction in ADF was observed in rice bran added sample. The acid detergent fibre content was reduced from 43.05% to 29.28% in rice bran enriched cashew apple waste whereas it was reduced from 46.24% to 42.53% in the control group (Table 20A; Fig. 15 a, b). In maize enriched substrate, the reduction in ADF was 29.89% which is rather comparable to rice bran treatment (Pl. 13a).

Lignin was reduced by 20.11% in maize enriched substrate as against 7.23% in control and 18.47% in rice bran added sample. In wheat bran treated sample, it was only 9.04% (Table 20E).

Cellulose was degraded to a maximum extent in all the treatments. In maize and rice bran enrichment, reduction in cellulose was 14.53% and 16.64% respectively. In control and wheat bran added samples percent reduction in cellulose was 11.99% and 16.9%. In all treatments, except in rice bran added substrate, degradation of cellulose was prominent than lignin. The nature of lignocellulosic structure in cashew fruit and the easily available carbohydrate source could be the possible reasons for preferential degradation of cellulose.

Table 20 A. Effect of fermentation with *Pleurotus florida* on the nutrient content of cashew apple waste (% Dry matter basis).

Nutrient	CAW	CAWPL	Difference	% Difference
NDF	68.19 ±0.73	62.89 ±0.89	5.30	8.43
ADF	46.24 ±0.85	42.53 ±0.51	3.71	8.72
HCEL	21.95 ±0.32	20.36 ±0.43	1.59	7.24
CEL	12.24 ±0.43	10.42 ±0.44	1.82	11.99
LIG	12.12 ±0.72	11.30 ±0.48	0.82	7.23
CP	9.50 ±4.19	11.09 ±1.07	1.59	1.59
OM	86.98 ±7.52	88.14 ±1.22	1.16	1.32
C2	39.94 ±0.84	42.46 ±0.83	2.52	5.94
IVDMD	55.52 ±0.75	51.33 ±0.43	4.19	8.17

Table 20 B . Effect of Rice bran enrichment on the nutrient composition of cashew apple waste after 30 days of fermentation (% Dry matter basis).

Nutrient	CAWRB	CAWRBPL	Difference	% Difference
NDF	63.74 ±0.56	57.57 ±1.04	6.17	9.68
ADF	43.05 ±0.55	29.28 ±0.72	13.77	31.99
HCEL	20.69 ±0.62	28.29 ±1.10	7.60	30.60
CEL	15.49 ±0.57	12.91 ±0.35	2.58	16.64
LIG	12.46 ±0.52	10.15 ±0.38	2.30	18.47
CP	8.08 ±0.49	12.98 ±0.97	4.90	4.90
OM	94.71 ±1.16	88.64 ±1.31	6.07	6.41
C2	41.68 ±0.84	38.28 ±0.53	3.40	8.16
IVDMD	48.69 ±0.89	52.35 ±0.61	3.66	7.52

CAW - Cashew apple waste

CAWPL - Cashew apple waste + *Pleurotus florida*

CAWRB - Cashew apple waste 75% +Rice bran 25%

CAWRBPL - Coir dust 75% +Rice bran 25% +*Pleurotus florida*

* Mean values of six analyses

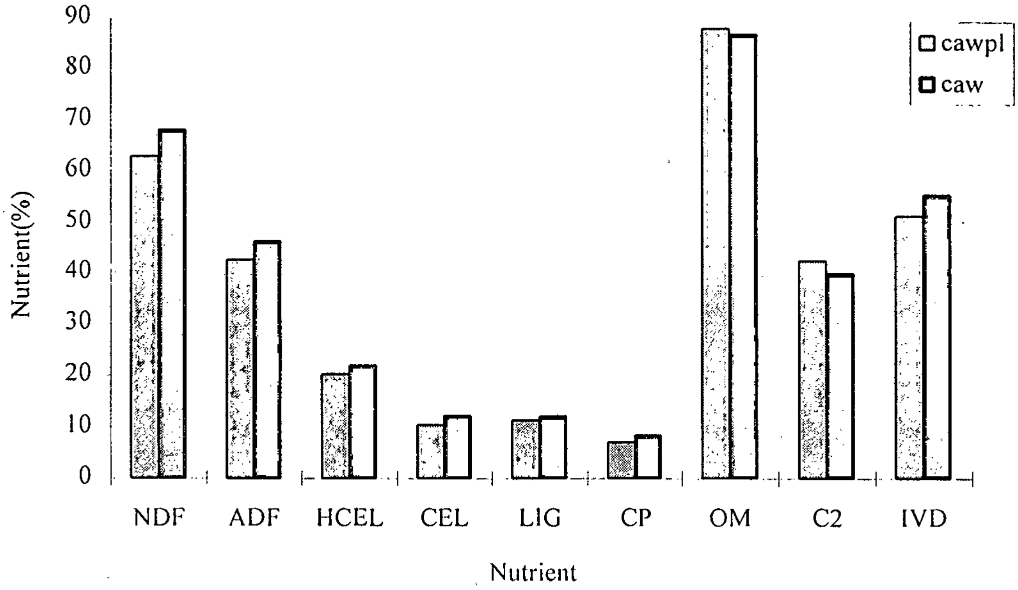


Fig 15 a: Effect of fermentation with *Pleurotus florida* on the nutrient content of cashew apple waste

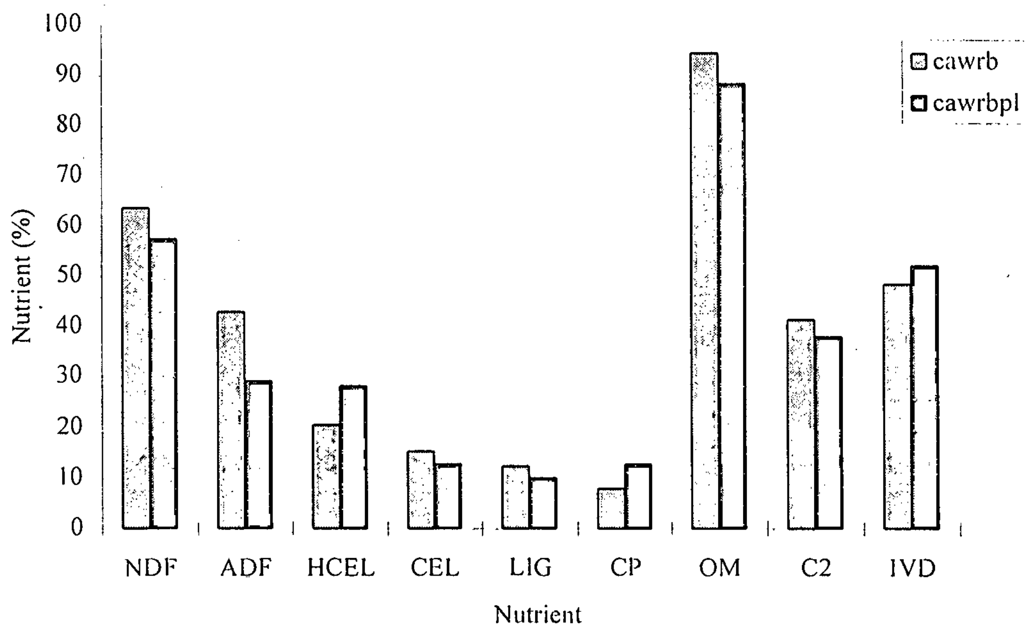


Fig 15 b: Effect of rice bran enrichment on the fermentation of cashew apple waste

Table 20 C. Effect of wheat bran enrichment on the nutrient composition of cashew apple waste after 30 days of fermentation (% Dry matter basis).

Nutrient	CAWWB	CAWWBPL	Difference	% Difference
NDF	58.48 ±1.02	56.82 ±1.12	1.66	2.84
ADF	35.31 ±0.91	31.50 ±0.85	3.81	10.79
HCEL	23.17 ±0.67	25.32 ±3.98	1.63	0.07
CEL	12.34 ±0.45	10.25 ±0.85	2.09	16.90
LIG	9.73 ±0.51	8.85 ±0.46	0.88	9.04
CP	12.31 ±0.96	14.15 ±0.33	1.84	1.84
OM	93.75 ±0.68	92.20 ±3.63	1.55	1.65
C2	41.29 ±0.57	37.66 ±0.52	3.63	8.78
IVDMD	52.80 ±0.68	57.04 ±0.25	4.24	8.03

Table 20 D. Effect of maize enrichment on the nutrient composition of cashew apple after 30 days of fermentation (% Dry matter basis)

Nutrient	CAWM	CAWMPL	Difference	% Difference
NDF	58.55 ±1.08	52.97 ±0.65	5.58	9.53
ADF	36.17 ±0.78	25.35 ±0.81	10.81	29.89
HCEL	22.38 ±0.72	27.62 ±0.97	5.24	23.41
CEL	8.60 ±0.53	7.35 ±0.66	1.25	14.53
LIG	9.62 ±0.71	7.69 ±0.49	1.94	20.11
CP	10.25 ±1.08	15.25 ±0.77	5.00	5.00
OM	94.20 ±0.65	86.25 ±0.69	7.95	8.44
C2	40.11 ±0.86	37.30 ±0.66	2.81	7.01
IVDMD	55.41 ±1.00	60.89 ±0.92	5.48	9.89

CAW - Cashew apple waste

CAWPL - Cashew apple waste + *Pleurotus florida*

CAWMPL - Cashew apple waste + Maize + *Pleurotus florida*

CAWM - Cashew apple waste 75% +Maize 25%

CAWWBPL - Coir dust 75% + Wheat bran 25% +*Pleurotus florida*

* Mean values of six analyses

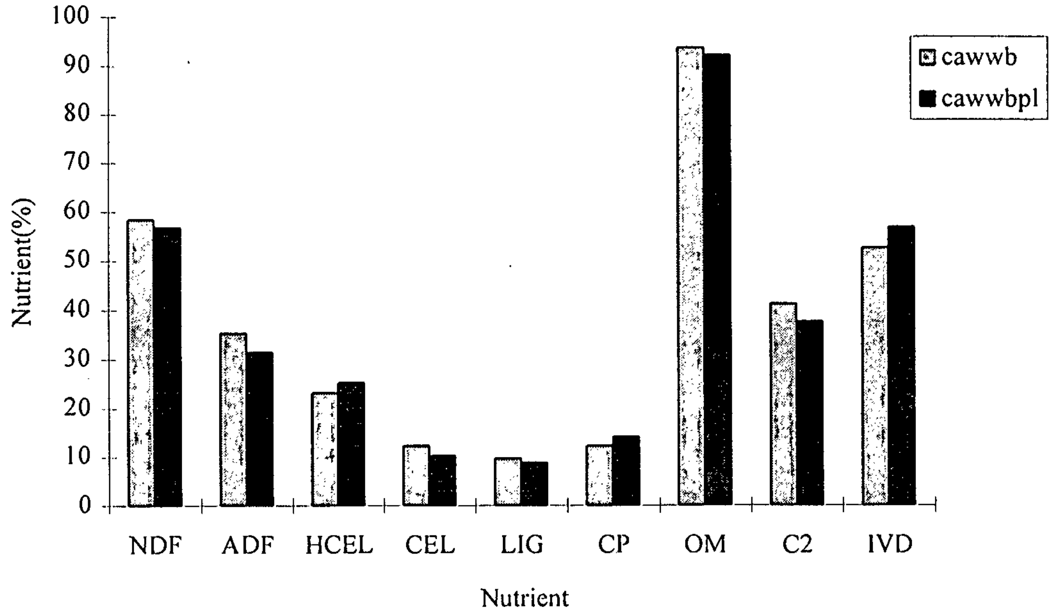


Fig 15 c: Effect of wheat bran enrichment on the fermentation of cashew apple waste

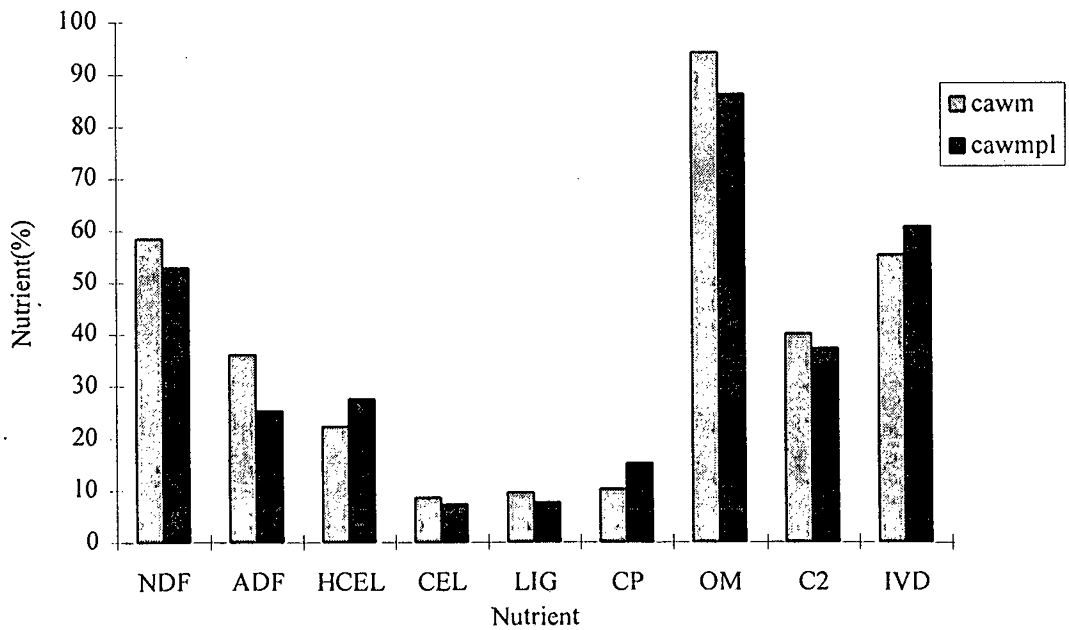


FIG 15 d: Effect of maize enrichment on the nutrient content of cashew apple waste after fermentation

Table 20 E . Comparative performance of added substrate on the biodegradation of cashew apple waste (percent nutrient degraded)

Nutrient	CAWPL	CAWRBPL	CAWWBPL	CAWMPL
NDF	8.43	9.68	2.84	9.53
ADF	8.72	31.99	10.79	29.89
HCEL	18.24	17.69	12.76	15.81
CEL	11.99	16.64	16.90	14.53
LIG	7.23	18.47	9.04	20.11
CP	19.86	60.58	14.98	48.80
OM	1.32	6.41	14.98	8.44
C2	5.94	8.16	8.78	7.01
IVDMD	8.17	7.52	8.03	9.89

CAWPL - Cashew apple waste + *Pleurotus florida*

CAWRBPL - Cashew apple waste 75% + Rice bran + *Pleurotus florida*

CAWWBPL - Cashew apple waste 75% + Wheat bran 25% + *Pleurotus florida*

CAWMPL - Cashew apple waste 75% + Maize 25% + *Pleurotus florida*

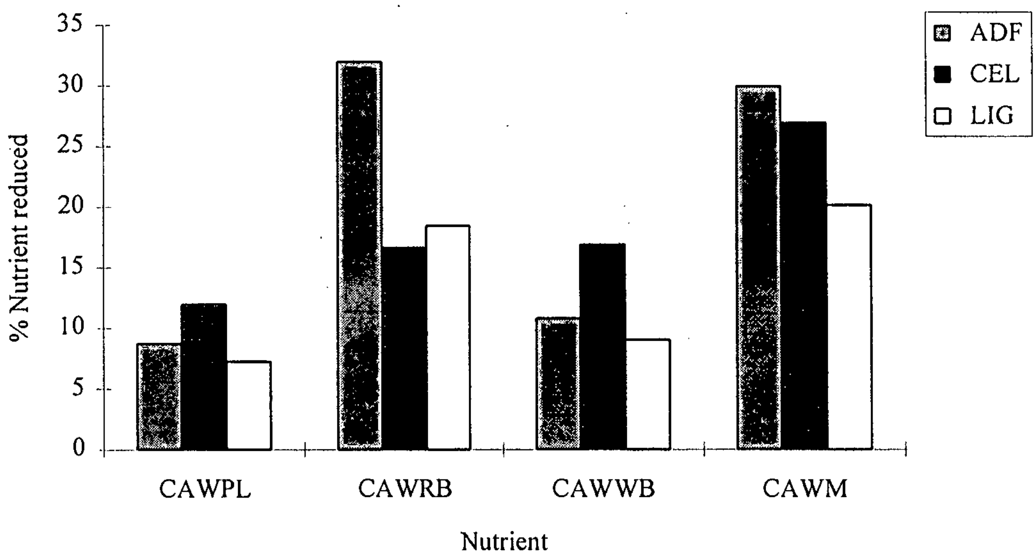


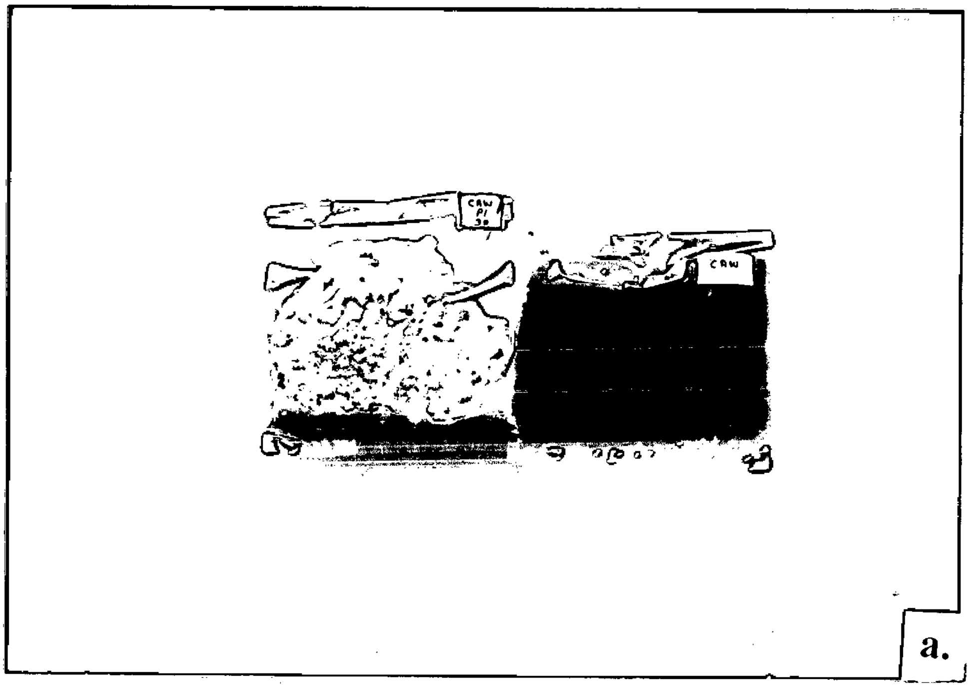
Fig 15 e: Comparative performance of added substrate on the structural carbohydrate reduction in cashew waste

PLATE - 13

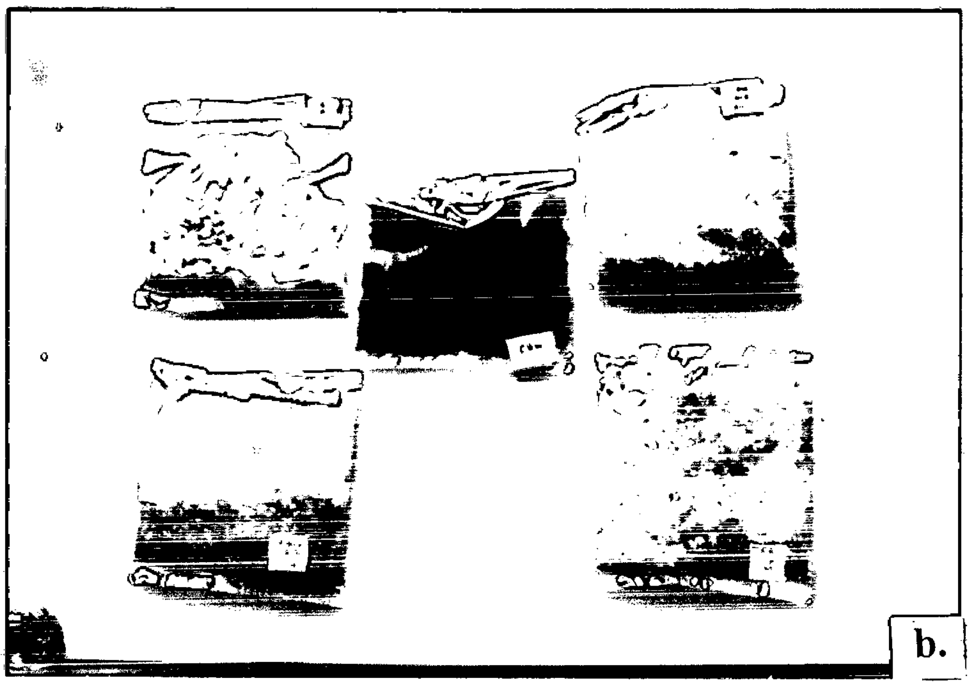
a. Cashew apple waste control and inoculated with *Pleurotus florida*.

b. Cashew apple waste control enriched with rice bran, wheat bran and inoculated with *Pleurotus florida*.

Plate - 13



a.



b.

Crude protien was enhanced to a maximum level in maize added substrate. It was increased from 10.25% to 15.25%. In the control, it was increased from 9.5% to 11.09% (Table 20D).

The *in vitro* digestibility of the fermented substrate was enhanced by 8.16% in control and 7.52% in rice bran added substrate. These observations indicate that addition of rice bran and maize have enhanced the process of degradation of lignocelluloses in cashew waste (Table 20E).

3.3. <u>Effect of enrichment on karad hay</u>.

The karad hay is highly lignocellulosic with 33.75% cellulose and 12% lignin. Although its digestibility is poor, it is used as substitute for paddy straw. Limited effort has been made to study the susceptibility of hay to substrate fermentation. Therefore, attempt was made to digest the complex structure using fungi in the present work. Effect of enrichment on biodegradation of the substrate after 30 days of fermentation was studied through analysis of the hay for nutrients(Pl. 14a)

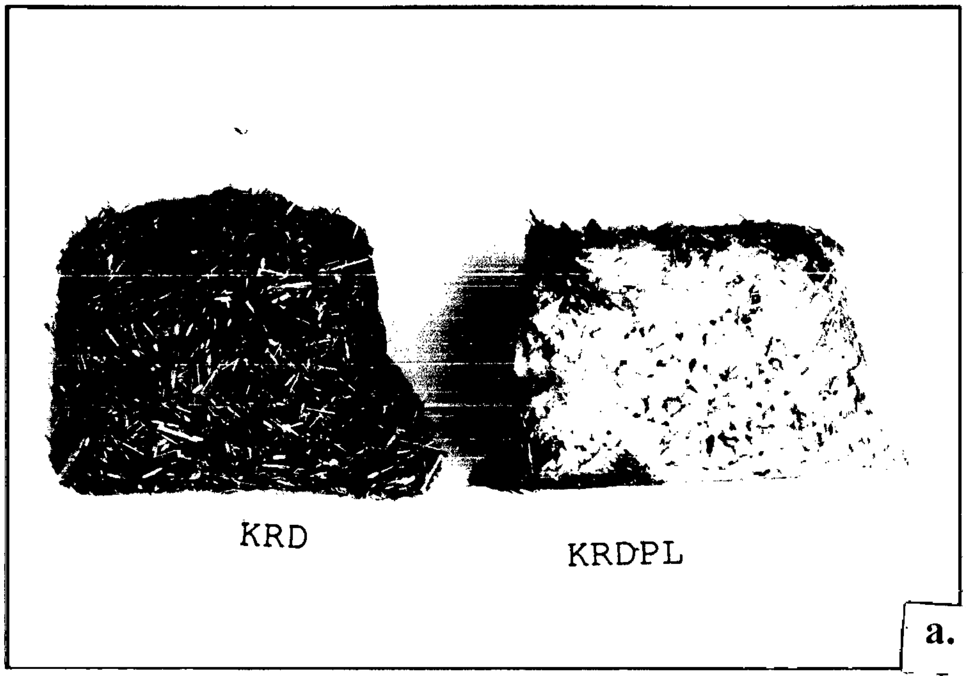
Of the four treatments, the substrate without enrichment, i.e. the control, has maximum reduction in ADF. The ADF was reduced from 42.69% to 26.17%, with an over all reduction of 38.71% (Table 21A). The percent reduction of ADF was lowest in wheat bran enriched samples (7.87%). In rice

PLATE - 14

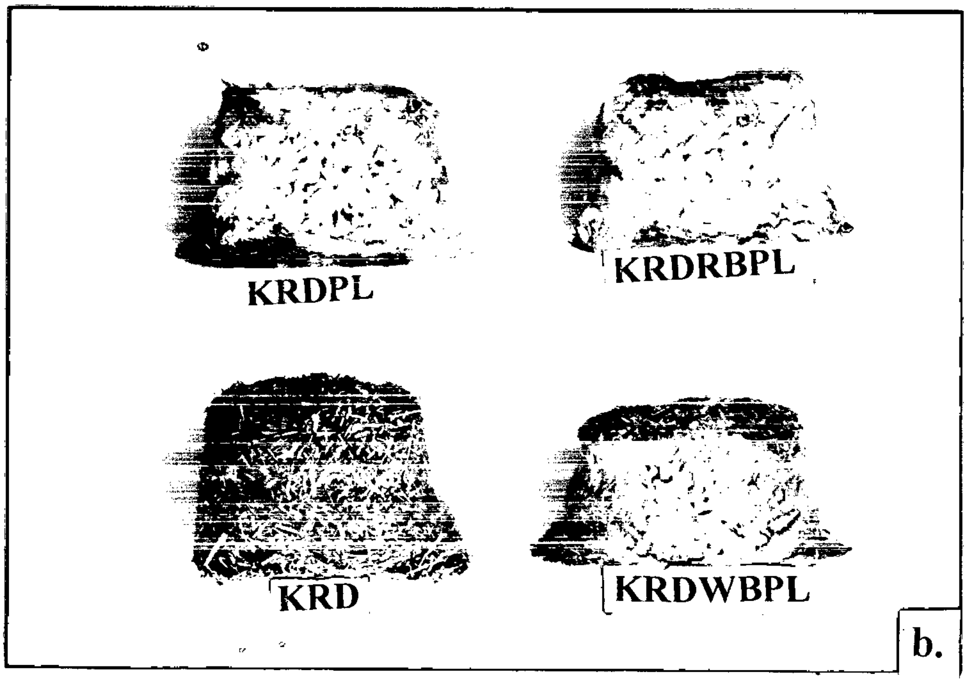
a. Karad hay control and inoculated with *Pleurotus florida*.

b. Karad hay control, enriched with rice bran, and wheat bran and inoculated with *Pleurotus florida*.

Plate - 14



a.



b.

bran and maize incorporated treatments the reduction was 21.27% and 13.67% respectively.

Lignin was degraded to the maximum extent of 29.29% in the rice bran enriched sample (Fig.16b). In maize enrichment only a minimum reduction of 7.46% was observed. In the control, however, substantially high reduction of 27.15% was observed. In wheat bran enriched sample it was only 13.9% (Table 21E).

Cellulose was degraded to the maximum extent of 27.65% in maize added substrate. With rice bran alone 22.09% reduction was observed in karad hay.

Table 21 A . Effect of fermentation with *Pleurotus florida* on the nutrient content of Karad hay (% Dry matter basis).

Nutrient	KRD	KRDPL	Difference	% Difference
NDF	66.08	56.55	9.52	14.41
ADF	42.69	26.17	16.53	38.71
HCEL	23.39	30.39	7.00	29.94
CEL	33.02	27.48	5.54	16.79
LIG	12.38	9.02	3.36	27.15
CP	3.75	6.25	2.50	66.58
OM	92.40	86.71	5.69	6.16
C2	42.63	39.22	3.42	8.01
IVDMD	39.65	48.49	8.85	22.32

Table 21 B . Effect of Rice bran enrichment on the nutrient composition of coir dust after 30 days of fermentation (% Dry matter basis).

Nutrient	KRDRB	KRDRBPL	Difference	% Difference
NDF	61.07	44.41	16.67	27.29
ADF	36.48	28.72	7.76	21.27
HCEL	24.59	15.69	8.91	36.22
CEL	32.87	25.61	7.26	22.09
LIG	13.18	9.32	3.86	29.29
CP	5.92	8.27	2.36	39.80
OM	92.50	85.60	6.90	7.46
C2	43.54	39.34	4.21	9.66
IVDMD	44.27	50.21	5.94	13.41

KRD - Karad hay

KRDPL - Karad hay + *Pleurotus florida*

KRDRB - Karad hay 75% +Rice bran 25%

KRDRBPL - Karad hay 75% + Rice bran 25% + *Pleurotus florida*

* Mean values of six analyses

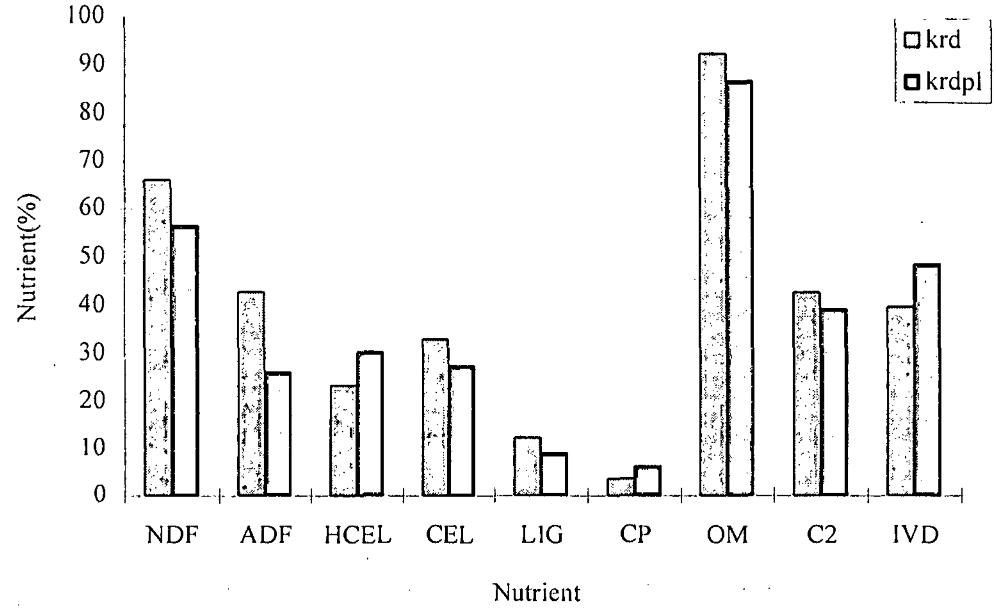


Fig 16 a: Effect of fermentation with *Pleurotus florida* on the nutrient content of karad hay

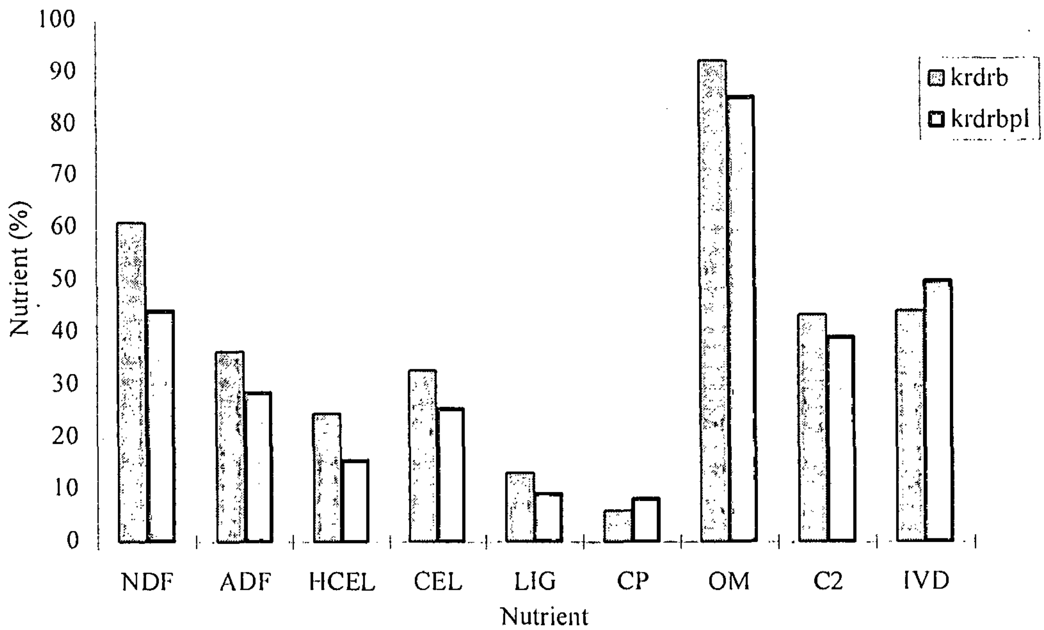


Fig 16 b: Effect of rice bran enrichment on the nutrient content of karad hay after fermentation

Table 21 C. Effect of wheat bran enrichment on the nutrient composition of karad hay after 30 days of fermentation (% Dry matter basis).

Nutrient	KRDWB	KRDWBPL	Difference	% Difference
NDF	48.33	34.68	13.65	28.25
ADF	27.47	25.31	2.16	7.87
HCEL	20.85	9.37	11.49	55.09
CEL	25.56	22.16	3.40	13.30
LIG	9.68	8.33	1.35	13.90
CP	8.42	10.21	1.79	1.79
OM	93.31	85.39	7.92	8.49
C2	43.23	38.06	5.17	11.96
IVDMD	51.17	52.56	1.39	2.72

Table 21 D. Effect of maize enrichment on the nutrient composition of karad hay after 30 days of fermentation (% Dry matter basis).

	KRDM	KRDMPL	Difference	% Difference
NDF	42.60	31.55	11.05	25.94
ADF	28.07	24.23	3.84	13.67
HCEL	14.54	7.32	7.21	49.63
CEL	24.08	17.42	6.66	27.65
LIG	10.65	9.86	0.79	7.46
CP	11.54	12.88	1.34	1.34
OM	93.51	84.94	8.57	9.16
C2	44.10	37.58	6.52	14.79
IVDMD	52.75	56.27	3.53	6.69

KRDWB - Karad hay 75% + Wheat bran 25%
KRDDWBPL - Karad hay 75% + Wheat bran 25% + *Pleurotus florida*
KRDM - Karad hay 75% + Maize 25%
KRDMPL - Karad hay 75% + Maize 25% + *Pleurotus florida*

* Mean values of six analyses

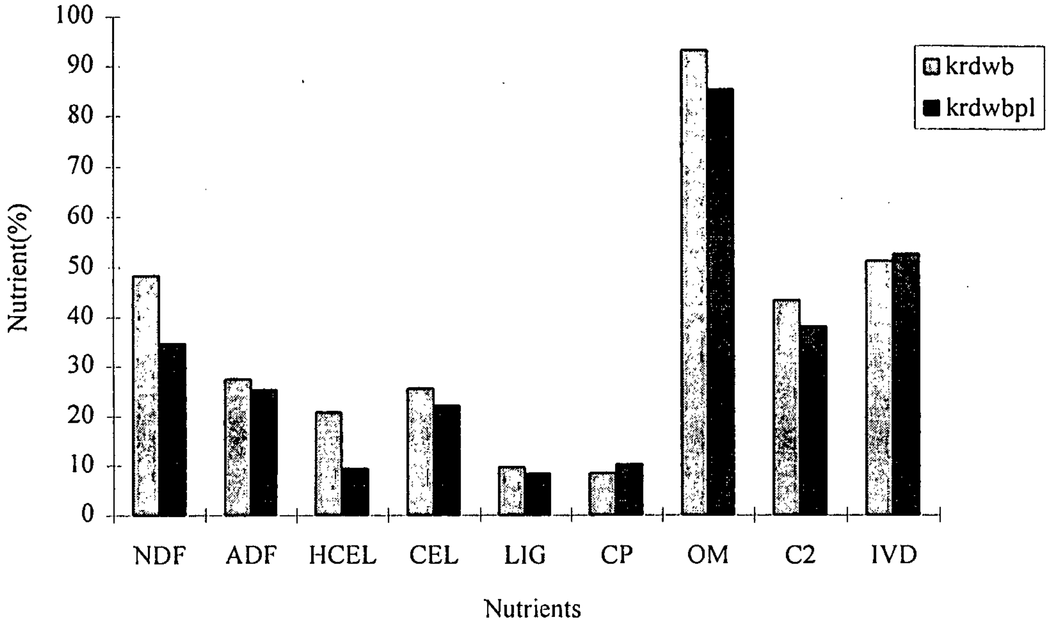


Fig 16 c: Effect of wheat bran enrichment on the fermentation of karad hay

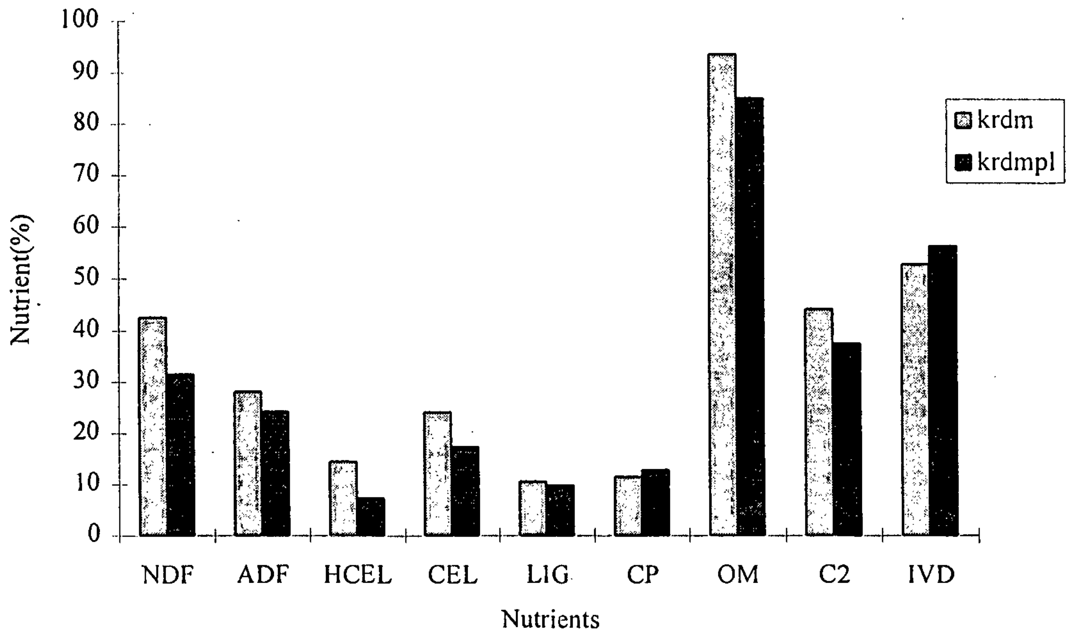


Fig 16 d: Effect of maize enrichment on the nutrient content of karad hay after fermentation

Table 21 E . Comparative performance of added substrate on the biodegradation of karad hay (Percent nutrient degraded).

Nutrient	KRDPL	KRDRBPL	KRDWBPL	KRDMPL
NDF	14.41	27.29	28.25	25.94
ADF	38.71	21.27	7.87	13.67
HCEL	29.94	36.22	55.09	49.63
CEL	16.79	22.09	13.30	27.65
LIG	27.15	29.29	13.90	7.46
CP	66.58	39.80	21.29	11.61
OM	6.16	7.46	8.49	9.16
C2	8.01	9.66	11.96	14.79
IVDMD	22.32	13.41	2.72	6.69

KRDPL - Karad hay + *Pleurotus florida*

KRDWB + - Karad hay 75% + Wheat bran 25% *Pleurotus florida*

KRDRB - Karad hay 75% +Rice bran 25% + *Pleurotus florida*

KRDM - Karad hay 75% + Maize 25% + *Pleurotus florida*

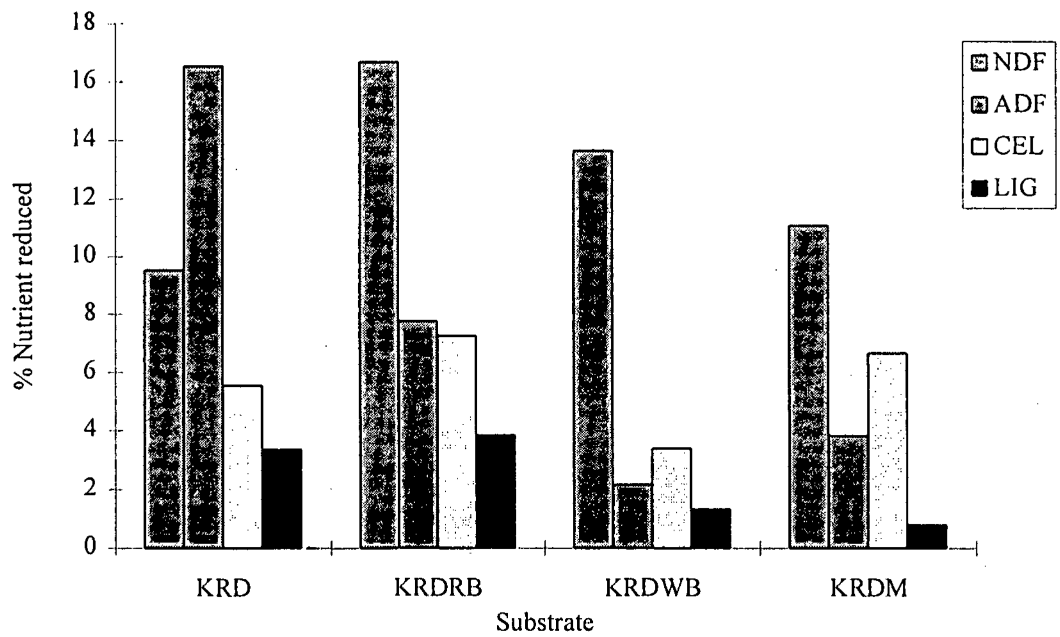


Fig 16 e: Comparative performance of added substrate on the structural carbohydrate reduction in karad hay.

PART IV

IV. Impact of solid-state fermentation on agro-by-products

4.1. Observation on physical and chemical nature of the by-products.

The three by-products used in this study widely differed in their physical nature. The dry coir dust although bulky in volume had low density and compactness. On soaking in water, coir dust became more compact. The dry and pulverised cashew apple waste was hard and gritty. On addition of water the cashew powder became sticky and compact. Dry karad hay was slender, light and fibrous material. On blending, the hay became coarse bits which absorbed sufficient moisture when soaked in water for 2-3 hr.

The coir dust has a high lignin content, i.e. 39.91%. Cashew apple waste contains 9.65% crude protein which is much higher than the other two substrates viz: coir dust (1.75%) and karad hay (3.75%). Karad hay is rich in cellulose, 33.75% when compared to the other two substrates. Growth of *Pleurotus florida* was monitored under identical conditions in all three substrates and evaluated through chemical analysis of the fermented by-product for a comparative study.

Growth of fungi on agro-by-products depends upon the nature of substrate used for solid-state fermentation. The physical texture, moisture content, temperature, pH and nitrogen availability in the substrate largely influence the growth of fungi and process of fermentation (Rai *et al.*, 1993).

4.2 Effect of duration of fermentation on by-products.

Pleurotus florida established well in all the three by-product substrates selected for the study. Reduction in the nutrient content was at a faster rate in the initial stage of fermentation, both in cashew apple waste and karad hay. In coir dust the process was slow upto 15th day as it can be seen from the Fig 19a-b. The percent degradation of ADF was lowest in cashew apple waste and maximum in karad hay on 30 days of fermentation (Table 23).

Loss in cellulose was maximum in cashew waste in the early days of fermentation when compared to the other two substrates. It was reduced by 22.02% in 30 days as against 28.66% on 90 days. Percent degradation of cellulose in coir dust and karad hay was almost comparable after 30 days of treatment as it can be observed from Fig 24. In karad hay the percent reduction of cellulose was 12.09% where as in coir dust it was 14.02%

Maximum reduction in lignin was observed, in karad hay, among the by-products used in this study (Fig. 18). The percent reduction in lignin was

Table 22 . **Effect of moisture level on structural carbohydrate degradation in coir dust and karad hay (% Nutrient reduced on Dry matter basis).**

Substrate	Nutrient	Moisture Level(%)					
		20	40	60	70	80	100
	ADF	0.78	1.98	5.47	5.77	9.72	6.00
CD	CELL	2.37	5.48	6.41	9.53	13.92	13.28
	LIG	1.97	3.78	7.94	14.45	15.20	7.46
	ADF	0.36	3.70	4.79	9.82	9.56	3.75
KRD	CELL	3.35	3.89	7.18	10.46	8.96	4.71
	LIG	2.63	4.77	5.80	6.63	3.82	2.30

Table 23 . Effect of moisture level on the structural carbohydrate of cashew apple waste after 30 day fermentation with *Pleurotus florida*:(% Nutrient reduced on dry matter basis).

Nutrient	20	30	40	50	60
ADF	0.45	1.96	4.27	5.78	2.37
CEL	5.13	5.62	16.62	22.49	20.29
LIG	0.28	5.28	7.35	12.64	11.03

Table 24 . Effect of duration of fermentation length on the structural carbohydrate of by-products (Percent nutrient reduced on dry matter basis).

Nutrient	Substrate	Duration in Days			
		15	30	60	90
ADF	CD	6.94	10.27	11.07	12.95
	CAW	0.50	2.66	3.91	5.61
	KRD	12.25	23.17	29.11	32.16
CEL	CD	12.10	14.02	16.44	17.19
	CAW	15.06	22.02	26.88	28.66
	KRD	7.20	12.09	16.62	18.43
LIG	CD	11.25	18.24	21.12	23.20
	CAW	2.33	6.28	12.71	23.49
	KRD	12.31	22.37	25.72	33.38

higher at 30 days in coir dust and karad where as in cashew apple waste lignin was degraded to the maximum extent only after 90 days of fermentation.The steady increase in percent reduction of lignin and an increase in ADF in the early stage of fermentation in cashew apple waste can be seen from Fig. 17a. In contrast to this, decrease in percent loss of cellulose was seen from 30 days to 90 days of fermentation. Comparative status of loss of the two nutrients is presented in Fig. 17b. These observations indicate that in cashew apple waste the reduction in cellulose was higher in the early stage of fermentation and lignin was degraded more in the latter stages (Fig. 17c) where as in coir dust, percent reduction of ADF and cellulose was lower in the initial stage of fermentation when compared to lignin.

Kishan singh *et al.* (1988) reported the difference in the degradation of structural components between wheat straw and paddy straw when treated with *Coprinus fimetarius* and indicated that the difference was due to the nature of substrate. In the present study also variation in reduction of structural components can attributed to the nature of the by-products.

The crude protein content was increased to the maximum in coir dust i.e from 1.75% to 5.65% where as in cashew apple waste it was increased from 9.65% to 12.35% only.

Fig 17 a.

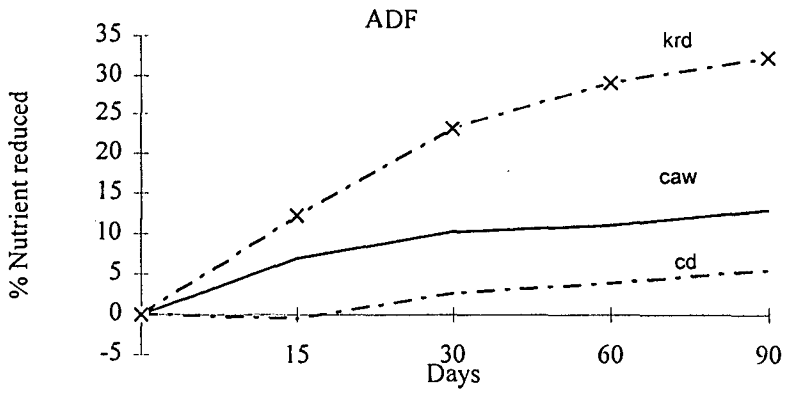


Fig 17 b.

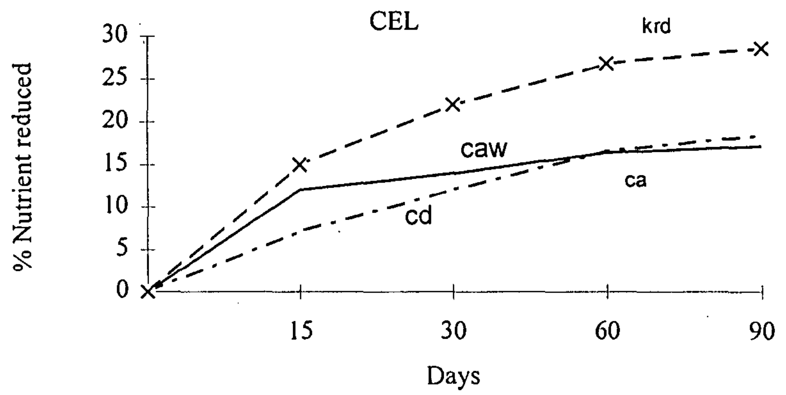


Fig 17 c.

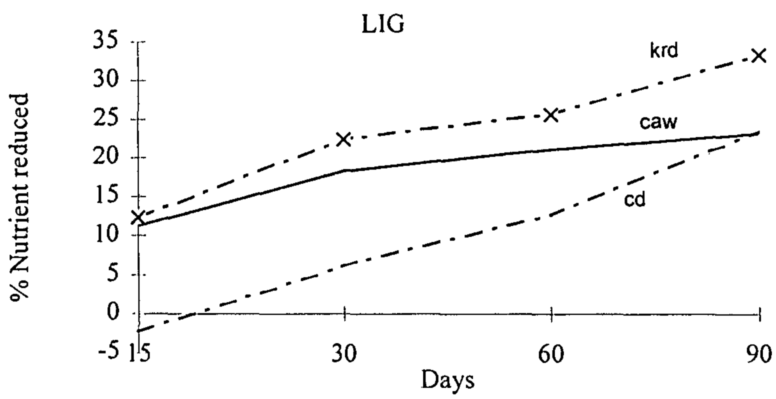


Fig 17 : Percent reduction of nutrient at different duration of fermentation with Pleurotus florida

cd - Coir dust

caw -Cashew apple waste

ADF -Acid detergent fibre

CEL -Cellulose

4.3. Effect of substrate enrichment on by-product.

When the by-products were fermented without enrichment, the percent reduction in structural carbohydrate was lower in coir dust and cashew apple waste (Fig. 18). Among all the substrates appreciable amount of reduction in ADF, cellulose and lignin was observed in karad hay. Minimum loss of structural components was observed in cashew apple waste in which the loss of cellulose was more when compared to the other two nutrients viz lignin and ADF (Table 25).

When the substrate was enriched with rice bran, maximum amount of lignin degradation was observed in coir dust as compared to karad hay and cashew waste. Both cellulose and lignin were reduced to a considerable amount with rice bran enrichment in all the by-products especially in coir dust (Fig. 19). Lignin was reduced by 33.21% in coir dust as compared to 18.47% in cashew apple waste (Table 25).

In wheat bran enrichment the loss of lignin and cellulose was almost similar to coir dust and karad hay (Fig. 20). However, in cashew apple waste loss of cellulose was more prominent. On an overall assessment, effect of wheat bran enrichment on structural carbohydrates under solid state fermentation was less prominent when compared to the other treatments in the study.

Table 25 . Effect of added substrate on the structural carbohydrate of by-products (% Nutrient reduced on dry matter basis).

Treatment	Nutrient	CD	CAW	KRD
PL	ADF	10.09	8.72	38.70
	CEL	16.30	11.99	16.78
	LIG	18.24	7.23	27.15
RB	ADF	23.64	31.99	21.27
	CEL	8.66	16.64	22.08
	LIG	33.21	18.47	29.28
WB	ADF	13.73	10.79	7.87
	CEL	15.19	16.90	13.29
	LIG	13.97	9.04	13.89
M	ADF	5.52	29.89	13.66
	CEL	5.28	26.90	27.65
	LIG	19.49	20.11	7.45

PL - Pleurotus florida
RB - Rice bran
LIG - Lignin
WB - Wheat bran
M - Maize
ADF - Acid detergent fibre
CEL - Cellulose

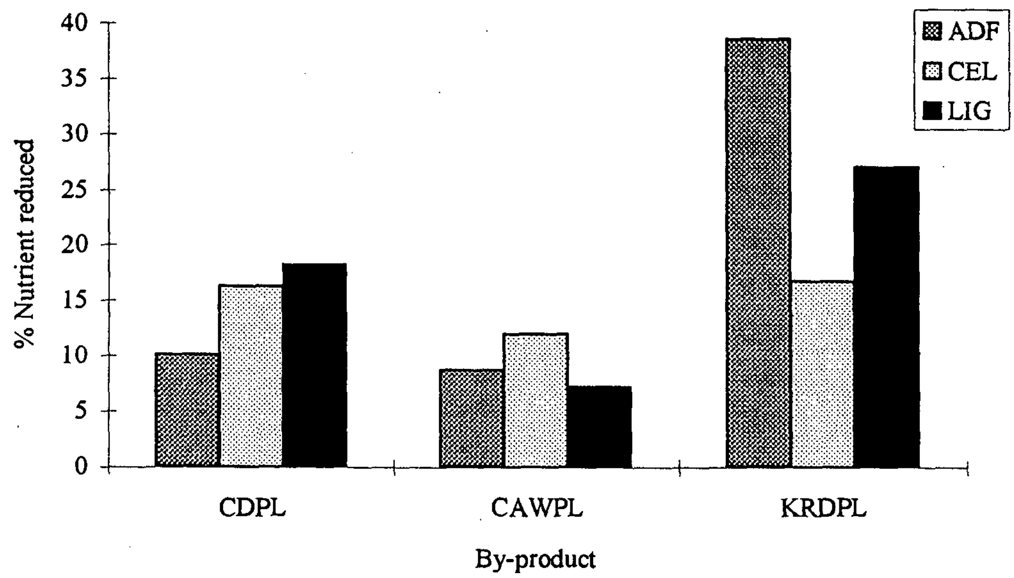


Fig 18 : Effect of fermentation by Pleurotus on the nutrient content of by-product without enrichments

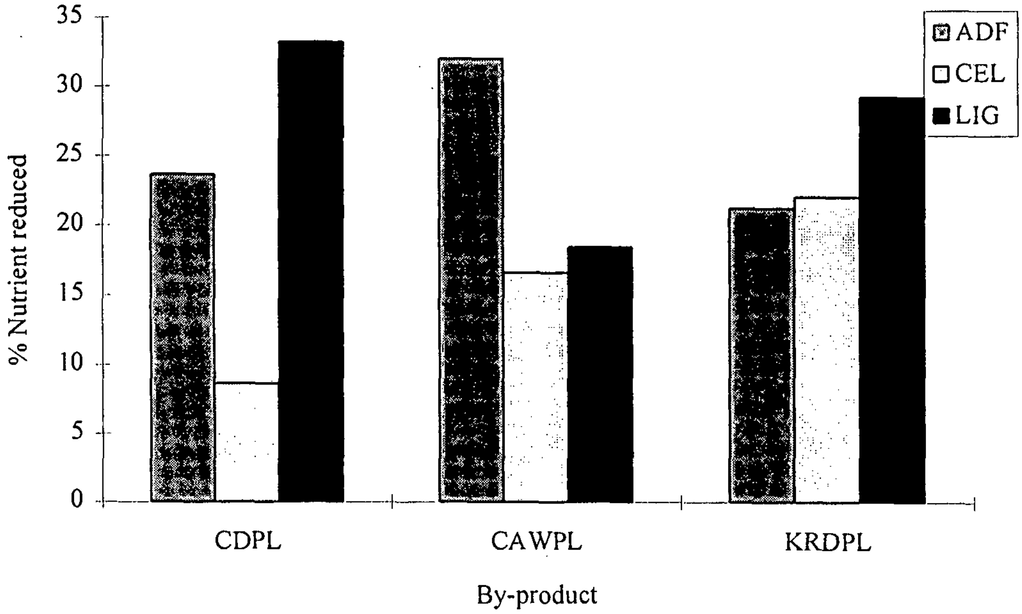


Fig 19: Effect of rice bran enrichment on the structural carbohydrates of by-products after fermentation

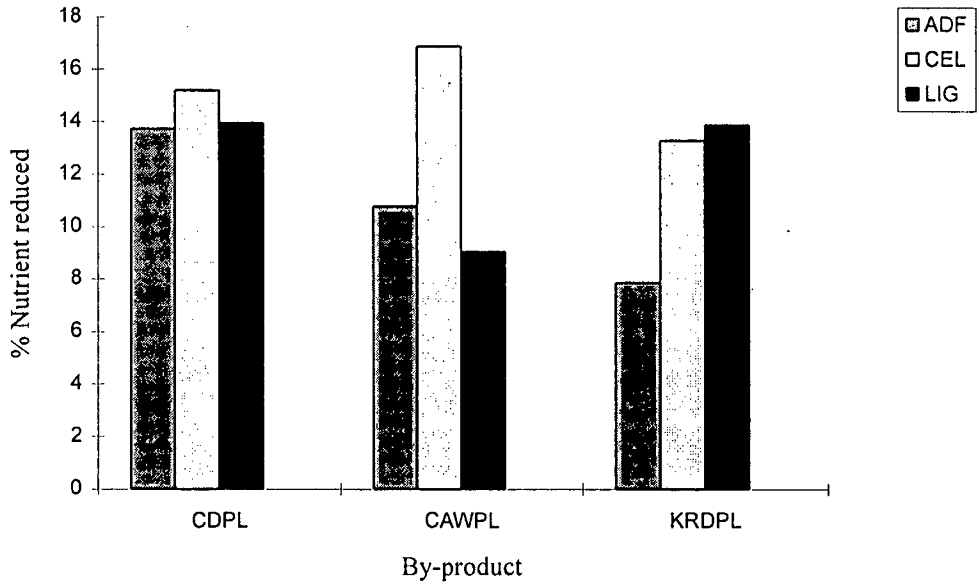


Fig 20: Effect of wheat bran enrichment on the structural carbohydrate components of by-products after fermentation

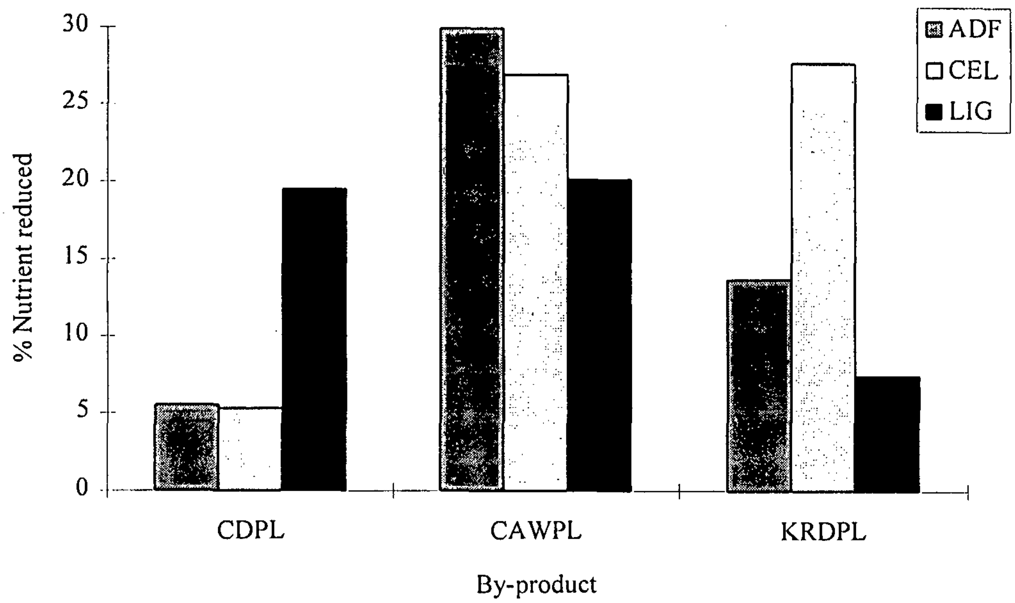


Fig 21: Effect of maize enrichment on the structural carbohydrate components of the by-products after fermentation

In maize enrichment study, all the three structural components were reduced in cashew apple waste (Fig. 21). Since maize starch is a source of easily available energy, probably the fungus had used this carbohydrate for its growth and production of favourable enzymes on the substrate. Considering the previous discussion at 4.2 in which it was observed that the reduction in structural carbohydrate was minimum due to the utilisation of soluble carbohydrates during early stages of fermentation, it is possible that *Pleurotus florida* established well in cashew apple waste in the presence of a ready source of starch.

4.4. ***In vitro* dry matter digestibility(IVDMD):**

The IVDMD estimated after 96 hr of digestion is presented in Table 27. The digestibility of coir dust was 38.76% in control where as it was 47.34% in fermented coir dust with an increase of 8.58% in digestibility. In fermented cashew apple waste and karad hay the increase was 4.19% and 8.85% respectively. The crude protein content was increased by 4.7% in coir dust (Table 26). In cashew apple waste and karad hay the increase was 2.7% and 3.5% due to fermentation of the substrate.

Table 26 . Effect of fermentation on in vitro drymatter digestibility and crude protein content of substrates (% increase on dry matter basis).

Nutrient	By-product	Control	PI treated	Difference
IVDMD	CD	37.82	46.65	8.83
	CAW	45.96	52.45	6.49
	KRD	41.57	48.92	7.35
CP	CD	1.75	6.45	4.70
	CAW	9.65	10.75	1.10
	KRD	3.75	7.25	3.50

CD - Coir dust
CAW - Cashew apple waste
KRD - Karad hay

IVDMD - in vitro dry matter digestibility
CP - Crude protein

Plate - 15

There was no significant improvement in the digestibility of enriched coir dust and cashew apple waste with any of the added substrate as it can be seen from the Table 27. These results clearly indicate the poor digestibility response of the substrate to enrichment under laboratory conditions.

Part V

V. Evaluation of feed quality, digestibility and animal performance by feeding trials

5. Feeding trials and animal performance:

Weaner rabbits of Chinchilla variety were used in the quality and digestibility studies of feed rations. Diets were formulatedand prepared with conventional feed ingredients and also with experimental feed substitutes. The agro-by-products, supposed to be evaluated for feed quality were incorporated in the ration at graded levels of 0, 10, 20 and 25% . The ingredient composition of experimental and control diet is presented in Table 1 to 3. All the rations formulated for the evaluation were analyzed for proximate principles and energy content before being fed to the animal.

5.1. Feeding trial with coir dust.

The chemical composition of the ration formulated with coir dust is presented in Table 28. The acid detergent fibre (ADF) content of the control feed was 12.70% whereas it was 11.75, 13.27 and 13.94% for 10, 20 and 25% coir dust feed. The crude protein (CP) content was 16.75% for control and 15.50% for 25% coir dust feed. The digestible energy (DE) content of the control feed was 2725 Kcal/Kg and for 25% coir dust feed it was 2575 Kcal/Kg. Fekete

Table 28 . Chemical composition of feeds with different levels of coir dust (% Dry matter basis).

	Control	CDC10	CDC20	CDC25
ADF	12.70	11.75	13.27	13.94
NDF	23.63	20.08	29.16	31.47
LIG	7.98	9.14	10.06	12.37
CELL	18.74	12.15	13.16	15.36
CP	16.75	16.15	16.04	15.50
DE(Kcal/kg)	2725	2665	2605	2575

(1985) recommended a minimum DE of 2500 Kcal/Kg feed. It may be concluded that the by-product added in the feed upto 25% level has provided the minimum energy and protein requirement.

5.1.1. As can be seen in Table 29, the average drymatter intake/day/animal was 89.26g and 90.90g for control and 25% coir dust incorporated feed. Feed consumption/Kg body weight was 51g and 44.8g for control and 25% coir dust feed. The dry matter digestibility was highest with control feed (77.42%) as against 69.50%, 63.75% and 61.48%, for the experimental rations with 10, 20 and 25 percent coir dust added rations (Fig.22a). The ADF digestibility was 12.83% and 24.56% for control and 25% coir dust diet.

Higher lignin content in the coir dust incorporated feed could be the possible reason for low digestibility value. The negative correlation between lignin content of feed and dry matter digestibility has been reported by several workers (Seoane, 1982; Minson, 1982; Givens and Moss, 1995). However, in the present work, it can be seen, that the percent digestibility of ADF was increasing as the proportion of coir dust incorporation was increased (Table 29; Fig. 22b). Probably, as the source of easily available carbohydrate is limited, the fibre utilisation was more. Similar observations were reported by Cheeke (1987).

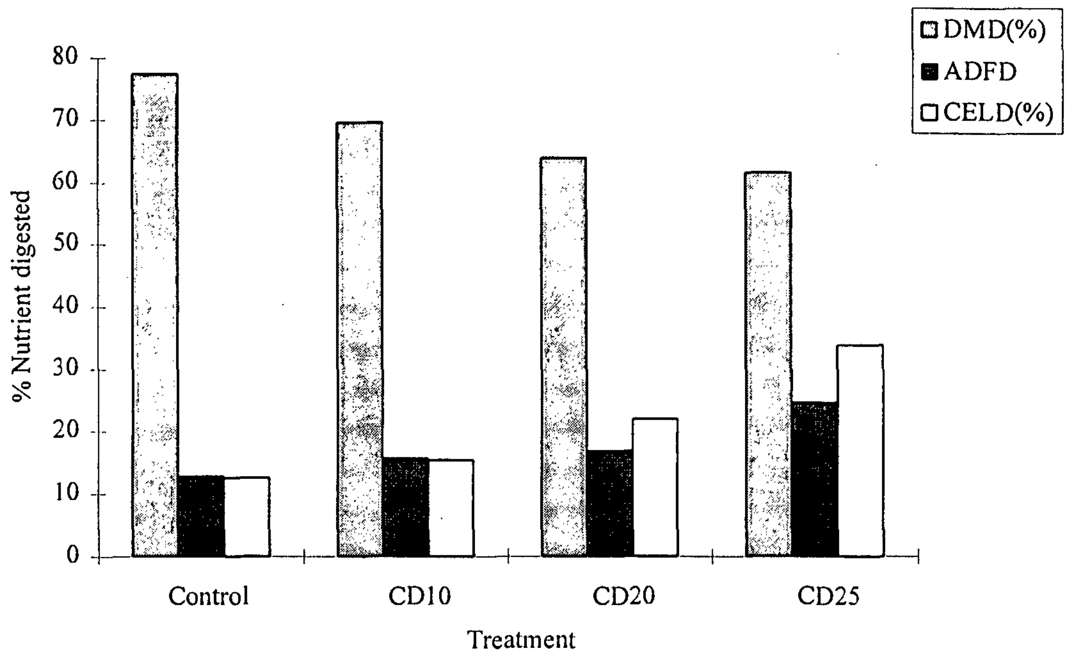


Fig 22 a: Dry matter and nutrient digestibility in coir dust feed

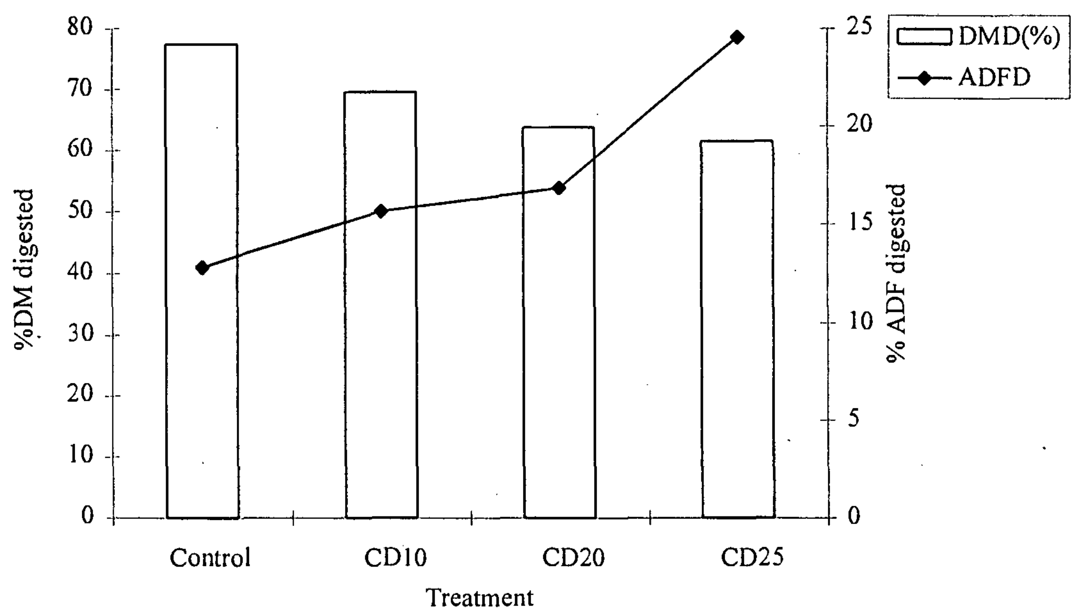


Fig 22 b: Comparison of DMD and ADFD with coir dust feeds

The relationship between dry matter digestibility and ADF and lignin content of feed is presented in Table 45. Negative correlation between the fibre components of feed and digestibility has been reported by several workers. (Grobner *et al.*, 1983; Ayers *et al.*,1996), as observed in the present study.

The digestibility of cellulose was increasing as the percent composition of coir dust was increased in the feed (Table 29). In the control, digestibility of cellulose was 12.58% where as the same was 33.86% for 25% coir dust feed. The average daily body weight gain was 16.25g and 12.75g for control and 25% coir dust diets.

5.1.2. Coir dust treated with *Pleurotus florida* was incorporated to the feed mixture at varying levels ranging from 0 to 25% replacing wheat bran proportionstely (Table 1). Chemical composition of the control and experimental diets are presented in Table 30. From the table it can be observed that the control feed has16.75% crude protein as against 16.5% in the experimental diet with 25% fermented coir dust (CDPL). The digestible energy (DE) content of the control diet was 2725 Kcal/Kg where as that of 25% CDPL experimental diet was 2600 Kcal/Kg feed. The drymatter intake per kg body weight was 54.09g for control and 39.3g, 38.4g and 43.7g for 10%, 20% and 25% diet respectively (Table 31). The dry matter digestibility of control diet was 77.42% where as it

Table 30 . Chemical composition of experimental feed with varying levels of fermented coir dust in the ration (%Dry matter basis).

Nutrient	Control	CDPL10	CDPL20	CDPL25
NDF	23.63	12.16	17.32	18.44
ADF	12.70	8.21	10.97	11.44
LIG	7.98	3.52	4.47	4.16
CELL	18.74	9.60	10.73	13.60
CP	16.75	17.12	16.10	16.50
DE(Kcal/kg)	2725	2675	2625	2600

Table 31 . Dry matter intake and digestibility of feed at different levels of fermented coir dust in rabbit diet.*

	Control	CDPL10	CDPL10	CDPL25
DMI(g/day)	89.26	85.32	76.83	80.49
DOP(g/day)	20.15	22.16	22.53	24.74
DDM(g/day)	69.11	63.16	54.30	55.75
DMD(%)	77.42	74.02	70.45	69.26
BWT(Kg)	1.65	2.17	2.02	1.85
DMKG(g)	54.09	39.30	38.40	43.70
ADFD(%)	12.83	16.00	19.72	52.00
CELD(%)	17.65	22.08	28.45	42.26
ADG(g)	16.05	15.86	13.75	14.20

CDPL - Coir dust fermented with *pleurotus florida*

* Mean value of four animals

was 74.02, 70.45 and 69.26% for the three levels of CDPL i.e. 10, 20 and 25 percent

These results indicate that the digestibility was more when the by-product was incorporated at a lower concentration (Fig. 23a). Since the conventional feed ingredients are rich in easily assimilable nutrients and the by-products are generally highly lignocellulosic the results obtained should be viewed in terms of improvement in its utility. As recorded in the present study, Sastry and Mahajan (1981) observed and reported a low dry matter intake and daily weight gain when high fibre diet was fed to Newzealand white rabbit. In the present feeding trial, incorporation of CDPL has increased the fibre level over the control feed as it can be seen from Table 30 with proportionate decrease in drymatter digetibility.

The acid detergent fibre digestibility was 12.83% for control and 16%, 19.72% and 52% for 10, 20 and 25 percent CDPL diets (Table 31). Fig. 23b shows an increase in ADF digestibility with corresponding increase of acid detergent fibre in the feed.Further it can also be observed from the fig. 23b that an increase in ADF digestibility with corresponding decrease in drymatter digestibility.The drymatter Sawal *et al.* (1995) reported an increase in ADF digestibility in feeds with higher ADF % in rabbits with apple pomace. The

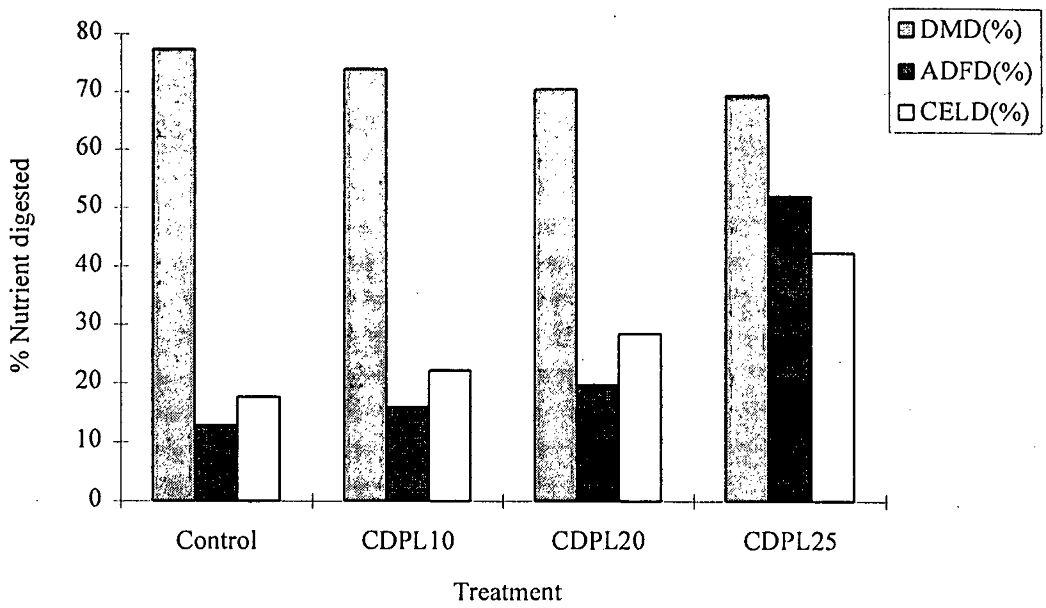


Fig 23 a: Dry matter and nutrient digestibility in coir dust feed.

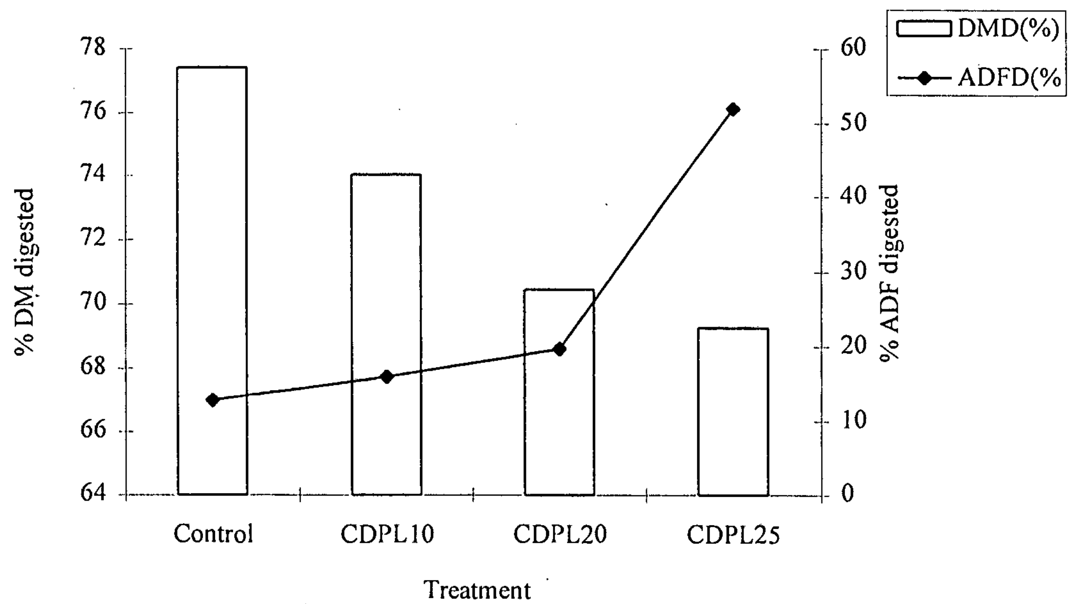


Fig 23 b: Comparison of DMD and ADFD with coir dust feeds

cellulose digestibility also increased with increase in cellulose content of the feed. Similar observation has been reported by Minson (1982).

During the trial period, the average daily weight gain was 16.05% for control group and 14.20g, 13.75g and 15.86g for 25, 20 and 10 percent CDPL diet. Although there was marginal raise in average daily weight gain in the control group, the difference between control and 10% CDPL diet was not significant (Table 31).

The coir dust which is commonly used as fuel or moisture retainer has been converted here into an useful animal feed. The by-product was used only as replacement of conventional feed ingredient by parts in order to reduce the maintenance cost. In an exercise such as this, only the associative effect of feed needs to be considered.

The dry matter digestibility of coir dust has been increased due to fungal treatment. This can be seen from the digestibility percentage of the two experimental diets viz: 25% CD and 25% CDPL diets (Table 40). The daily drymatter intake of 25% CD was 44.8g/kg body weight where as for 25% CDPL diet it was 43.7g only. The digestibility of 25% CD and 25% CDPL was 61.48% and 69.26% rcspectively. There was also an increase in the ADF digestibility in the fermented coir dust diet. The ADF digestibility of coir dust feed at 25% CD was 24.56% were as that of 25% CDPL diet was 52.00%. This can be related to the loss of lignin in the fermented coir dust.

According to Minson (1982), the lignin content of the feed is negatively correlated with intake and digetibility. In the present study, the drymatter digestibility of the fermented feed was higher than the control coir dust feed at all the levels of replacement. In coir dust, the digestibility of feed increased from 61.48 to 69.26% due to *Pleurotus florida* treatment. These observation indicates that the fermented coir dust can be safely added at 10% level to the diet of rabbits.

5.2. <u>Feeding trial with cashew apple waste.</u>

5.2.1. Chemical composition of the the experimental diets with cashew apple waste (CAW) is presented in Table 32. The results of feeding trial are presented in Table 33. Average daily drymatter intake/kg body weight was 64.68g, 58.72g and 56.46g for 10, 20 and 25% CAW feed as against 60.9g for the control diet indicating that the dry matter intake was significantly lower in 25% cashew apple waste feed. The drymatter digestibility of the control diet was 80.49% where as that of 25% CAW was only 71.84%. Daily weight gain of the control group was 16.58g whereas that from the 25% CAW experimental diet was 14.95g. Weight gain with 10% and 20% CAW diet was 15.73g and 15.3g

Table 32 . Chemical composition of cashew apple waste incorporated feed (% Dry matter basis).

Nutrient	CAW10%	CAW20%	CAW25%
ADF	10.95	11.83	12.54
NDF	58.18	60.36	63.42
LIG	3.18	4.92	5.16
CEL	11.36	13.11	14.20
CP	17.50	17.70	17.75
DE	2675	2650	2650

Table 33 . Effect of cashew apple waste incorporated diet on digestibility of nutrients , feed intake and growth in rabbit.*

	Control	CAW10	CAW20	CAW25
DMI(g/day)	100.50	113.21	105.71	90.35
DOP(g/day)	19.60	30.12	28.50	25.44
DDM(g/day)	80.90	83.08	77.21	64.91
DMD(%)	80.49	73.39	73.04	71.84
BWT(Kg)	1.65	1.70	1.80	1.60
DMKG(g)	60.90	64.68	58.72	56.46
ADFD(%)	12.75	22.19	23.64	24.02
CELD(%)	16.43	34.41	37.34	41.59
ADG(g)	16.58	15.73	15.30	14.95

* Mean value of four animals

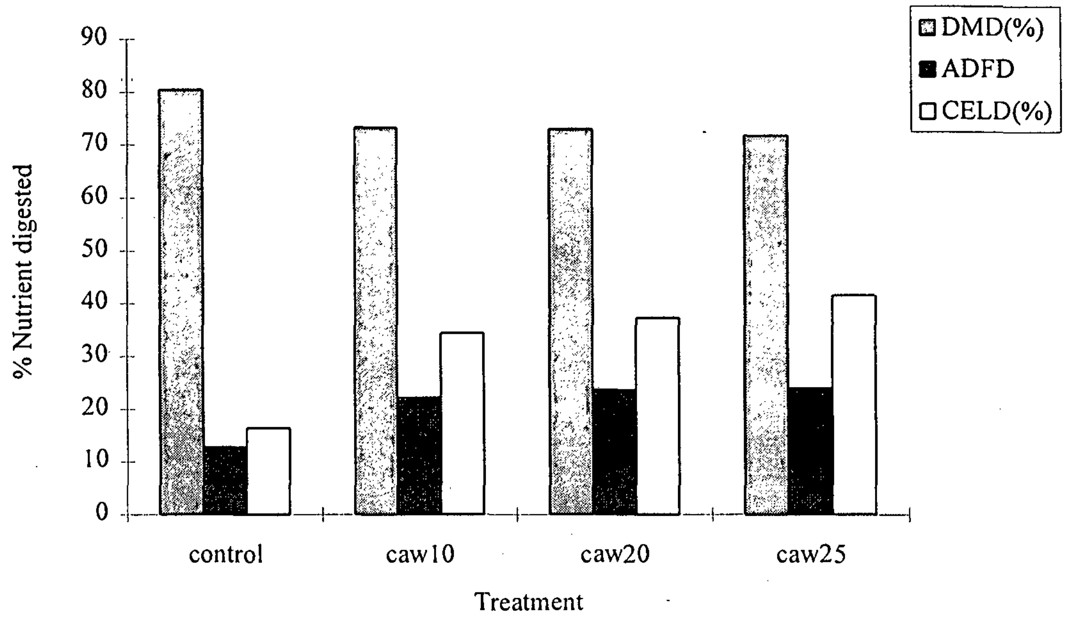


Fig 24 a: Comparative digestion of sructural carbohydrates ofration with CAW at different levels.

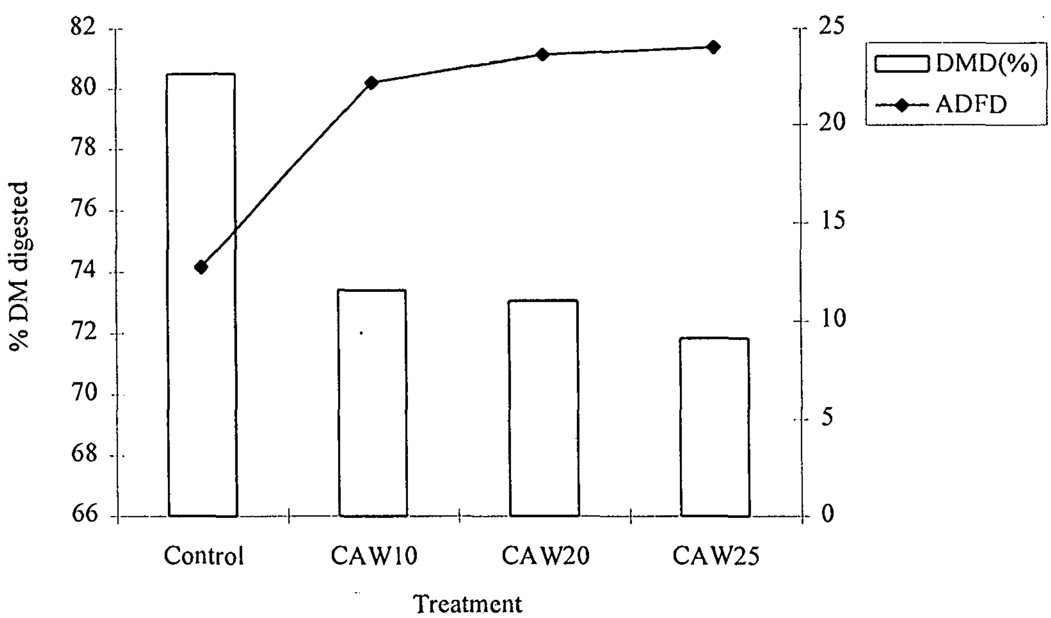


Fig 24 b: Comparartive digetibility of ADF and DMD(%) in cashew apple wast added diet in rabbit

respectively. ADF and cellulose digestibility was marginally higher with 25% CAW diet than in 10% CAW diet (Fig. 24a).

5.2.2. Drymatter digestibility of *Pleurotus florida* treated 25% cashew waste feed (CAWPL), was 77.44% (Table 35) where as that of control, 10% and 20% CAWPL feed was 82.74%, 79.41% and 76.93% respectively (Fig. 25a). Daily average feed intake of 25% CAWPL feed was 55.93g which is lower than control ration i.e. 62.73g. The minimum ADF digestibility of 27.82% was observed in the control group and the maximum digestibility of 37.69% observed in the fermented byproduct added ration, at 25% CAWPL. There was also a considerable amount of increase in cellulose digestibility. Digestibility of cellulose was 44.02% in the experimental CAWPL 25% diet than control feed (Table 35). The average daily weight gain was almost at par in the control and the other three treatments.

Since the conventional feed ingredients have been included in the ration of control feed, its digestibility was higher when compared with the other experimental feed formula. However the feed utilistation was more advantageous if a minimum fibre level is provided in the ration. Similarly De Blas *et al.* (1986) had described the role of fibre in rabbit diet for improving digestibility.

Table 34 . Chemical composition of fermented cashew apple waste incorporated feed (% Dry matter basis).

Nutrient	CAWPL10	CAWPL20	CAWPL25
NDF	60.41	64.32	66.83
ADF	9.76	12.81	13.30
CEL	6.93	11.12	12.50
LIG	3.16	3.55	3.84
CP	17.85	18.00	18.10
DE(Kcal/kg)	2650	2625	2625

CAWPL - Cashew apple waste fermented with *pleurotus florida.*

Table 35 . Effect of fermented cashew apple waste incorporated diet on digestibility of nutrients , feed intake and growth in rabbit.*

	Control	CAWPL10	CAWPL20	CAWPL25
DMI(g/day)	106.82	112.28	98.32	95.09
DOP(g/day)	18.48	23.11	22.68	21.45
DDM(g/day)	88.34	89.16	75.63	73.63
DMD(%)	82.74	79.41	76.93	77.44
BWT(Kg)	1.70	1.65	1.62	1.70
DMKG(g)	62.73	68.04	60.69	55.93
ADFD(%)	27.82	29.29	34.50	37.69
CELD(%)	37.45	28.70	42.70	44.02
ADG(g)	16.15	16.64	15.82	15.33

CAWPL - Cashew apple waste fermented with *pleurotus florida.*

* Mean value of four animals

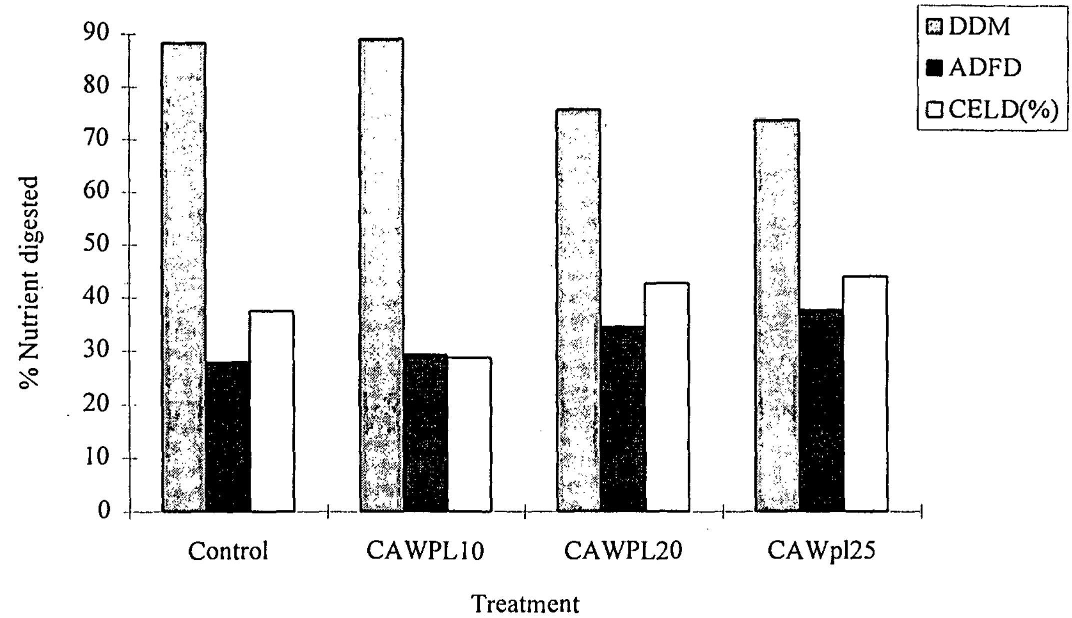


Fig 25 a: Effect of CAWPL incorporation in the digestibility of nutrients in rabbit feed

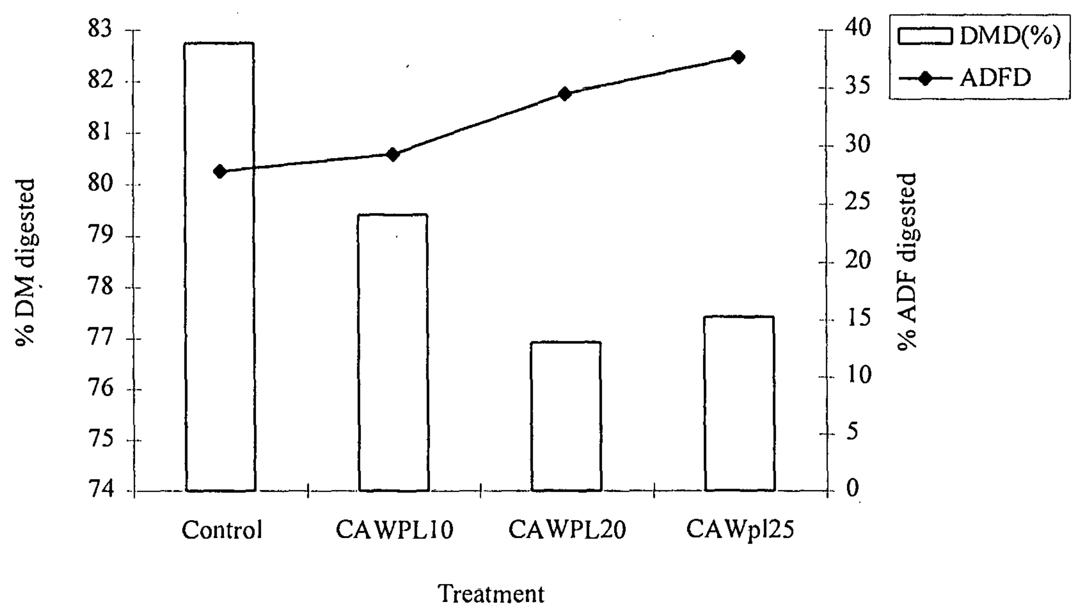


Fig 25 b: Regression of DMD(%) on ADF digestibility in CAWPL diet

The ADF digestibility was lower in untreated cashew apple waste (CAW) feed as compared to *Pleurotus florida* treated feed (CAWPL) (Table 41). The increase in drymatter digestibility from 71.84% in 25% CAW to 77.44% in 25% CAWPL could be due to the degradation of the lignocellulosic components in the cashew waste. It can be seen that the increase in digestibility was only 5.60%.

The digestibility of cashew apple waste incorporated feed was higher than coir dust feed with fermented as well as nonfermented by-product. High lignocellulosic nature of coir dust could be the reason for low digestibility of experimental feeds formulated with coir dust in this study. However, from the point of feed utilization the effect of fermentation can be more in coir dust than in cashew waste. In coir dust incorporated feed the increase in digestibility was 7.78% as against 5.6 % in cashew waste substituted feed. The loss of soluble carbohydrate in cashew waste in the early stage of fermentation might have affected the performance of this by-product.

Further it can be seen from the Fig. 24b and Fig. 25b that the digestibility of ADF increased with a corresponding decrease in drymatter digestibility and this indicates that when the digestibility is less the structural carbohydrates are utilised more effectively.

5.3. Feeding trial with karad hay.

5.3.1. The karad hay (KRD) was incorporated with conventional feed ingredients at 0, 10, 20 and 25% level and feeding trials were conductedas in other trials. Results of the feeding trial are presented in Table 37. Digestibility of drymatter was 80.54% for control as against 77.63%, 72.85% and 69.24% for 10, 20 and 25% KRD feed (Fig. 26a). The feed consumption was more in all the treatments ranging from 56 to 66g per day per kg body weight when compared to other by-product, viz. coir dust and cashew waste, used in this study. ADF digestibility was increasing as the % karad component in the diet increased (Fig. 26b). At 10% level it was 10.63% where as at 25% level it was 24.17. Cellulose digestibility was 11.05% for the controlled and 27.07% for the experimental feed with 25% KRD. The daily weight gain was 15.82g and 14.22g for control and 25% diet.

5.3.2. The drymatter intake/kg body weight for control and 25% KRDPL diet was 54.19g and 61.65g (Table 39) indicating the higher requirement of the experimental feed. ADF digestibility of 10% KRDPL, 20% KRDPL and 25% KRDPL was 18.58, 22.36 and 28.74%.The drymatter digestibility and ADF digestibility are negatively correlated as it can be seen from Fig.27b The cellulose digestibility also increased from 19.04% to 30.52% in these three

Table36 . Chemical composition of karad hay incorporated feed (% Dry matter basis).

Nutrient	Control	KRD10	KRD20	KRD25
NDF	17.32	18.14	24.70	31.50
ADF	12.70	12.06	16.12	20.75
CEL	10.76	11.75	14.06	14.06
LIG	6.82	6.75	8.72	9.60
CP	18.00	17.85	17.35	16.68
DE(Kcal/kg)	2725	2650	2625	2575

Table 37 . Effect of incorporation of Karad hay at different levels in rabbit feed on the digestibility of nutrients.*

	0	10	20	25
DMI(g/day)	94.60	96.05	104.62	112.33
DOP(g/day)	18.41	22.10	28.41	30.87
DDM(g/day)	76.19	73.96	76.22	77.78
DMD(%)	80.54	77.63	72.85	69.24
BWT(Kg)	1.70	1.60	1.60	1.70
DMKG(g)	56.71	60.03	65.39	66.08
ADFD(%)	12.84	10.63	18.96	24.17
CELD(%)	11.05	14.73	23.21	27.07
ADG(g)	15.82	15.05	14.65	14.22

* Mean value of four animals

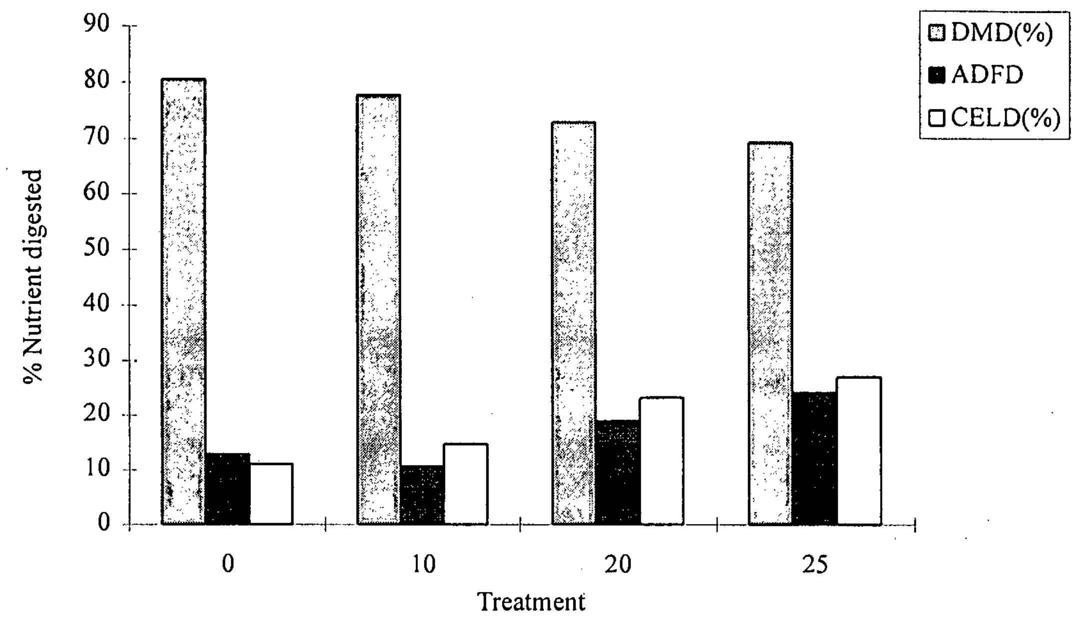


Fig 26 a: Effect of Incorporation of karad hay on the digestibility of nutrients in rabbit feed.

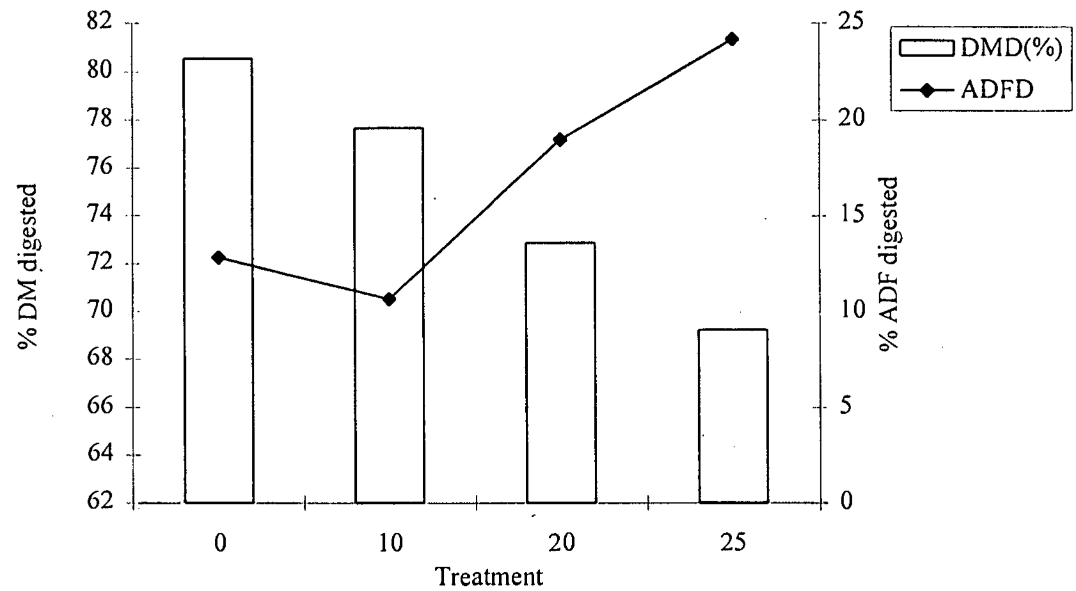


Fig 26 b: Regression of DMD(%) on ADF digetibility in KRD incorporated fee

Table 38 . Chemical composition of fermented karad hay incorporated feed (% Dry matter basis).

Nutrient	Control	KRDPL10	KRDPL20	KRDPL25
NDF	17.32	19.50	28.70	31.25
ADF	12.70	14.75	19.74	21.25
CEL	10.76	12.50	14.74	15.93
LIG	6.82	8.13	8.17	8.72
CP	18.00	17.10	16.50	17.50
DE(Kcal/kg)	2725	2725	2675	2650

KRDPL - Karad hay fermented with *pleurotus florida*

Table 39 . Effect of incorporation of Pleurotus treated Karad hay at different levels in rabbit feed on the digestibility of nutrients.*

	0	10	20	25
DMI(g/day)	97.55	96.35	104.61	110.97
DOP(g/day)	19.66	20.16	24.78	74.61
DDM(g/day)	77.89	76.19	79.83	85.58
DMD(%)	79.85	79.08	76.32	77.13
BWT(Kg)	1.80	1.71	1.75	1.80
DMKG(g)	54.19	56.34	59.77	61.65
ADFD(%)	8.27	18.58	22.36	28.74
CELD(%)	10.22	19.04	27.63	30.52
ADG(g)	17.32	16.85	15.96	16.30

* Mean value of four animals

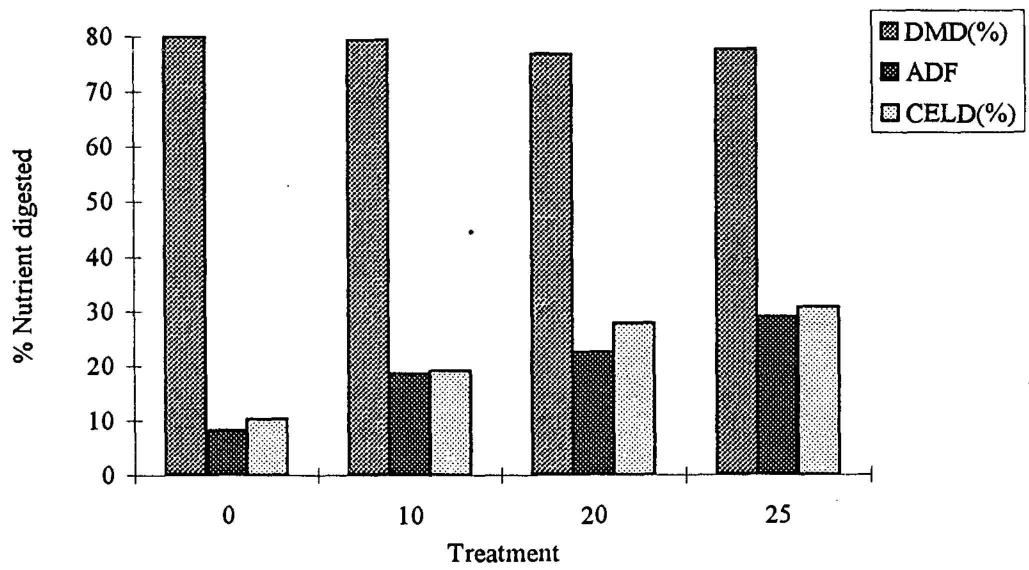


Fig 27 a: Effect of incorporation of fermented karad hay on the digestibility of nutrients in rabbit feed.

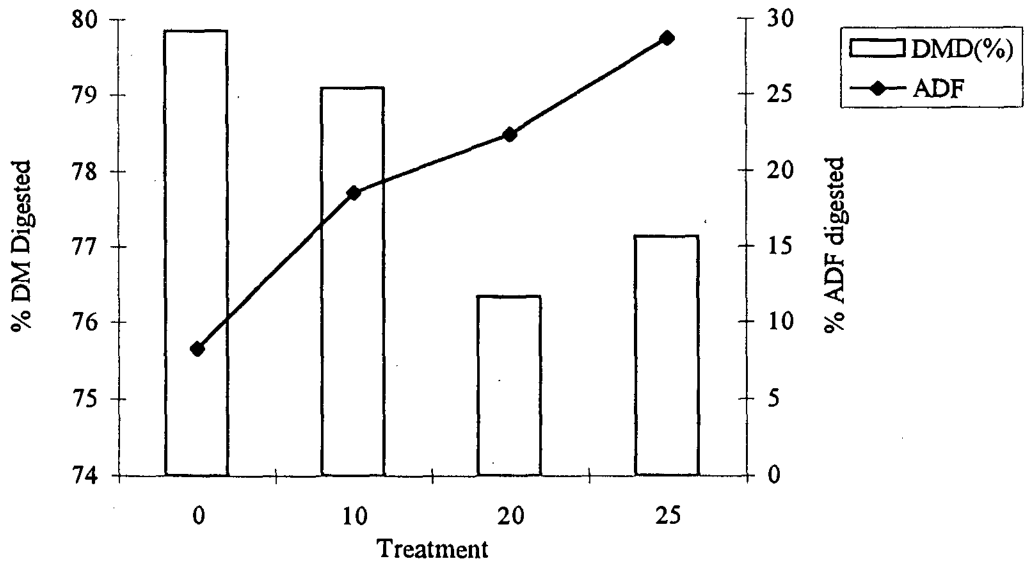


Fig 27 b: Regression of DMD(%) on ADF digetibility in KRDPL incorporate feed

Table 40 . Effect of fungal treatment on the digestibility of coir dust feed at different levels of incorporation.

Nutrient	10%		Difference	20%		Difference	25%		Difference
	CD	CDPL		CD	CDPL		CD	CDPL	
DMD(%)	69.50	74.02	4.52	63.75	70.45	6.70	61.48	69.26	7.78
BWT(Kg)	2.16	2.17	0.01	1.65	2.02	0.37	1.71	1.85	0.14
DMKG(g)	4.12	3.93	0.19	4.58	3.84	0.74	44.80	43.70	1.10
ADFD	15.62	16.00	0.38	16.81	19.72	2.91	24.56	52.00	27.44
CELD(%)	15.37	22.08	6.71	21.87	28.45	6.58	33.86	42.26	8.40
ADG(g)	15.32	15.86	0.54	13.56	13.75	0.19	12.75	14.20	1.45

Table 41. Effect of fungal treatment on the digestibility of cashew apple waste feed at different levels of incorporation

Nutrient	10%			20%			25%		
	CAW	CAWPL	Difference	CAW	CAWPL	Difference	CAW	CAWPL	Difference
DMD(%)	73.39	79.41	6.02	73.04	76.93	3.89	71.84	77.44	5.60
BWT(Kg)	1.7	1.65	0.05	1.80	1.62	-0.18	1.60	1.70	0.10
DMKG(g)	64.68	68.04	3.36	58.72	60.69	1.97	56.46	55.93	0.53
ADFD	22.19	29.29	7.10	23.64	34.5	10.86	24.02	37.69	13.67
CELD(%)	34.41	28.70	5.71	37.34	42.7	5.36	41.59	44.02	2.43
ADG(g)	15.73	16.64	0.91	15.30	15.82	0.52	14.95	15.33	0.38

Table 42 . Effect of fungal treatment on the digestibility of karad hay feed at different levels of incorporation.

Nutrient	10%			20%			25%		
	KRD	KRDPL	Difference	KRD	KRDPL	Difference	KRD	KRDPL	Difference
DMD(%)	77.63	79.08	1.45	72.85	76.32	3.47	69.24	77.13	7.89
BWT(Kg)	1.60	1.71	0.11	1.60	1.75	0.15	1.70	1.80	0.10
DMKG(g)	60.03	56.34	3.69	65.39	59.77	5.61	66.08	61.65	4.43
ADFD	10.63	18.58	7.95	18.96	22.36	3.40	24.17	28.74	4.57
CELD(%)	14.73	19.04	4.31	23.21	27.63	4.42	27.07	30.52	3.45
ADG(g)	15.05	16.85	1.80	14.65	15.96	1.31	14.22	16.30	2.08

Table 43 . Comparative digestibility performance ofcashew apple waste and coir dust.

Nutrient	CD25%	CDPL25%	CAW25%	CAWPL25%	KRD25	KRDPL25
DMI(g/day)	90.90	80.49	90.35	95.09	112.33	110.97
DMD(%)	61.48	69.26	71.84	77.44	69.24	77.13
DMKG(g)	44.80	43.70	56.46	55.93	66.08	61.65
AVBWT(Kg)	1.71	1.85	1.60	1.70	1.70	1.80
ADFD(%)	24.56	31.90	24.02	37.69	24.17	28.74
CELD(%)	33.86	42.26	41.59	44.02	27.07	30.52
LIGD(%)	17.60	2.14	3.95	4.29	5.32	3.45
ADG(g)	12.75	14.20	14.95	15.33	14.22	16.30

groups. The digestibility of KRDPL feed was higher than KRD feed for all the nutrients as it can be observed from Table 42.

5.4. Meat quality study:

Two experimental animals from each group were slaughtered for carcass yield study (Pl. 15) The data on meat yield are presented in Table 44. The dressing percentage of control, 25% CDPL, 25% CAWPL and 25% KRDPL group was 55.22%, 58.37%, 52.84% and 56.42% respectively.

Joy *et al.* (1985) reported 48.27% carcass yield in cross bred chinchilla rabbit. Nath and Rao (1985) observed a higher dressing percentage of 61.94 in wild rabbit and 53.21% for Newzealand white breed. In the present study, a higher bone : meat ratio of 1:3.86 and protein value of 22.75 was observed in 25% CDPL feed treatment group. The protein content of meat in the control group was 19.5%. All the three feed treatments viz: CDPL, CAWPL and KRDPL incorporated diets had more protein and bone : meat ratio which indicated a better quality of meat and animal performance. Although the dry matter intake and weight gain in the 25% CDPL was lower than the other two feed compositions used in this study, it appeared to have advantage over other treatments in terms of meat quality.

Table 44 . Comparative carcass yield and meat quality performance of by-product diets.

Treatment	Liv Wt	Dressing%	Flesh Wt	Bone Wt	Bone:Meat ratio	Protein%
	(Kg)		(g)	(g)		
Control	2.20	55.22	744	346	3.15	19.50
CDPL25	1.85	58.37	767	273	3.86	22.75
CAWPL25	1.90	52.84	650	304	3.04	21.63
KRDPL25	2.10	56.42	750	325	3.30	22.05

Further research is necessary to exploit the possibility of using fibrous agro-by-product feeds and to achieve better quality meat.

Table 45 . Coefficient correlation of nutrients in coir dust and digestibility in rabbits.

	NDF	ADF	CEL	LIG	CP	DE	DMKG	DMD	ADFD	CELD
NDF	1									
ADF	68153	1								
CEL	.59906	0.19905	1							
LIG	.87012	0.66505	0.51790	1						
CP	-.42438	-0.34510	-0.35120	-0.52660	1					
DE	-.33586	-0.66100	0.08997	-0.27980	0.34255	1				
DMKG	.59397	0.03619	0.69991	0.42063	-0.11911	0.26145	1			
DMD	-.72973	-0.89040	-0.23470	-0.71050	0.43993	0.78933	-0.0510	1		
ADFD	.42383	0.66266	0.09249	0.27334	-0.28950	-0.71648	-0.0132	-0.7147	1	
CELD	.16376	0.46498	0.03630	0.03620	0.08326	0.69970	0.0643	-0.4956	90542	1

CRITICAL VALUE (1-TAIL, .05) = + Or -0.3176 6
CRITICAL VALUE (2-tail, .05) = +/- .3731 5
N = 28

Table 46 . Correlation coeffeicient of nutrients in cashew apple waste

	NDF	ADF	CEL	LIG	CP	DE	DMKG	DMD	ADFD	CELD
NDF	1									
ADF	.25469	1								
CEL	.30764	0.26093	1							
LIG	.56919	0.00398	0.62356	1						
CP	-.35022	0.28686	0.24340	0.54940	1					
DE	-.19838	0.13210	0.37566	0.64331	0.74497	1				
DMKG	.24397	0.31600	0.71730	0.32600	0.11322	0.17822	1			
DMD	-.54976	0.29300	0.37590	0.20790	0.05168	0.04404	0.37442	1		
ADFD	.25815	0.12657	0.33530	0.71070	0.74472	0.82409	0.14290	0.0176	1	
CELD	.49768	0.33399	0.12771	0.57200	0.60683	0.59719	0.43590	0.5575	76517	1

CRITICAL VALUE (1- TAIL, .05) = + Or -0.3176 6
CRITICAL VALUE (2- tail, .05) = + / - .3731 5
N=28

Table 47 . Correlation coeffeciet of nutrients in Karad hay.

	NDF	ADF	CEL	LIG	CP	DE	DMKG	DMD		ADFD	CELD
NDF	)										
ADF	.98138	1									
CEL	.93191	0.91652	1								
LIG	.75916	0.75444	0.77673	1							
CP	-.43888	0.45840	0.45290	0.54710	1						
DE	-.30879	0.19019	0.14587	0.04250	0.12850	1					
DMKG	.64565	0.52711	0.62014	0.50411	0.02721	0.46431	1				
DMD	-.61656	0.51870	0.63460	0.59070	0.43447	0.28255	0.72750	1			
ADFD	.89500	0.90657	0.88483	0.81336	0.44815	0.06111	0.54501	0.4687	adfd 1.	0	
CELD	.87695	0.91574	0.84653	0.60816	0.46809	0.05429	0.28983	0.3649	celd .	77525	1

CRITICAL VALUE (1- TAIL, .05) = + Or -0.3176 6
CRITICAL VALUE (2- tail, .05) = +/- .3731 5
N = 28

RECOMMENDATIONS

Recommendations

1. The agricultural by-products which are available in sufficiently large quantity in the state of Goa can be utilised, following microbial enrichment, as animal feed substitute for economic livestock rearing.

2. The coir dust which is generally used as fuel can be enriched through fermentation by appropriate fungi and used as animal feed. Although, fermented coir dust has been successfully used as bio-fertilizer elsewhere, this is the first attempt made to make use of the waste as animal feed. Fermented coir dust can be incorporated safely at 10% level in rabbit feed.

3. The cashew apple waste, a seasonal by-product, can be used as animal feed substitute after fermentation. Use of this by-product as rabbit feed has been attempted for the first time and the possibility of using cashew waste as animal feed after enrichment is very bright.

4. The nutritive value of the locally available dry roughage karad grass can be enhanced through bio-degradation using *Pleurotus florida* and using this as feed ingredient for livestock including rabbit would greatly reduce the feed cost.

SUMMARY

SUMMARY

1. It is now realized that, although known to be poor in their nutritive value, the fibrous agricultural by-product and wastes which are available in large quantity in rural India can be utilised as feed substitutes by enrichment through solid state fermentation.

2. In the present study, locally available three fibrous agro-by-products, viz. coconut coir dust, cashew apple waste and karad grass hay were tested for their suitability as feed substitutes after fermentation. The Chinchilla variety of rabbits were used as experimental animals for feeding trials.

3. Among the three species of fungi tested, viz. *Pleurotus florida, Ganoderma lucidum* and *Trichoderma viride, Pleurotus florida* established well in ambient temperature in all the three feed substrates. The fungus was more active in the degradation of lignin than *Trichoderma viride* and *Ganoderma lucidum*. Since lignin is the major limiting factor in the overall utilisation of lignocellulosic waste by animals as feed, *Pleurotus florida* could be used as an instrument for effective biodegradation.

4. A higher reduction of cellulose with restricted lignin degradation by *Trichoderma viride* was observed in this study and this performance of the fungus is in conformation with earlier reports.

5. Maximum amount of crude protein increase and reduction in cellulose was observed with *Trichoderma viride* treatment in cashew apple waste.

6. In karad hay, degradation of structural carbohydrates by *Trichoderma viride* and *Ganoderma lucidum* was poor. The apparent absence of the required enzymes together may be the reason for poor growth of the two species in this substrate.

7. Among all the three substrates studied, karad hay facilitated maximum growth of *Pleurotus florida*.

8. Although the growth of *Pleurotus florida* was prominent in cashew apple waste, it may be inferred that the fungus has utilised cellulose more than lignin.

9. The optimum growth of *Pleurotus florida* and maximum reduction in organic matter and nutrient content in coir dust at 80% moisture level indicted that this is the suitable moisture level for fermentation.

10. In Cashew apple waste, reasonable wet texture was achived at 50% moisture level. Maximum fermentation by *Pleurotus florida* was also recorded at 50% moisture. These indicated that this moisture regime would permit acceptable

permit acceptable exchange of air with gaseous metabolites and enrichment during fermentation.

11. In cashew apple waste, in the initial stage of fermentation, percentage reduction of cellulose and organic carbon were higher than lignin indicating that the fungus might have preferably utilised the soluble carbohydrates and cellulose for its own growth.

12. Maximum loss of lignin, ADF and organic matter was observed in karad hay than in coir dust and cashew apple waste.

13. In coir dust, substantially high amount of lignin degradation was observed when treated with *Pleurotus florida*. Enrichment of coir dust with maize and wheat bran had less effect on lignin degradation. It is evident that *Pleurotus florida* had its preference for lignin degradation in this substrate even in the absence of a source of easily available carbohydrate.

14. Higher loss of organic matter in coir dust was estimated in maize enriched sample where growth of fungal mycelium was also extensive but marked reduction in lignin was not recorded. The increase in protein content from 2.98% to 9.76% observed on the substrate may be attributed to growth of fungal biomass.

15. Lignin was reduced by 20.11% in maize enriched cashew fruit apple substrate as against 7.23% in control and 18.47% in rice bran added sample. In wheat bran treated sample, it was only 9.04%. These observations indicate that addition of rice bran and maize has enhanced the process of degradation of lignocelluloses in cashew waste.

16. The percent reduction in lignin was higher in 30 days in coir dust and karad hay whereas in cashew apple waste lignin was degraded to the maximum extent only after 90 days of fermentation. The steady increase in percent reduction of lignin and. decrease in percent loss of cellulose was seen from 30 days to 90 days of fermentation in cashew apple waste.

17. In cashew apple waste reduction in cellulose was higher in the early stage of fermentation and lignin was degraded more in the latter stages indicating that lignin degradation was more only when the available source carbohydrate was limited.

18. There was no significant improvement in the digestibility of enriched coir dust and cashew apple waste with any of the added substrate under *in vitro* condition. These results clearly indicate the poor digestibility response of the substrate to enrichment under laboratory conditions.

19. Feed consumption per Kg body weight was higher for control than 25% coir dust feed, i.e. 51g and 44.8g. The dry matter digestibility was also high with control feed, i.e. 77.42% when compared with the experimental rations of coir dust.

20. Digestibility of coir dust was increased due to fungal treatment. Although it was lower than in control feed, there was an improvement by 7% in the digestibility of fungus-treated coir dust. This can be seen from the digestibility percentage of the two experimental diets, viz: 25% coir dust (CD) and 25% coir dust plus *Pleurotus florida* (CDPL) diets.

21. These results indicate that the digestibility was more when the by-product was incorporated at a lower concentration. Since the conventional feed ingredients are rich in easily assimilable nutrients and the by-products are generally highly lignocellulosic the results obtained should be viewed in terms of improvement in its digestibility and utility.

22. The ADF digestibility was lower in untreated cashew apple waste (CAW) feed as compared to *Pleurotus florida* treated feed (CAWPL) indicating the possible improvement in the structural components of the feed due to fungal treatment.

23. The digestibility of cashew apple waste incorporated feed was higher than coir dust feed with fermented as well as nonfermented by-product.

24. The feed consumption with karad hay was more in all the treatments when compared to other two by-products, viz. coir dust and cashew waste, used in this study.

25. A higher bone to meat ratio of 1:3.86 and protein value of 22.75 was observed in 25% CDPL feed treatment. The protein content of meat in the control group was 19.50% indicating an improvement in the meat quality due to incorporation of fungus treated lignocellulosic wastes in rabbit feed.

26. Although the dry matter intake and weight gain in the 25% CDPL was lower than the other two feed compositions used in this study, it appeared to have advantage over other treatments in terms of meat quality.

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PERFORMANCE OF CROSS BRED PIGS UNDER GOA CONDITION

II. STUDIES ON CARCASS CHARACTERISTICS

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Pork is one of the most important sources of meat for the Goan population. Rearing non descriptive pigs under scavenging condition is a traditional practice in the rural part of this State. Since the growth and production performance of these local pigs was unsatisfactory, cross breeding programme with Large White Yorkshire was initiated. In an earlier report (Bhattacharyya *et al.*, 1983), the reproductive parameters and growth performance of the F1 cross bred pigs were published. In the present paper the carcass characteristics of the crossbred pigs are reported. Three Fl cross bred males maintained in field conditions under scavenging and supplementary feeding, attained an average body weight of 59 kg at the 48th week indicating much better growth performance of crosses, than local pigs. The daily average weight gain of 175 g for the cross bred pigs in this study under semi-scavenging condition was found much better than that of 114 g for the indigenous pigs in stall fed condition as reported by Saseendran and Rajagopalan (1982). From the reports on carcass weight and characteristics of the pure bred Yorkshire (Ramaswami *et al.*, 1985) it can be seen that the dressing percentage at 60 kg body wt.

Table 1. Carcass characteristics of Fl cross bred pigs

Trait	Measurement SE	Trait	Measurement SE
Carcass length (cm)			
Pin bone to shoulder	63±0.87	Girth (cm)	90±1.73
Snout to back spine	120±0.16	Height at loin	72±0.57
Fore head to shoulder	27±0.48	Height at back	78±1.73
Shoulder	36±0.51	Snout diameter	21±1.16
Loin to Loin	60±0.86	**Weight (kg)**	
Loin to rump	21±1.39	Head weight	4±0.46
Face length	18±1.15	Shoulder weight	6±0.63
Ham	21±0.87	Bacon	5.3±0.46
		Ham	5±0.28
		Side	5.8±0.55

was 77% for pure bred Yorkshire, while in the present study it was 64.5% in cross bred pigs, which were reared under semi scavenging condition. Thus, it can be seen that in comparison, the cross breds in this present report performed well. Carcass characteristics of Fl cross bred, slaughtered at 52nd week is presented in table 1.

From the charcass characteristics it appeared that the growth of cross bred male pigs were quite promising, however, studies with more number of crossbreds are necessary to establish the norms.

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LOW COST POULTRY RATIONS BASED ON INGREDIENTS AVAILABLE IN GOA

I. STARTER RATIONS FOR EGG TYPE CHICKS

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Two low cost starter rations for egg type chicken were formulated incorporating locally available ingredients viz. rice bran, brewery grain waste, molasses, fish meal, oyster shells etc., and the efficiency and economics were tested with a control ration. Both the test rations were found to be better than the control ration, but the test ration containing the combination of rice bran and brewery grain waste was found to be most efficient and economical (28%).

INTRODUCTION

The cost of feeding represents and will probaby always represent major part (70-80%) of the whole poultry production cost (Muller 1972). Chicken feed with large portions of coarse grains is not only costly but also scarce as coarse grains constitute major food items for human use also. In Goa coarse grains and oil cakes, the major ingredients in the poultry feed, are not produced locally. As a result, the conventional poultry feed is further costlier in the Territory. On the other hand, rice bran, brewery grain waste, cane molasses, fish meal and oyster shell, are available in plenty at a cheaper rate since these are produced locally as by-products. Several investigators have reported the use of these by-products in different proportions in poultry rations (Mahadevan et al. 1975; Din et al. 1975; Panda and Gupta, 1965; Ott et al 1942. Rosenberg, 1953; Sundaram et al., 1980).

However, there is no report from Goa regarding the formulation of cheap ration using locally available ingredients and by-products. The present paper is the first report on the successful formulation and testing of economic starter rations incorporating local ingredients of the Territory.

MATERIALS AND METHODS

Two test rations for layer type chicks were prepared incorporating local ingredients. The feed formulae are given in Table 1. A commercial chick ration was taken as a standard ration for comparison.

TABLE 1. Feed formulae of test rations

Ingredient	Percentage inclusion	
	Test Ration I	Test Ration II
Yellow maize	25	25
Rice bran	28	18
Brewery grain waste	—	10
Groundnut cake	25	25
Fish meal	12	12
Molasses	6	6
Shell grit	2	2
Bone meal	1	1
Mineral & Vit.mixture	1	1
	100	100

All the three rations were analysed as per AOAC (1970) methods and the results are presented in Table 2.

A feeding trial was conducted at the Government Poultry Farm, Ela, Old Goa for a period of 8 weeks. Seventy five one-day-old HH 260 chicks (White Leghorn strain cross) were randomly allotted to two test groups and a standard group having 25 chicks each.

Feed and water were supplied ad libitum. The chicks were vaccinated against Ranikhet Disease with Lasota strain vaccine and reared in brooder cages under identical and optimum management conditions.

Bi-weekly body weight, feed intake and mortality were recorded during the entire experimental period. The feed efficiency and feeding cost was calculated for comparison. The data was analysed as per Snedecor and Cochran (1967).

Table 2 : Chemical composition of chick rations

Rations	Percentage composition				
	C.F.	C.P.	E.E.	NFE	Total ash
Standard ration	7.80	19.36	3.50	47.03	13.36
Test ration I	10.02	17.66	3.21	46.55	12.76
Test ration II	11.41	18.26	3.48	46.19	13.42

Table 3. Comparative efficiency of chick rations

Chick ration	Bi-weekly body weight (g)				Av. gain in body weight (g)	Av. feed intake (kg) bird	Av. feeding cost Rs./bird
	IInd	IVth	VIth	VIIIth			
Standard ration	54.7 [a]	120.6 [a]	201.0 [a]	266.5 [a]	236.5	2.7 [a]	5.21
Test ration I	53.7 [a]	103.8 [b]	136.9 [b]	163.5 [a]	233.5	3.0 [a]	4.74
Test ration II	47.7 [b]	95.4 [b]	191.2 [a]	265.4 [a]	235.4	2.4 [a]	3.76

Averages within the same column having same superscripts are not significantly different $P < 0.05$.

RESULTS AND DISCUSSION

The results of the feeding trial represented in Table 3.

GROWTH RATE :

The average bi-weekly body weight showed significant difference (P 0.05) among the groups up to the 6th week. But it was interesting to note that there was no significant difference during the 8th week (Table 3). This is indicative of a slower growth rate of both the test ration groups at the initial stages. This lower growth rate in the initial stagee may be due to less utilization of test rations by baby chicks probably because of their higher fibre content .(Table 2). However improved body weight gain from 6th week compensates the initial slow growth rate & this couldpossibly be due to the attainment of better digestive ability and adaptibility of the chicks to the type of feed with increase in age.

FEED CONSUMPTION

Feed consumption was highest in the group fed with test ration I followed by standard ration. The lowest feed intake was observed in the group fed with test ration II (Table 3). But these differences were not statistically significanty.

FEEDING COST

The feeding cost calculated had indicated that test ration II was most economical (28% more than s t a n dard). The test r a t i o n-I was the least efficient. However, it was found more economical (9% more) than the standard ration (Table-3).

MORTALITY :

The mortality was within normal range and no significant difference among the groups was observed.

The overall result had shown that rations formulated with local ingredients were more economical than conventional poultry feeds. The ration incorporating rice bran and brewery grain waste was found most efficient and economical; and this could be a suitable ration for the economic poultry production in the territory.

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LOW COST POULTRY RATIONS BASED ON INGREDIENTS AVAILABLE IN GOA:

II. GROWER RATION

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ABSTRACT

The low cost economic grower rations formulated by incorporating local by-products like rice bran and brewery grain waste as partial replacement of costly maize was found more economica (16%) than the standard commercial ration.

INTRODUCTION

The cost of pullets at the point of lay is one of the major factors affecting the cost of production of the egg. Therefore, it is essential that efficient feeding practices and good management must be followed during growing stage of the pullets to produce economical pullets which will have good growth, production and livability during the laying stage. Number of reports are available on feeding systems followed for grower pullets of egg and meat types. One of the methods followed was adding ingredients with more fibre content to formulate low energy grower rations. Following this principle, a study has been conducted using feed formulation incorporation locally available by-products as feed ingredients partially replacing maize in order to reduce the cost without adversely affecting the production efficiency.

MATERIALS AND METHODS

Two low cost grower rations (GR 1 and GR 2) were formulated incorporating the locally available cheap ingredients like ricebran, brewery grain waste, fish meal, molasses and shell grit.

The feed formulae are given in Table 1.

To reduce the cost of feed incorporation of the costly ingredient namely maize was brought down from 15% in GR 1 to 10% in GR 2 with simultaneous increase of brewery grain waste from 10% (GR 1) to 15% (GR 2). A commercial grower ration was taken as standard for comparison.

Averages within the same column having same superscripts are not significantly different $P<0.05$.

With respect to cost of feeding it was found that GR 1 was 16.28% more economical than standard ration. The better efficiency of GR 1 was also evident from the findings of early maturity (age at 1st egg-125 days) which was 6 days earlier than control and 15 days earlier than GR 2 group. The average egg production upto 26 weeks was the highest (24.1/hen) in the same group. Feeding cost calculated for the group was the lowest (Rs. 7.60). Further it can be seen from Table 3 that GR 2 was inferior to both GR 1 and SR as GR 2 groups had lowest average body weight at 18th week (950.9 g) and delayed maturity (age at 1st egg 140 days. However, from the cost point of view GR 1 was slightly cheaper than the standard ration. Low efficiency of GR 2 might be due to comparatively higher fibre content in the ration. Similar results were obtained by Sugandi et al. (1979) using feed formulation with 10% and 15% yellow maize. From these results it is apparent that locally available bi-products like rice bran and brewery grain waste can be profitably incorporated in grower rations, particularly replacing costly maize to bring down the cost of feeding replacement pullets considerably.

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Table 2 : Chemical composition of grower ration

Sl. No.	Ration	Percentage composition C.F.	C.P.	E.E.	NE	TOTAL ASH
1.	GR. I	10.42	16.32	3.26	47.37	12.52
2.	GR. II	12.96	17.41	2.77	47.31	10.91
3.	Control (SR)	8.41	16.25	3.86	48.10	13.10

Table 3 : Comparative efficiency of grower rations.

Sl. No.	Rations	Bi-weekly body weight (g) 8th	10th	12th	14th	16th	18th	Av. feed intake (Kg/bird)	Feeding cost (Rs./bird)	Age at first egg (days)	Average egg Production
1.	Control	581.5a	591.1a	655.4a	753.9a	886.1a	1002.6a	5.0a	9.15a	131	18.2
2.	GR 1	539.4a	35.1a	702.9a	773.1a	950.9h	1097.9b	5.8b	7.66	125	24.2
3.	GR 2	536.8a	616.1a	666.0a	670.7b	849.9a	950.9c	6.4c	7.87	140	17.6

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UTILIZATION OF CASHEW APPLE WASTE IN DAIRY CATTLE FEED

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ABSTRACT

Cashew apple waste (CAW), a seasonal waste product, was analysed and incorporated in the concentrate mixture at 10% level of replacement of groundnut cake. Effect of feeding CAW on milk production was studied in Gir cows for 90 days experimental period. The average daily DM intake was 8.92 and 8.95 kg and milk yield was 5.17 and 5.19 kg for the experimental and control groups, respectively, indicating no significant difference between the groups. The study suggested that cashew apple waste can be incorporated in dairy cattle feed at 10% level without any adverse influence on milk production.

Cashew apple is one of the most commonly available seasonal fruit in south lia. In certain areas like Goa, the fruit is utilised for the extraction of juice and nainder is discarded as waste. More than 100 tonnes of this by-product is avail-

Fig. 1. Cashew apple showing spherical bulb.

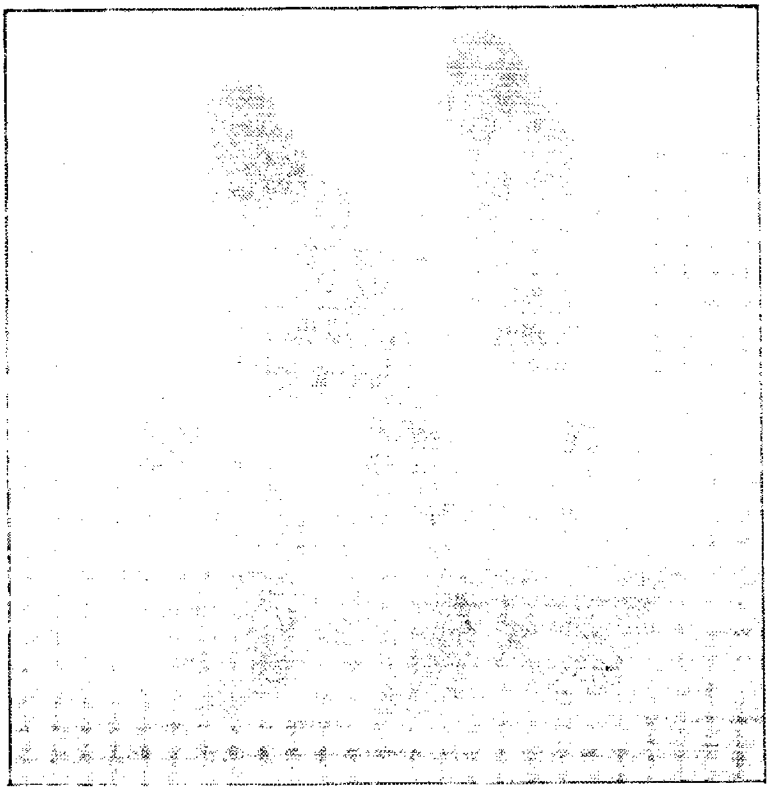

Fig. 2. Cashew apple showing elongated bulb.

able in Goa[1], during the season (Feb.-May). Reports on its utilisation as cattle feed are very limited. An attempt was made to evolve a ration incorporating cashew apple waste (CAW) for dairy cattle and study the effect on milk production.

Fresh CAW, collected from the country distillation units, was sun-dried for 4 days, ground and stored for incorporation in cattle feed. Control and experimental feeds were formulated (Table 1) and analysed for chemical composition[2]. Eight Gir cows, in early lactation and with similar body weights were selected and divided into 2 groups of 4 animals each and were fed with control and experimental concentrate feed respectively for a period of 105 days including 15 days preliminary period. Both the groups were maintained under identical managemental conditions. The ration consisted of 2 kg straw, 22 kg green grass and 2 to 4 kg concentrate. The animals were fed as per recommended standards[3] to meet the maintenance and production requirements. Data on milk yield, DM intake and feed cost of milk production were recorded and statistically analysed[4].

Proximate analysis of CAW, control and experimental concentrate mixtures is presented in Table 2. The composition of CAW was comparable to by products like wheat bran. In cashew apple meal, however, lower value of CP (6.4%) has also been reported earlier[5]. In the present feeding trial, CAW partly replaced the costly

Table 1. Ingredients of control and experimental concentrate feed

Ingredient	Feed (%)	
	Control	Experimental
Maize	7	7
Groundnut cake	25	15
Cotton seed cake	15	15
Rice bran	40	40
Molasses	10	9.5
Cashew apple waste	—	10
Urea	—	1.5
Mineral mixture	2	2
Salt	1	—

Table 2. Chemical composition of experimental feed (% on DM basis)

Feed	CF	EE	CP	T. Ash	NFE
Cashew apple waste	14.32	4.04	10.50	3.72	69.00
Control concentrate mixture	16.10	3.44	14.90	10.28	55.26
Experimental concentrate mixture	15.24	2.83	16.16	9.40	56.50

Table 3. Production performance of experimental and control animals

Particulars	Control	Experimental
I. Average milk yield (kg/cow/day)		
(a) Preliminary period	5.81±1.64	5.95±0.97
(b) Experimental period	5.19±1.01	5.17±0.74
II. DM intake (kg/day)		
(a) Concentrate	2.67±0.10	2.71±0.04
(b) Grass (NB21)	4.46±0.03	4.44±0.12
(c) Straw	1.80±0.01	1.80±0.02
(d) Total	8.92±0.12	8.95±0.15
II. Cost (Rs) of feed comsumed/kg of milk production	1.94	1.77

'eed ingredient groundnut cake with a view to reduce the feed cost without affecting :he feed quality. Chemical composition with regard to major nutrients in the control ɪnd experimental feeds was almost similar except that CP was slightly higher in ɜxperimental feed. The average daily milk yield of control and experimental groups during the preliminary period was 5.81 and 5.95 kg whereas during the experimental period it was 5.19 and 5.17 kg, respectively (Table 3), indicating that there was no significant difference in milk yield between the groups. The DM intake (8.92 and 8.95 kg, respectively) was also similar in both the groups. Although cashew apple contained 0.35% tannin, incorporation of the by-product CAW at 10% level had no undesirable influence on health and production of the animals during the trial period, indicating that CAW could be utilized as an ingredient in dairy cattle feed.

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A NOTE ON THE INCIDENCE OF HAEMORRHAGIC DISEASE IN RABBITS IN INDIA

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An epidemic among meat type rabbits in India, with 100% mortality, simulating viral haemorrhagic disease of China and Mexico, has been described.

The outbreak of an epidemic was observed during June, 1990, in this unit. Initially, it was observed that adult animals were dull, went off feed and did not drink water. Subsequently, a febrile condition with temperature of 49° C along with lacrimation and nasal discharge followed by dyspnoea was observed. Affected animals died within 24 to 48 hours after onset of symptoms. At time of death the animals showed bleeding from the nostrils (Figure 1). The outbreak lasted 10 days, during which 100% mortality was observed in adult animals. Although all the animals were housed in the same rabbitry, those younger than 12 weeks of age remained healthy and did not show any symptoms.

In the beginning, feed poisoning in the formulated diet was suspected. The feed was withdrawn and the animals were given only tender grass and cabbage leaves. However, no change was observed in the disease pattern. Febrile symptoms continued with anorexia and dyspnoea followed by mortality. Antibiotics and sulpha drugs were also administered regularly, without any favorable response.

Post mortem examination revealed profuse hemorrhage in the lungs (Figure 2), inflammation with hemorrhagic streaks in the liver and petechial hemorrhage in the small intestine and subcutaneous tissue. Blood samples collected from the lungs and cultures made from lung tissue were negative for pasteurella or any other bacterial infection. In view of this, as well as symptoms and course of the disease, a viral infection was suspected. However, this could not be tested, for want of a specific antigen and facilities. Literature pertaining to rabbit diseases was extensively reviewed. No literature or information was available on the occurrence of any hemorrhagic disease of rabbits in India. However, in a report from outside India, a hemorrhagic disease with similar symptoms and post mortem findings named Viral Haemorrhagic Disease of the rabbit was described by Patton (1989) as occurring in China, Mexico and some European countries. From this article, it appeared that the epidemic under report could possibly be due to a similar type of viral infection.

Acknowledgement

The authors are grateful to Dr. S. Ray, Director of Animal Husbandry and Veterinary Services, Govt. of Goa, for his valuable guidance and help in the investigation. They are also thankful to Dr. D.G. Dhandar, Officer on Special Duty, ICAR Research Complex for Goa, for providing facilities.

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Figure 1. Hemorrhagic discharge from the nostrils.

Figure 2. Thoracic cavity showing profuse bleeding in the lungs.

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w Cost Economic Rations for Dairy Cattle uitable for Coastal Rice Growing Areas

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e economy of milk production dire- ıpends upon feeding, as feeding constitutes more than 80% of the milk production. The balanced trate feed for dairy cattle usually ıs maize, wheat bran and oil cakes jor ingredients. In areas where ngredients are not locally produced, st of feeding is all the more high e of dependance from outside age- In the coastal belt where wheat be grown because of hot humid ic condition, rice is the major cer- ɔp cultivated round the year. In ne areas agricultural bye-products :e bran, molasses, baggassa etc., ilable in plenty. Incorporation of ɪy products and formulation of bal- ivestock ration would facilitate r livestock feeding in these areas. esent paper is the report of succes- ırmulation and feeding trial of a ɜd ration in Goa wherein tne costly ingredients like wheat bran and maize were replaced completely and partially with the locally available cheap by produ- cts, rice bran and molasses respectively.

MATERIALS AND METHODS:

Two test rations were prepared by completely replacing wheat bran and part- ially replacing maize with rice bran and molasses. The ingredients and percent- age inclusion are presented in Table 1.

A feeding experiment was conducted at Government Livestock Farm, Goa, for a period of 90 days to test the efficiency of the testrations. Eighteen cross bred cows (Jersey x Red Sindhi) in the early lactation (60-90 days) having similar body weights were selected and randomly alloted to 3 rations (6 in each group). The feeding schedule was same in all the three groups i.e. 2 kg Karad hay, 10 kg green grass and 1.5 kg concentrate feed with additi- onal, concentrate feed to meet the produ-

rtment of Animal Husbandry & Veterinary Services, Goa, Daman & Diu, Panaji.

ction requirement as per Sen and Ray (1971).

The data on daily feed intake, and ion was recorded for the entire period. Milk fat content was recorded once a month. These data were analysed as per Snedecor and Cochran (1967).

RESULT AND DISCUSSION:

The feed intake, milk production and feed efficiency are presented in Table III.

PROXIMATE ANALYSIS:

It was noted that there was not much difference in the chemical composition except in the C. fibre (17. 48% vs 13. 36%) and total ash contents (13.71% vs 7,36%) which were higher in test rations (Table II) which could possibly be due to the high proportion of rice bran in the test rations.

FEED INTAKE

All the animals remained healthy throughout the experimentation. From the observations on the feeding trial given in Table III, it may be observed that the total dry matter intake (9.76, 9.03 and 9.12 kg) as well as the concentrate feed intake among the groups were not significantly different. This was indicative in that the inclusion of rice bran and molasses did not adversely affect the palatability or the acceptability of the ration.

The pattern of feed intake remained normal throughout the experimental period which showed that the digestibility was normal although there were differences in the ration ingredients.

MILK PRODUCTION

It can also be noticed from the table that there was no significant difference among the groups in daily average milk yield (6.23,5.05 and 4.98 kg) or in the butter fat % (4.20, 4.31 and 4.28%). The difference in efficiency of production was also not significant. The pattern of lactation curve remained normal in all the groups throughout the experimental period. This indicated that the inclusion of these cheap ingredients had adversely affected neither the quantity nor the quality of milk.

Feed cost : On computing the economics it was found (Table III) that feeding cost/kg of milk production was Rs.1.54/kg in the group fed with control ration, and in the group fed with test rations I &II it was considerably lower viz Rs.1.32 and Rs.1·31 respectively. However, between the test rations no appreciable difference is observed.

The result clearly indicated that by inclusion of locally available cheap ingredients like rice bran and molasses in place of costly items like maize and wheat bran, the cost of concentrate feed for dairy cattle could be reduced considerably, without adversely affecting production. Therefore, for economic milk production in Goa as well as in other similar rice and sugar cane producing coastal areas, rice bran molasses can be profitably included upto 40% and 10% levels respectively for making blanced concentrate feed for milch animals.

TABLE I.

Feed ingredients] and percentage inclusion of the experimental and contro ns.

dients	Test Ration I Group A	Test Ration II Group B	Control Ration Group C
:e	17	7	20
. Cake	25	25	—
on Seed Cake	15	15	36
Bran	30	40	—
at bran	—	—	40
sses	10	10	—
Mix	2	2	3
	1	1	1
	100	100	100
Rs/kg	1.48		1.69

These rations were analysed as per A.O.A C. (1970) and the chemical composi- is given in Table II.

TABLE II.

Chemical composition of the two test rations and control ration under trial.

	Moist	C. Prot.	CF	Ex. Ext.	T. Ash	NFE
on I	9.81	15.82	13.82	4.02	11.01	45.52
on II	9.61	15.12	17.48	3.97	13.71	40.11
rol	8.11	14.85	13.36	4.19	7.36	52.13

TABLE 3

Average Feed intake, milk production & feed efficiency: during trial period.

	Test Ration I	Test Ration	Control
Av.D.M. intake cow/day (kg)	9.76[a]	9.03[a]	9.12[a]
Av. Con. Feed intake cow/day (kg)	5.12[a]	4.40[a]	4.48[a]
Av. milk yield cow/day (kg)	6.23[a]	5.05[a]	4.98[a]
Fat %	4.20	4.31	4.28
Efficiency of production (feed intake/kg milk production)	1.57[a]	1.77[a]	1.83[a]
Feed cost/kg milk production	1.32	1.31	1.65

The values with same superscript within rows in not significantly different

ABSTRACT

Two test rations were formulated by completely replacing wheat bran and partially replacing maize with rice bran @ 40% and 30% and molasses @ 10% levels. The efficiency ofthese test rations were compared with a control ration by conducting a feeding trial on dairy cattle for a period of 90 days. The results indicated that addition of 40% rice bran, and 10% molasses could considerably bring down feeding cost for milk production (Rs.0. 34/kg milk) without any adverse effect.

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Feeds and Bye Products Resources of Goa for Livestock Feeding

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The territory of Goa has about 35000 adult cows and 19,000 buffaloes which require 112 tones of concentrate feed every day: In addition to this, considerable amount of concentrate feed is also required for raising poultry and piggery. Although 36% of the land is under cultivation. mostly rice is grown in these areas: Coarse grains like maize, jowar etc., which are essential ingredients in livestock feed are not commonly cultivated: Consequently majority of the feed ingredients are brought from the neighbouring States. A survey conducted by the ICAR Research Complex Goa has revealed that 82% of the total maintenance expenditure in dairy units goes for feeding alone, indicating the necessity for identifying alternative meth ods to reduce the feed costs: Several agro industrial units and fish canning centres in Goa produce a large amount of bye products and waste materials. Utilization of these unconventional materials in the concentrate feed for partial replacement of costly ingredients will help to reduce the feed cost. With this view a survey to identify the availability of various bye products and waste materials was carried out.

Availability of various bye products and their approximate costs is furnished in Table I below.

Table I: Bye products resources of Goa.

Sl: No.	Item	Qty available	Approx. costs/kg
1.	Molasses	4000 tons	0.10
2.	Brewery grain waste	300 tons (DM)	0.70
3.	Rice bran	8000 tons	0.70
4.	Fishmeal	5000 tons	1.50 -3.50
5.	Cashew apple waste	100 tons	0.20

FISHMEAL :

The 100 km long coastal line of Goa, gets 25000 tons of fish per annum; 5000 tons of thrash fish is available which is sundried as fishmeal and exported to the neighbouring states. In addition to this there are 15 fish canning units which provides 25 tons of fish processing waste, which is discarded in the surrounding area creating health hazards.

MOLASSES :

The Co-operative sugar factory, with a crushing capacity of 1 lakh tons of cane per annum, produces 4000 tons of molasses. This can be utilised for partial replacement of cereals like maize and jowar, which are brought from the neighbouring states, to reduce the feed cost.

BREWERY GRAIN WASTE :

Sprouted barley grain is discarded as waste material after fermentation in the breweries. It has 18% C. proteins and 20% C. Fibre Two large scale breweries located in the territory produces 1200 tons of brewery grain waste/annum.

RICE BRAN :

Paddy is the major food crop in Goa. 1,40,000 has of land is under paddy cultivation. Annually 8000 tons of rice bran is availalbe as a bye product, which is cheaper (half the price) than wheat bran.

CASHEW APPLE WASTE :

A seasonal waste product available during summer months. The apple is used for the extraction of fenny and the remnants are discarded. It has 10.2% crude protein and 14 % cr. fibre. Annually 100 tons of this waste is available which can be fed to pig and cattle. Dried waste has been incorporated at 10% level in cattle and satisfactory production performance has been obtained.

FLOUR MILLWASTES :

There are two commercial flour mills, producing atta and Besan; wastes from these factories are available for feeding pigs.

In addition to the above frnit canning factory wastes like pineapple and mango wastes are available seasonally, which can be incorporated in pig mash to reduce the cost of feeding.

Table II. Chemical composition of bye products :

Bye product	Moist	C.C F.	E.E.	C.P.	Total ash	N.E.E.
1. Brewery grain waste	80.9	20.6	3.5	17.9	3.7	54.3
2. Cashew apple waste	77.3	14.3	4.0	10.5	2.5	69.0
3. Bagasse	11.2	43.0	2.6	2.6	4.2	47:6
4. Fish meal	9.2	5.8	4.0	42:0	37:2	11.0

Besides the above, coconut oil cake and distillery wastes are also available in limited source by adopting the pantented practices which are already available for incorporating these bye products in concentrate feed livestock maintenance expenditure can be reduced to an economic level.

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CHEMICAL COMPOSITION AND DRY MATTER DIGESTIBILITY OF KARAD HAY (*THEMEDA QUADRIVALIS*)

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arad (*Themeda quadrivalis*) is a wild grass growing extensively in the laterite soil of region in Goa. It grows abundantly in the forest lands. Dry grass is harvested as ecember-January and stacked for feeding-cattle during the summer months. It is an t substitute for paddy straw in this territory. Therefore a study was made to ascertain tive value of karad hay to find out as to what extent this preserved fodder can be

Materials and Methods

imples of karad hay and straw were collected from the stall, oven dried at 60°C for 8 round to pass through 20 mm mesh and analysed for proximate principles as per . (1970). *In vitro* dry matter digestibility of karad and paddy straw samples was l in 20 mm culture tubes by two stage digestion trial, technique (Tilley and Terry 1963). noculum for the above study was obtained from bullocks maintained on sole roughage karad and filtered through 4 layered cheese cloth in a prewarmed flask. Nutrient was prepared as per Cheng *et al* (1955) and D.M. digestibitity estmated as per dt *et al* (1962).

vivo digestion trial was conducted on five Sindhi x Jersey cross bred bullocks of 4 to age. Animals were maintained on karad hay for 28 days which included 21 days, ary period and 7 days collection period. Dry matter intake was ascertained for the during the preliminary period. Dung samples were collected daily during the collection om individual animals, oven dried at 60°C and analysed for acid insoluble ash (A I.R) gestibility was estimated by indicator technique using Acid Insoluble ash as indicator, va and Talapatra 1962).

Results and Discussion

rude protein, ether extract and total ash content of karad hay were 3.5, 1.68 and 10.5% that of paddy straw were 3.21, 1.82 and 11.42% respectively indicating that both the s are similar with respect to the nutrients mentioned above. However crude fibre of karad hay was higher (36.9%) than that of paddy straw (31.71%). Higher crude tent observed in the present study might be due to the dry grass being harvested at the ering stage. Increased crude fibre content has also been reported for other natural y like Anjan hay (Chandra and Jayal 1966).

vitro digestibility: Dry matter digestibility of karad hay *in virto* was 43.02% nimum and maximum digestibility of 41.49% and 44.21% respectively. Paddy straw

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›orded a higher digestibility (48.95%) than karad hay. Increased crude fibre content could the possibie factor responsible for lower digestibility in karad.

In vivo digestibility Srivastava and Talapatra (1962) reported the A.I.A. technique as simple method for the determination of digestibility. Thorney *et al* (1979) compared the gestibility estimation by total collection and A.I.A. methods and reported the reliability A. I. A. as a suitable indicator. Therefore in the present study, to avoid the laborious tal collection method, *in vivo* D. M. digestibility of hay was estimated by indicator method ing acid insoluble ash as indicator. The mean D. M. digestibility estimated was 37.81± 19% with minimum and maximum digestioility of 35.62 ± 5.61 and 39.9 ± 5.54% respecti- ly. There was no significant difference between animals on D. M. digestibility.

Studies conducted on the *in virto* digestibility of the natural grass hay (*Themada quadri- lis*) in comparison to the popular dry roughage paddy straw indicated that the karad hay is s digestible (43.02%) than paddy straw (48.95%). *In vivo* digestibility of the hay timated by indicator method also revealed the poor digestibility (37.81%) of karad. Higher ude fibre content could be the possible reason for the lower digestibility of karad hay.

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vet. J. 68. July, 1991 : 693 - 694

GROWTH PERFORMANCE OF EXOTIC MEAT RABBIT AND ITS CROSSES UNDER THE TROPICAL COASTAL CLIMATIC CONDITION*

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he available reports about the exotic meat rabbits (Parillo and Vasenina, 1981; and Rasmussen, 1986: C. S. W. R. I. 1986) indicate that their performance is n temperate region than in tropical region. Hence cross breeding was carried isaging to overcome climatic constraints if any. The precent paper reports the ative growth performance of exotic, local and their crosses in Goa which has l coastal climate.

laterials and Methods : Soviet Chinchilla (SC) and local (L) adult rabbits were ned under identical management conditions at the ICAR Research Complex Goa, for the production of young ones. All the animals were provided 70 gm trate and 350 gm grass daily. Lactating does were given 120 gm concentrate and odder *ad libitum*. Breeding was programmed to produce three groups of rabbits Pure Exotic (SC×SC) 2. Crossbred (XB) / (L×SC) and 3. Pure Local Breeding was done by bringing the female to the male. Altogether, 10 batches oduced in each group which were routinely followed up. Weaning was done on h day of kidding. Weaned animals were provided with concentrates and green as per the recommened level (Gheke, 1987). A total of 168 kits involving 70 SC, nd 46 L were available to study the growth. Observations on litter size, litter and weekly weight gain upto the marketing age of 16th week were recorded. ere analysed as per the procedure described by Snedecor and Gochran (1967) ious growth parameters and presented in the table.

Comparative growth performance of exotic, crossbred and local rabbits

	SC	XB	L
ze at birth	7.00±1.24	5.20±1.03	4.6±0.90
ze at weaning	5.00±0.81	4.9 ±0.98	4.0±0.40
eight at birth (kg)	0.38±0.05	0.27±0.05	0.21±0.04
eight at weaning (kg)	2.10±0.44	1.73±0.45	1.77±0.28
t 16th week (kg)	2.00±0.25	1.73±0.18	1.50±0.12
daily weight gain (g)	17.37	15.03	13.31

ICAR Research complex for Goa / contribution No. 4

The findings are in conformity with the report about exotic rabbits from /.R.I. (1986). From the table it could be observed that there was no appreciable 'ence in litter size at weaning between SC and XB animals. However litter weight aning and weight to kit at 16th week was higher in SC than in other groups ating its better growth rate. The average daily weight gain was also significantly r (P<0.01) in Soviet Chinchilla. It was interesting to note that the daily weight in SC was 16 g during the 4th week and 18 g during 16th week as compared to the kits in which it was 19 g at the begining and 9 g at 16th week and in case of XB it 4 g at the beginning and 15 g at 16th week. Thus, it was apparent that in local ts the high growth rate was maintained only for a short period upto weaning; ;as in case of SC and XB the growth rate was maintained till the marketable age as 1 earlier. Considering the growth rates of the three groups, it was clear that the :enance of the locals upto 16th week may not be profitable.

From the overall studies it was observed that under the tropical coastal climatic tion, the purebred SC performed better in comparison to XB. Thus, it can be)reted from the present work that there is no advantage in crossbreeding of meat Soviet Chinchilla rabbit with local and it would be beneficial to go in for pure ing for better growth under the prevailing agroclimatic conditions.

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PERFORMANCE OF EXOTIC MEAT RABBIT UNDER TROPICAL COASTAL CLIMATIC CONDITION

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ABSTRACT

Out of 4 meat type exotic breeds (Soviet Chinchilla, New Zealand White, Grey Giant and White Giant) of rabbit introduced under the coastal climatic condition (Goa), production performance of Soviet Chinchilla was better with highest kindling (78.5%), litter size (6) and average daily weight gain (19.17 gm). The result is indicative that the meat type rabbits, particularly, Soviet Chinchilla can be successfully reared for quality meat production.

Rabbit rearing for meat and wool has been gaining popu!arity in India uring the recent years. Exotic meat breed was introduced in 1979, in sub :imalayan region. There is dearth of literature on the introduction and produ- on performance of this species under coastal climatic condition. Goa is a coastal ate, having annual rainfall of 300 cm, restricted to 4 months (June to Sept.), with ıoderate temperature (20°C to 30°C) and high humidity (75% to 92%). It offers ɔod scope for meat producing livestock because of the unique non-vegetarian ıod habits of the Goans as well as demand due to heavy tourist inflow. The aper presents important informations for the possibilities of rearing meat ıbbits in Goa.

Four exotic meat breeds of rabbit viz., Soviet Chinchilla, New Zealand 'hite, Grey Giant and White Giant were introduced from Central Sheep and 'ool Research Institute, Station (Division of Fur Animal Breeding, Garsa, istt. Kulu, H.P.). These animals were maintained in individual cages under ɔtimum managemental and hygienic condition. A concentrate feed mixture :epared with 35 parts wheat and 65 parts pelletised feed (TDN 65% and DCP '%) was provided @ 65 gm/animal/day. Mixed green fodder containing rythrina, Subabul and NB 21 grass was fed @ 350 gms/animal/day. Drinking ater was provided ad libidum. Breeding was done by bringing the female to the ale. After successful mating, the female was separated and followed up. arious economic traits viz., kindling percent, litter size and litter weight were :corded for each kindling and data analysed.

Performance of the four exotic meat breeds (Table 1) indicate that the ndling (78.5%) and growth rate (19.2 gm) were higher in Soviet Chinchilla

Table I. Performance of Exotic meat breeds in Goa

Breed	No. of Obser-vattons	Kindling percent	Litter size at birth	Weight at Birth (g)	Gestation period (days)	Av. daily weight gain (g)
Soviet Chinchilla	28	78.50	6.00	59.48	32.0	19.2
New Zealand White	17	41.20	6.7	64.0	31.3	14.1
White Giant	16	50.00	5.3	69.2	31.6	15.0
Grey Giant	11	54.54	5.0	61.3	32.3	14.2

ıough litter size was higher in New Zealand White (6.7). The overall perfor-ıance of Soviet Chinchilla was found better than other breeds under local ›nditions. However, comparative performance of these breeds under sub-:imalayan region (Garsa) was superior for White Giant than the others (Singh ıd Kishore 1984).

In view of the better performance of Soviet Chinchilla, further observations ere made on this breed. The result is presented in Table 2.

Table II. Performance of Soviet Chinchilla rabbit in Goa

Gestation period (days)		32.3±0.82
Litter size at birth		6.0±2.40
Litter size at weaning (28 days)		4.4±1.50
Litter weight at weaning (kg)		1.95±0.37
Birth weight (g)		59.5±13.77
Weight at 16th week (kg)		2.1±0.36
Adult weight (kg)	Male	3.7±0.62
(1 year)	Female	3.6±0.72
Average daily weight gain upto 16 weeks (g)		19.17±3.23

The performance of Soviet Chinchilla was satisfactory and comparable to ːir performance at the Himalayan region, which is indicative of that the meat pe rabbits particularly Soviet Chinchilla can be successfully reared under coastal imatic condition.

The authors are thankful to Dr. M.K. Nair, Director, Central Plantation ·ops Research Institute, Kasaragod and Dr. K. Venugopal, Ex-Joint Director of is Research Complex for their keen interest and providing facilities for the ›rk.

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)LUNTARY FEED INTAKE AND NUTRIENT DIGESTIBILITY)F EXOTIC MEAT RABBIT UNDER TROPICAL COASTAL CLIMATE

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nformation on voluntary feed intake of ; meat rabbit under tropical coastal :ic condition is lacking. In view of this, a arative feeding trial was conducted on ›xotic meat breed of rabbits under cal management condition, to find out daily feed requirement. Eight each of ›t chinchilla and New zealand white s of 45 days age were selected for the Individual animals were weighed and adlibitum with green grass and ›ntrate feed and maintained under iden- nanagement condition.

The feed intake, leftover and dung output were recorded daily for individual animals for one week after the preliminary trial of three weeks. Dry matter intake and digestibility were calculated based on the data collected during the feeding trial. Comparative performance of the breeds is presented in the table.

The average daily weight gain and feed intake per day were almost at par for both breeds. The digestibility of ADF was 40.02 and 40.03, whereas that of CP was 62.06 and 65.66 for SC and NW breeds, respectively. Evans *et al.* (1983) reported the DM intake of

Comparative performance of exotic meat rabbits on DM intake and nutrient digestibility

ulars	Soviet Chinchilla	New Zealand White
DMI (g/day)	88.12 + 6.15	81.99 + 3.02
digested (g/day)	51.88 + 3.17	49.65 + 1.65
igestibility (%)	58.87 + 2.14	60.55 + 1.76
ıtake/kg body wt (%)	9.27 + 0.54	9.24 + 0.61
ligested (%)	40.02 + 2.04	40.03 + 1.13
gested (%)	62.06 + 2.81	65.66 + 1.96
ge body weight (g)	950.00	887.00
ge daily weight gain (g)	24.60	24.38

per cent per kg body weight for bits. The average intake of DM in ıt study was 9.27 and 9.24 for SC rabbits, respectively. The DM y was 58.87 and 60.55 for these milar values have been reported by and Grandi (1984) for young NW th mixed feed. The present study :hat the DM requirement is around t of the body weigh for weaners, irrespective of the breed under tropical coastal climatic conditions.

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