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KILIFI PLANTATIONS LIMITED

Private Bag, KILIFI

KENYA

PRODUCT AND MARKET DEVELOPMENT OF SISAL AND HENEQUEN PRODUCTS PROJECT- COMMON FUND FOR COMMODITIES

(Final Report on Sub component B1-Animal Feed Trials)

Contract No. 97/100

December 2001

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Eng, MIAgrE

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Forward

Kilifi Plantations Limited was started in 1923 as a sisal Estate. In 1963, dairy cattle and a few beef cattle were introduced as a diversification from the sisal monoculture. The estate is situated 60 km North of Mombasa on both sides of the Mombasa - Malindi road.

It occupies 2023 ha (5000 acres) out of which 324 ha is on sisal and the rest carries 2,700 head of cattle. The soils are sandy loam and sandy clays. Rainfall is bimodal with the long rains between April and June and short rains from October to December. The mean annual rainfall is 1150 mm and the temperature ranges from 25^0 C in June to 34^0 C in March.

The animals are free grazed on well-managed natural pastures and supplemented with a farm-made concentrate. During the dry season (January to March) the cows are fed silage made from natural pastures. Bogas and sisal boles also form part of the diet. The annual milk production from the Estate is 3.5 million litres, which is processed and packed for sale mainly in Mombasa town and its environs. The Estate has computerized animal records, which have been analysed by International and National Institutes for research and training of MSc and PhD students.

The objectives of the reported study were to refine the bogas recovery machinery and to test the effectiveness of feeding fresh and ensiled bogas to dairy and beef cattle, sheep and goats.

It is hoped that the results from the study will contribute to the knowledge on use of sisal waste. The trials were carried out at the Ranch with funding from the Common Fund for Commodities through the Kenya Sisal Board. Revenue calculations and the mechanical part of the report were written by Daniel Amedi Mutuli (University of Nairobi). The animal feeding data was analysed by John Rowlands (International Livestock Research Institute) and the report written by Rahab W. Muinga (Kenya Agricultural Research Institute) who also edited the final report.

Chris Wilson
Chairman/Managing Director
Kilifi Plantations Limited

1. BOGAS RECOVERY SYSTEM

1.1 Description of the System.

1.1.1 The Corona

In the factory, the leaves are decorticated to extract the cortex of ribbon fibres that run along the length of leaves. The fibres are found in the fleshy tissue of the leaf, mostly in association with vascular bundles. Decortication is the fibre extraction operation, which involves beating, crushing and scraping which is carried out in the automatic stationery sisal decorticator, often referred to as the "Corona". The basic working units are wheels or drums 100-150 cm in diameter, and about 30 cm wide.

Blunt beater blades, 5 cm high and spaced 25 cm apart, are attached to the drum at right angles to the direction of rotation. An adjustable breastplate 1/3 the circumference of the drum is set so that the beater blades clear it by about the thickness of a fibre at its narrowest part, the tailing edge. The space is wider where the leaf enters at the leading edge. As the leaf passes between the breastplate or saddle and the drum, pulp is beaten out and the fibres scraped clean. Jets of water, directed into the fibre as it passes through each drum, wash the fibre and carry away the waste otherwise referred to as bogas. A carrying and gripping device moves a layer of leaves sideways into one end of the machine through the first drum where the lower half of the leaves are processed and released. Then the grip is transferred to the processed fibre and the layer of partly processed leaves continue through to the second drum, where the process is completed. Figure 1, is a schematic illustration of the working principles of the Corona, showing both the top and the side view.

The modern corona can process 40,000 leaves per hour with remarkable speed and efficiency. At Kilifi Plantation Limited, the average task is 30 bogeys for every 8-hour shift, which approximately rationalizes as follows:

$$\frac{30 \text{ x } 200 \text{ (bundles/bogey) x } 27 \text{ (leaves/bundle)}}{8}$$

= 20,250 leaves /hour

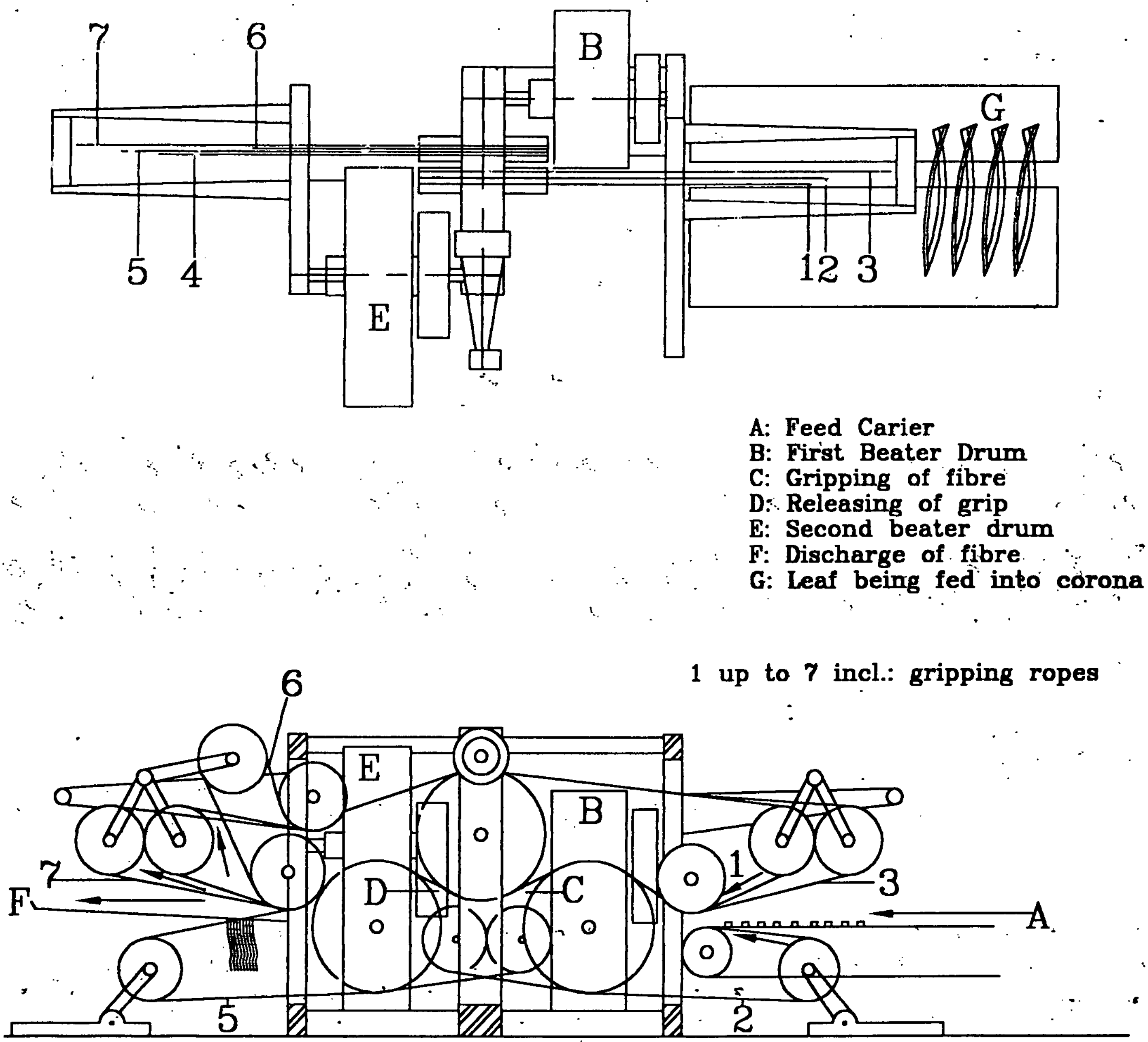


Figure 1: Schematic Diagram of A Decorticator

During the period of trials, the corona was run "dry" that is, no water was used during decortication, and that the bogas was collected from both drums of the corona in the following ratios:

Drum 1:	20% fibre	=	15 kg/hr
	60% bogas	=	866 kg/hr
Drum 2:	80% fibre	=	60.8 kg/hr
	40% bogas	=	577 kg/hr

1.1.2 The characteristics of fresh bogas

During the decortication process, the cellular tissue in the sisal leaf structure has to be crushed and torn away from the line fibres thereby resulting in a waste composed of leaf juice and soft biomass that is often referred to as bogas. Normally, about 8 per cent by weight of the fibres in the sisal leaf that is one metre long are too short to be recovered directly by the corona and thus find their way into the waste along with bogas. The physical properties of the fresh bogas describe it as a soft fleshy substance broken down into sizes of between 3 mm and 5 mm diameter with waxy particles interspersed (the waxy particles are from the surface of the leaf). Fresh bogas is acidic having PH values of between 3.9 and 4.16. Assuming a leaf, on average, is 300 g by weight of which 25 per cent is dry matter (of which 5 per cent is fibre and 95 per cent is bogas,) then the corona mass flow rate is estimated to be as follows:

Fibre = 76 kg/hour

bogas = 1443 kg/hour

Assuming 90 per cent fibre recovery, then this leaves 7.6 kg/hr of fibre in the bogas. Table 1.1 shows the chemical analysis of the bogas.

Table 1.1 chemical analyses of fresh bogas

Feed Characteristics	% of Total leaf weight
Dry matter	18.7
Crude Fibre (CF)	28.1-30.7
Total Digestible Nutrients	-
Crude protein (CP)	4.3 - 7.0
EE	2.5-3.7
Ash	8.7 - 11.9
Soluble Carbohydrates	26.6 - 30.7
Gross energy	3.70 kcal/kgDM
Minerals	g/kgDM
Ca	47.0
P	1.0
Mg	09.0
Zn	1.5 mg/kg DM
Cu	1.0
Mn	1.0
Fe	0.3
Organic acids	% DM
Lactic	1.0
Citric	1.2
Oxalic	5.2
PH	3.9 - 4.16

1.1.3 Bogas recovery system

The bogas recovery system is made up of three (3) working units namely, the Squirrel cage, the Squeezer unit and a system of conveyor belts for moving the material. Upon recovering the fresh bogas, it can either be compounded into feed and fed directly to the animals or it can be ensiled and compounded later for feeding the animals. It starts with a system of channels that recover the waste from both drums 1 and 2 on to conveyors which convey the waste onto a conveyor that lifts the material on to the Squirrel cage, which is a cylindrical cage that is tilted and revolving slowly for the purpose of "tumbling and tossing" the waste so that the bogas falls through the grating leaving the fibre, otherwise referred to as "flume tow", free to be collected at the end of the cage. The bogas is then conveyed on to the moving feed belt of the Squeezer unit for the purposes of expressing surplus water from the bogas. The Squeezer unit consists of two rollers that are spring tensioned to allow even amounts or clumps of bogas to be squeezed. The spring tension is adjustable to allow the operator to either increase or reduce the pressure exerted on the bogas to ensure good removal of excess water. It is after this stage that one can either compound it with other feed inputs for direct feeding of the animals as fresh bogas or one can ensile it for purposes of preservation, before compounding for feeding as ensiled bogas.

The compounding process is greatly enhanced when a feed mixer is used. In this case, a small batch electric motor-driven feed mixer is recommended with a capacity of 50-80 kg. For the dimensions and setting of the bogas recovery system, refer to the drawings and plates presented in the appendix. The system capacity is two tons per hour of dry matter.

1.1.4 Manufacture of the bogas recovery system

Arising from the description of the bogas recovery system above is the need to rationalize the manufacture of same of the components of the system in line with good manufacturing principles aimed at arriving at the lowest possible cost per unit of materials used. From the plates presented it is clear that all the working parts, that is the motors, gear reduction units, and other parts, are locally available from various outlets while the special ones like the squirrel cage and the Squeezer unit can be manufactured in most workshops of average ability (like that at the University of Nairobi) and the total cost of manufacture and assembling the system, inclusive of labour is found in the economic analysis presented later in the report.

The manufacture of the Squirrel cage involves rolling several metal bars into hoop irons and then welding the cross pieces on them as shown in the drawings. The only tricky bit is that of making the homemade gear to the diameter of 1340 mm - the gear that facilitates the rotational motion to effect the tumbling action. There are 112 pieces of 15 mm diameter bars that are 3660 mm that are welded onto the hoop irons made of angle bars.

The manufacture of the Squeezer unit is rationalized to avoid using the solid rollers as shown in the plates and drawings but instead use a blank mild steel sheet of a thick gauge (the actual thickness of the sheet can be calculated once the pressures involved in the squeezing action are determined) and then roll it into shape before welding it into a drum and subsequently polishing it. The ends of the drums are secured by flanges that are welded on to the drum on which the shaft is secured to ensure no play. The driving sprockets, tensioning springs, pulleys and the shafts can be machined in the workshops from blanks of appropriate sizes as shown.

The conveyor belt system is composed of an endless belt operating between two pulleys and several idlers. The belt material was flexible enough to conform to the pulleys and wide enough to carry the quantity of material.
The take-up that is necessary because of stretch of the belt and of contraction and expansion due to changes in moisture and temperature can be manual by adjusting screws or automatic by attaching a dead weight and should be at the foot end pulley. The drive should be at the discharge end of the belt and can be a conventional belt drive. The pulley must be large enough to provide enough contact surface with the belt to ensure a positive drive. Troughed idler pulleys can be used when the carrying capacity is to be increased. For the purpose of bogas recovery, the belt should be made of rubber. A rubber belt is usually made of canvas or woven material impregnated and vulcanized with rubber and covered with a rubber sheet.

Description of the method used to produce ensiled bogas

1.2.1 Introduction

Preserving and storing an adequate and nutritionally suitable feed supply is an essential part of livestock production. With feed costs making up a major portion of total livestock production expenses, it is essential that the most efficient and effective method be used. Silage offers the opportunity of consistently putting up high quality feed with a minimum of losses. The ensiling process results in the acidification of the forage material as a result of fermentation in the absence of oxygen.

There are two main phases in the ensiling process. The first is an aerobic phase where plant enzymes and microbes consume oxygen and burn up plant water-soluble carbohydrates (sugars) to produce carbon dioxide and heat. The idea is to minimize the time when water-soluble carbohydrates are being consumed. The second phase is initiated when all the oxygen is used up. Anaerobic bacteria will begin to multiply rapidly and then fermentation process starts. Ideally, *Lactobacilli* species, which produce lactic acid using the water-soluble carbohydrates as an energy source, will dominate. Fermentation stops after 2-4 weeks when pH becomes so low that all microbial growth is inhibited. The ensiling process itself does not affect the quality of the feed.

When a silage routine is selected, it pays to understand the process well and to do it correctly. Low quality silage can result from lack of understanding of the process, poor planning, or inadequate or imbalanced equipment, labour, or storage facilities.

1.2.2 Silage pit specifications

There were three (3) masonry built pits next the Squeezer unit for the purpose of making silage from the bogas. They were of equal dimensions for which one was:

16 metres long
3 metres wide
1 metre high

And the capacity of the pit was calculated as shown below :

{ 16x3x1} x 0.7 specific gravity

= 33 tonnes of bogas of moisture content of around 75-80%

The number of animals that can be fed from the silage per specific period of time will largely depend on the feed ration after compounding. But as an example, each animal needs 3% of its body weight in dry matter per day. Of this 3%, 50% can be fodder for example, bogas. Therefore, a 400 kg cow needs:

400 x 0.03 x 50%

6 kg DM bogas

@ 75% moisture the cow will need 24 kg bogas.

However, realistically it can only be around 15 kg therefore, a 33-ton pit can supply 100 cows for 22 days at 15 kg per day. The balance of the fodder then comes from other sources.

1.2.3 Method and condition of ensilage.

The routine followed in making silage from the bogas involved first receiving the bogas after it has passed through the Squeezer unit where excess water. Upon receiving this bogas, it is then stockpiled and compressed, by running a tractor over the pit to further remove moisture and prevent air getting in which causes decomposition. Effectively compressed, the material is then covered with black, heavy gauge plastic sheeting to prevent air, water and sunlight from interfering with the silage making process. The edges of the plastic sheeting are properly secured on the ground using heavy objects to ensure an airtight environment in which the bogas is ensiled. This is then left for 14 days after which the silage is ready for use.

However, a critique of this method of ensiling is necessary. The moisture content of the silage material at storage is one of the most important factors affecting the quality of the resultant silage. Attempts were made to reduce the moisture content of the bogas to 50 per cent before ensiling. However, the exact moisture determination on the farm is usually more of a qualitative than absolute exercise, and a simple rule-of-the thumb criterion had not been established for the bogas at 50 per cent moisture content (something akin to the grap test used to determine moisture content of forage).

Adequate attempts were made to ensure air exclusion by having the bogas tightly packed into the pits and providing a good seal. The most critical time in silage making is during the first few hours of storage. Long exposure of the bogas to air may result in the disappearance of much of the readily available carbohydrates. This may prevent the production of an adequate amount of lactic acid and result in a high pH conducive to deterioration of the feed material. Undesirable bacteria belonging to the genus *Clostridium,* grow under high pH and result in butyric acid, ammonia, and various amines associated with poor silage quality. It is therefore vital that the packing process is rapid and properly done. Further, the longer the period of aerobic activity, the more the heat produced which will raise temperatures and increase the risk of heat damage.

Molasses, a source of readily fermentable carbohydrates is added while ensiling grasses like panicum. Perhaps a side experiment should have been set up to establish whether bogas actually needs supplemental carbohydrates to ensure good silage production as is the case of panicum or the addition of chemical preservatives like formic, propionic or lactic acid as an alternative way to reduce the pH. Desirable properties of the plastic cover include ultra-violet light inhibitors, stretch, puncture resistance and stickiness. Four to six layers of plastic are recommended for storage of up to one year. Feeding systems that reduce oxygen re-entry at feeding are recommended to reduce silage deterioration. Rodents and just about any other animal capable of putting holes in the plastic sheeting should be avoided. The silage area should therefore be clean of vegetation as much as possible to eradicate hiding places for rodents.

1.2.4 Yield and chemical characteristics of ensiled bogas versus fresh bogas

There is no real difference in physical yield except that the dry matter (DM) is around 25 per cent for ensiled bogas as compared to 18.7 per cent for fresh bogas. The chemical characteristic of ensiled bogas is similar to that of fresh bogas.

1.3 Investments and operational costs

1.3.1 Introduction

It is assumed that the farmer has 30 dairy cows, 36 steers, 42 sheep and 42 goats. Apart from the cows it is assumed that the animals are bought during the first year. The cost of a dairy cow is US$ 562.5 and this cost is not included in the reported calculations. It could be considered among the fixed assets and depreciated over 15 years.

Other assumptions have been made in study formulation as follows:

- 42 sheep and 42 goats are disposed after one year at US$ 31.25 each and replaced by similar numbers at a cost of US$ 18.75 per animal.
- All the beef steers are disposed after 2 years for US$ 187.5 each and replaced by a similar number at a cost of US$ 125 per animal. No beef animals are sold in the first year.
- The lactation period of each dairy animal is 320 days and a kg of milk is sold at US$ 0.225
- Exchange rate of 1US$ to Kshs 80 is used.

1.3.2 Investment costs

A Squeezing Unit.

2 pieces of squeezing rollers	=	US$ 25
3 tension sprockets/gears	=	US$ 25
1 driving pulley	=	US$ 5.6
1 Shaft for holding the rollers	=	US$ 37.50
1 Motor	=	US$ 562.50
Total cost of Squeezing Unit	=	**US$ 655.62**

B Squirrel cage.

2 Angles lines	=	US$ 12.50
4 Reinforcement rings	=	US$ 23.50
112 pieces of squirrel bars	=	US$ 1680
Labor & Welding costs	=	US$ 45
Stand for squirrel cage	=	US$ 125
1 motor	=	US$ 187.50
Gear reduction unit Small	=	US$ 306.25
Big	=	US$ 445
Total cost of squirrel cage	=	**US$ 2824.75**

C Mixer, conveyer belts and accessories.

66 meters conveyer belts	=	US$ 1072.50
11 meters stands of angle iron	=	US$ 137.5
8 Conveyer rollers	=	US$ 250
3 motors	=	US$ 562.50
1 Mixer	=	US$ 750
1 Electrical switch for the system	=	US$ 1500
Total cost of conveyer and accessories		**US$4272.50**

Total investment cost (A+B+C) is US$ 7752.88
Depreciation = 37% per year.

1.3.3 Operational costs

Labor cost

5 people per day	=	US$ 7.5
Labor cost per annum	=	US$ 2337.50
Monthly labor cost	=	US$ 225

Power/Electricity cost

20kw/hr	=	US$ 0.125/hr
Consumption per day	=	US$ 20
Annual power cost	=	US$ 7300

1.3.4 Bogas Ration (fresh/ensiled) costs for different animals

Dairy Unit

13.62 kg DM of the feed is offered to a cow daily costs US$ 0.61

30 cows use 30 x US$ 0.61 = US$ 18.45 / day.

Monthly cost US$ 553.50 or annual cost US$ 6642 per year

Beef unit

8.34 kg DM is offered to each animal daily at a cost of US$ 0.37

36 steers use 36 x 0.37 = US$ 13.23/ day.

Monthly cost US$ 396.90 or US$ 4762.80 per year.

Sheep/goat Unit

0.58 kg DM is offered to each animal at a cost of US$ 0.01.

42 sheep use 42 x 0.01 = US$ 0.4 / day.

Or US$ 12.6 per month or US$ 151 per year)

Revenue

Animal disposal

42 goats	=US$ 1312.50
42 sheep	=S$ 1312.50
30 beef	=US$ 5625.00

36 dairy cows =36x 7 kg milk x US$ 0.225 x320days = US$ 19176 /year.

1.4. Financial feasibility appraisal

One criterion for selecting a viable project is to use the NPV (Net Present Value). If NPV>0 then select the project. This is shown in Table 1.2 for five years. Within the five years, the break-even point is not achieved. The costs are likely to be lower than in the calculations shown in Table 1.2 because the feed offered could equal to intake if better troughs were used to minimize feed wastage. The cost of the goats and sheep could also be reduced where breeding stock is maintained on the farm. There are too many assumptions and calculations beyond five years were found not to be useful. It is however evident that the project is viable for the different types of animals. The most profitable enterprise is likely to be dairy, beef and sheep/goats in that order.

Table 1.2 A five yearly budget for the proposed sisal feed mill (US$)

Item	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
EXPENSES					
Equipment	7753	2866	1806	1138	717
Salaries	2738	2738	2738	2738	2738
Power	7300	7300	7300	7300	7300
Feed Dairy	6642	6642	6642	6642	6642
Beef	4763	4763	4763	4763	4763
Sheep	151	151	151	151	151
Goats	151	151	151	151	151
Purchase					
Goats	777	777	777	777	777
Sheep	777	777	777	777	777
Beef	3500	3500	3500	3500	3500
Total	34552	29665	28605	27937	27516
REVENUE					
Milk Sales	19174	19174	19174	19174	19174
Sale-Goats	1312	1312	1312	1312	1312
Sheep	1312	1312	1312	1312	1312
Beef		5625	5625	5625	5625
Total	21798	27423	27423	27423	27423
BALANCE	**-12754**	**-2242**	**-1182**	**-514**	**-93**

NB

The financial calculations in Table 1.2 are obviously only descriptive of one case study. Every situation will warrant careful financial investigation . There are many factors not allowed for like:

1) Cost of buildings
2) Cost of money (loans/overdrafts)
3) Cost of land
4) General opportunity costs

Essentially it is apparently true to say that bogas and bole feeding gives extremely marginal returns and is not economically viable except in special circumstances.

PLATES AND DRAWINGS

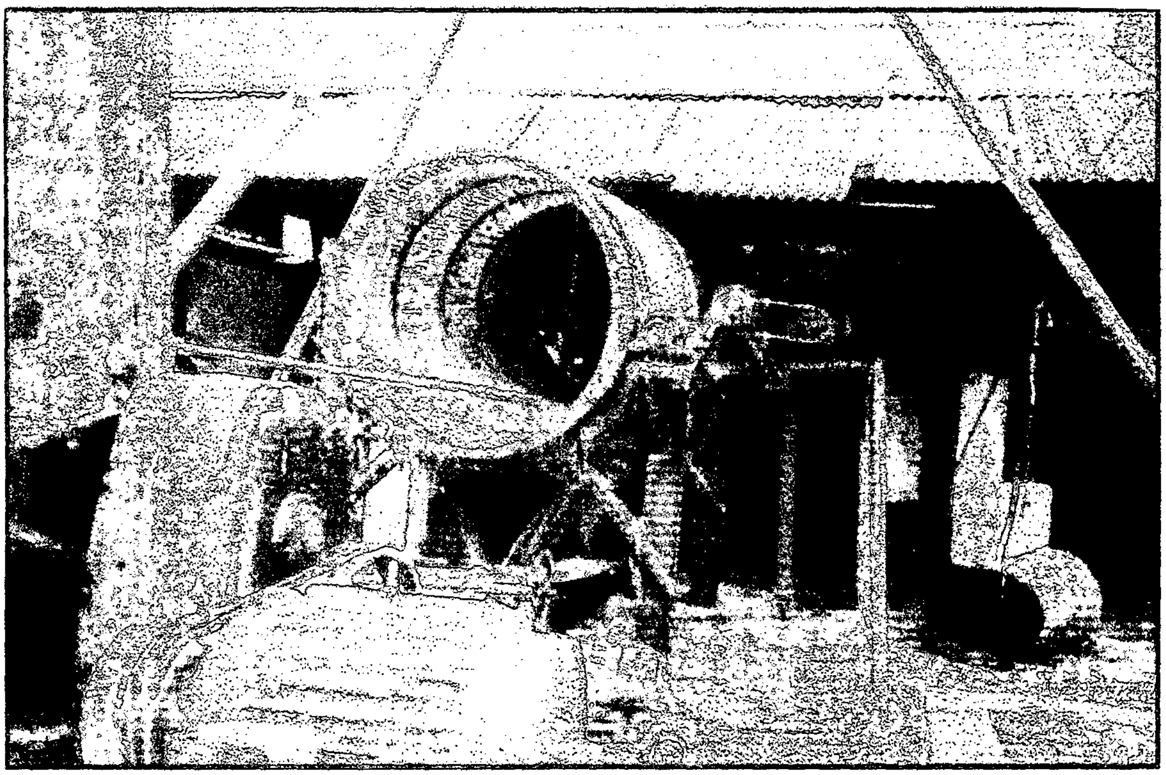


PLATE 1: A Back View of the Squirrel Cage Assembly Shortly after Operation.

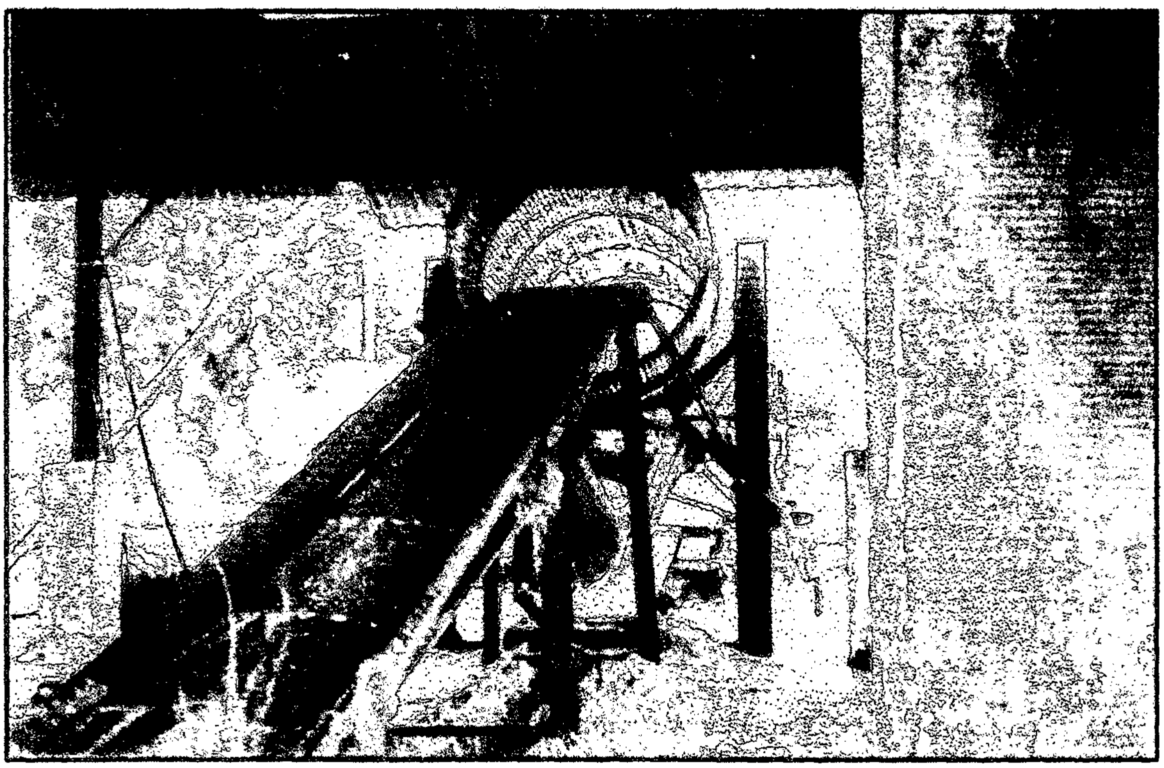


PLATE 2: Front View of the Squirrel cage Assembly showing the feed conveyor lifting bogass on to it.

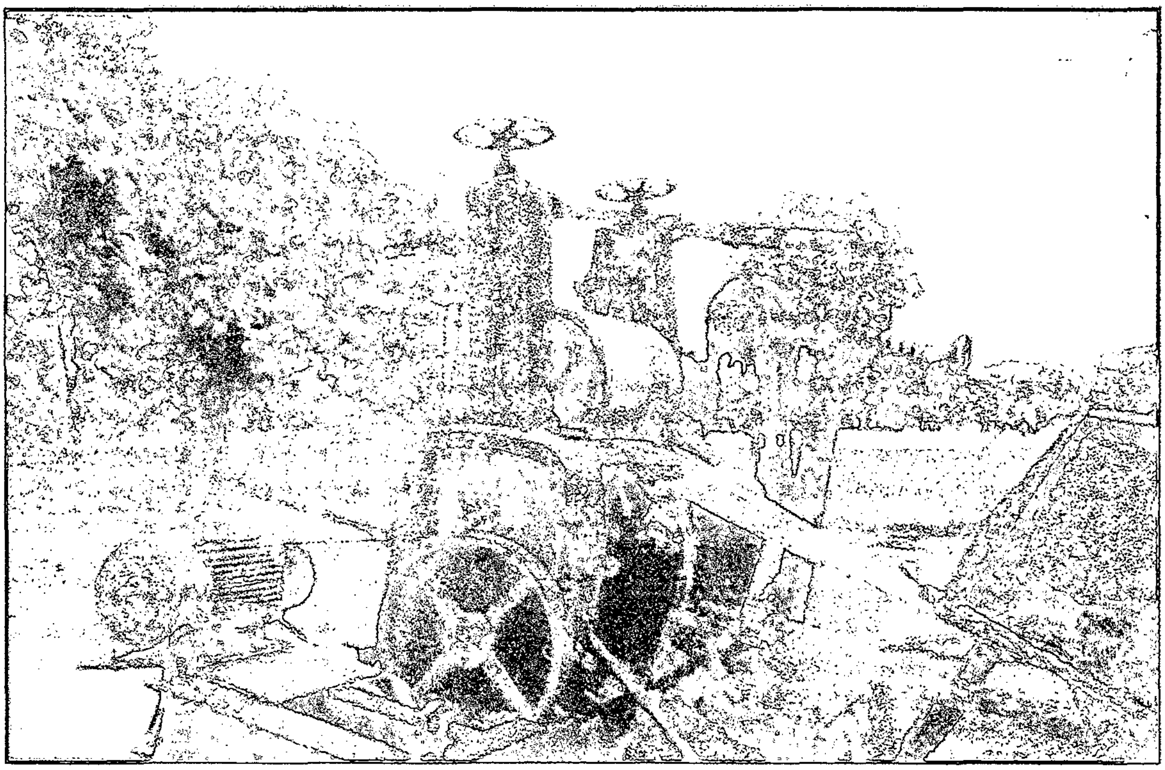


PLATE 3: The Squeezer Unit Assembly while at work.

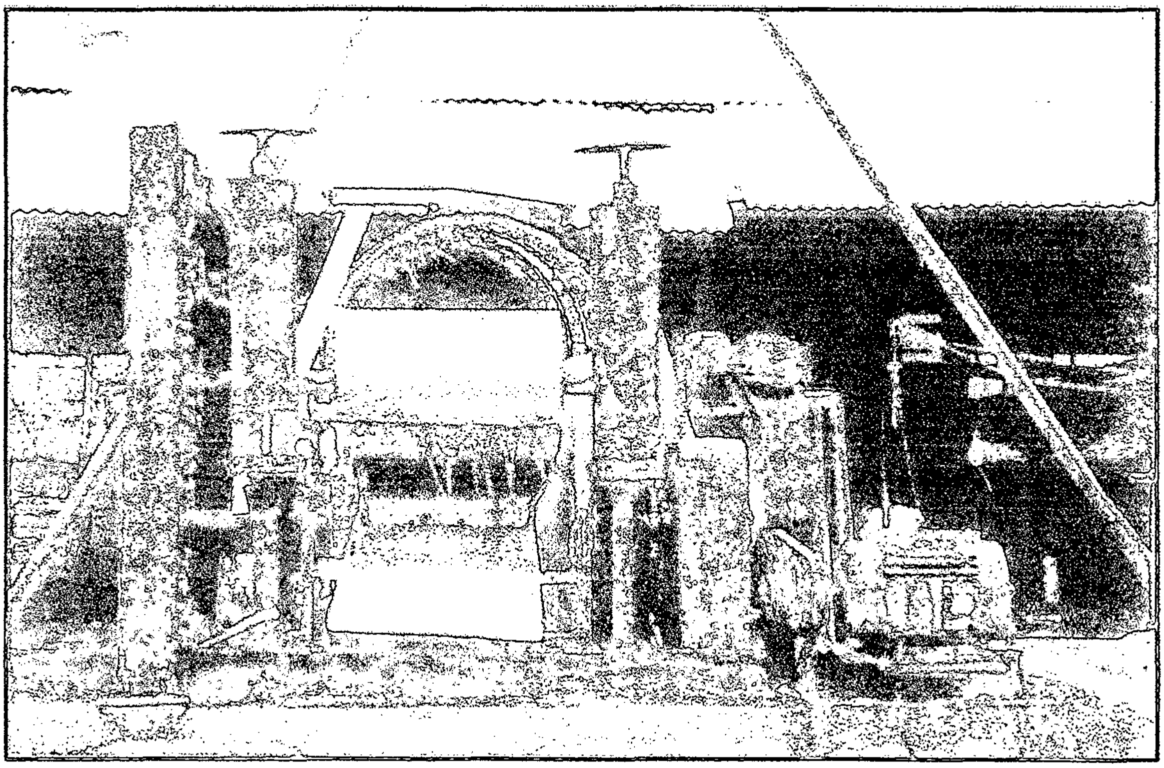
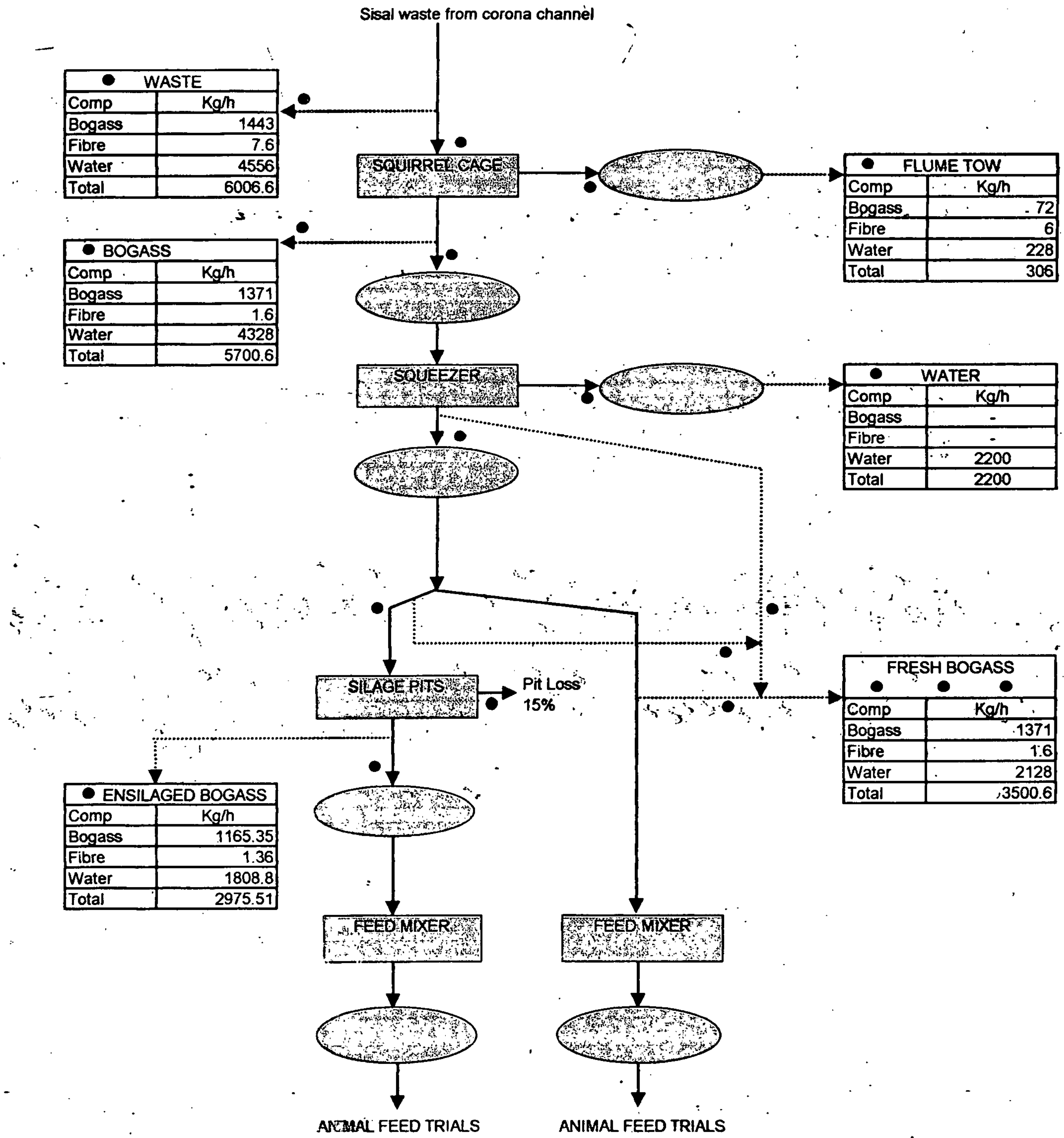


PLATE 4: A Back View of the Squeezer Unit Assembly.



WASTE

Comp	Kg/h
Bogass	1443
Fibre	7.6
Water	4556
Total	6006.6

BOGASS

Comp	Kg/h
Bogass	1371
Fibre	1.6
Water	4328
Total	5700.6

FLUME TOW

Comp	Kg/h
Bogass	72
Fibre	6
Water	228
Total	306

WATER

Comp	Kg/h
Bogass	-
Fibre	-
Water	2200
Total	2200

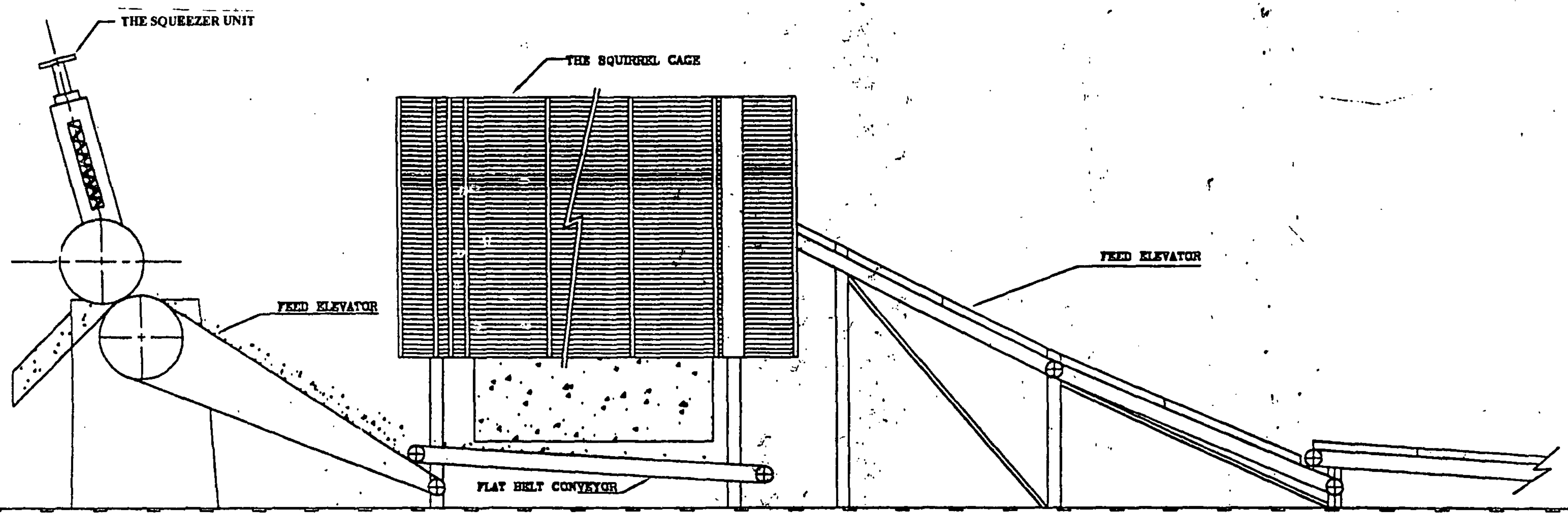
FRESH BOGASS

Comp	Kg/h
Bogass	1371
Fibre	1.6
Water	2128
Total	3500.6

ENSILAGED BOGASS

Comp	Kg/h
Bogass	1165.35
Fibre	1.36
Water	1808.8
Total	2975.51

Figure 2: Mass Flow Diagrams of Bogass Recovery System at Kilifi Plantations Ltd

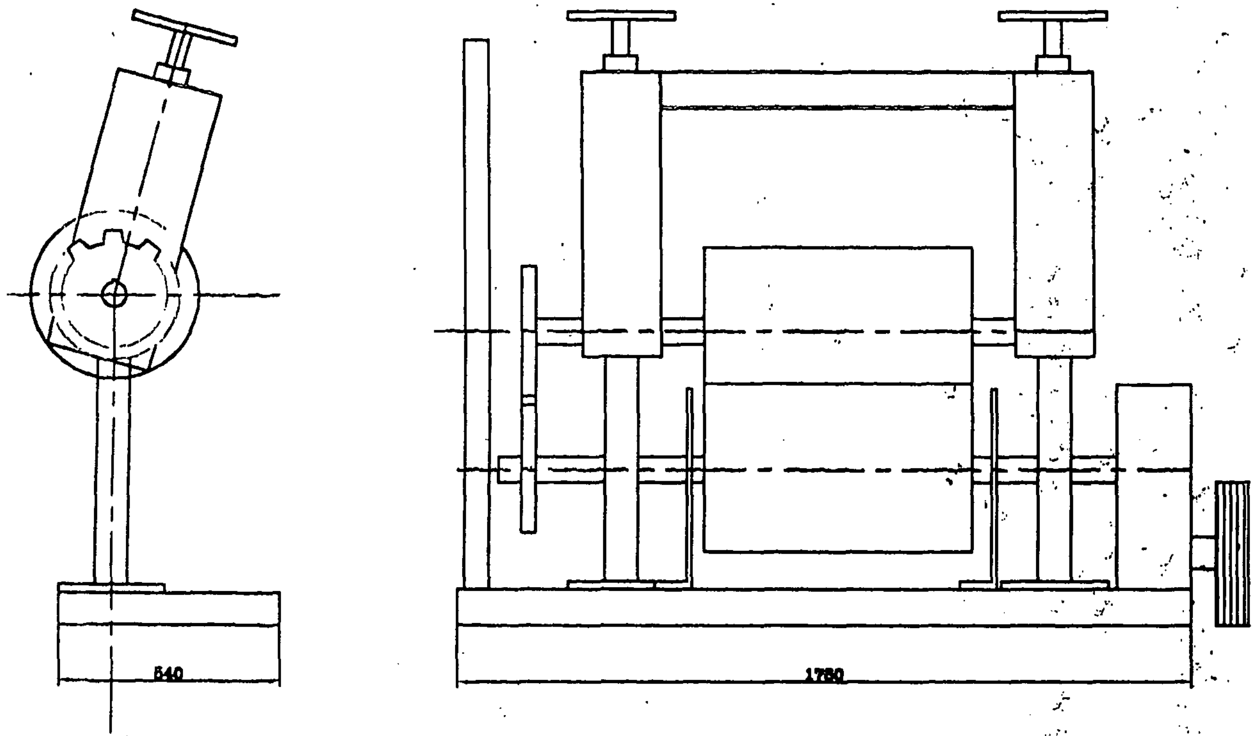


A CROSS SECTION OF THE BOGAS HANDLING MACHINERY PLANT LAYOUT

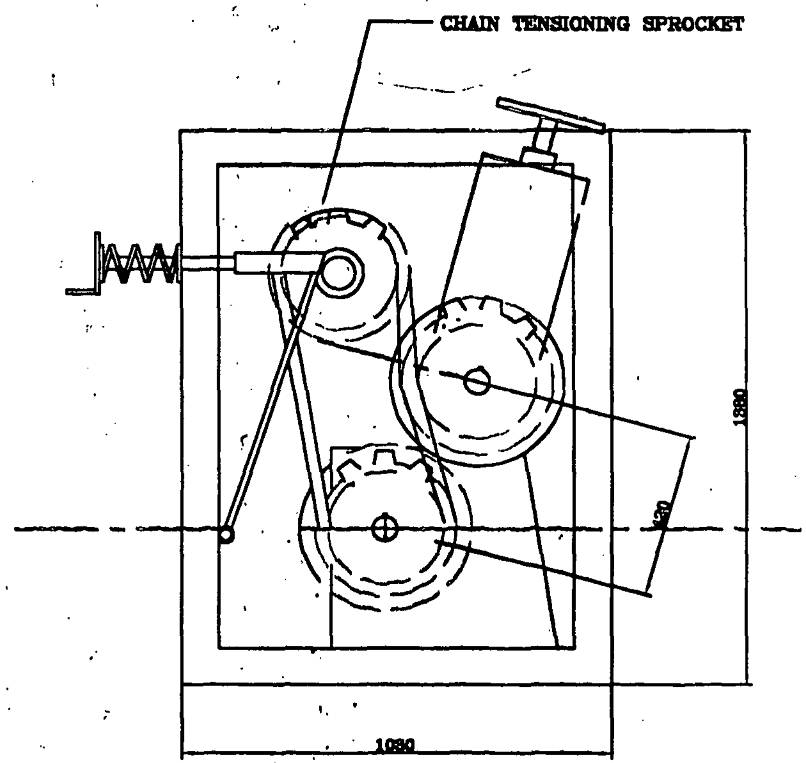
NOTES

1. THE LENGTH AND HEIGHT OF THE CONVEYOR AND ELEVATOR ARE NOT DRAWN TO SCALE
2. HIDDEN DETAILS ARE NOT SHOWN
3. MOTORS AND REDUCTION GEARBOXES USED TO DRIVE CONVEYORS/ELEVATORS ARE NOT SHOWN

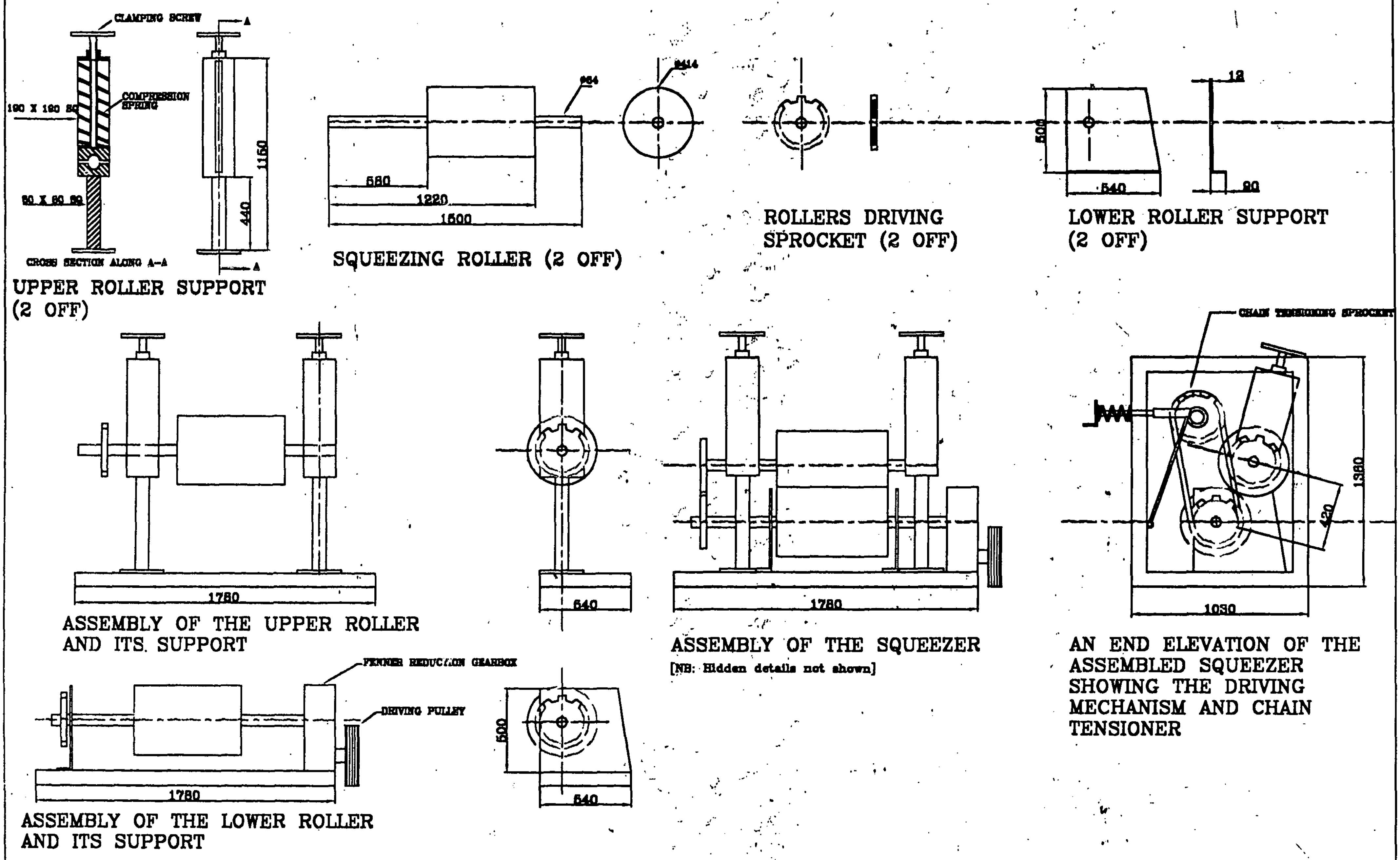
KILIFI PLANTATIONS LIMITED



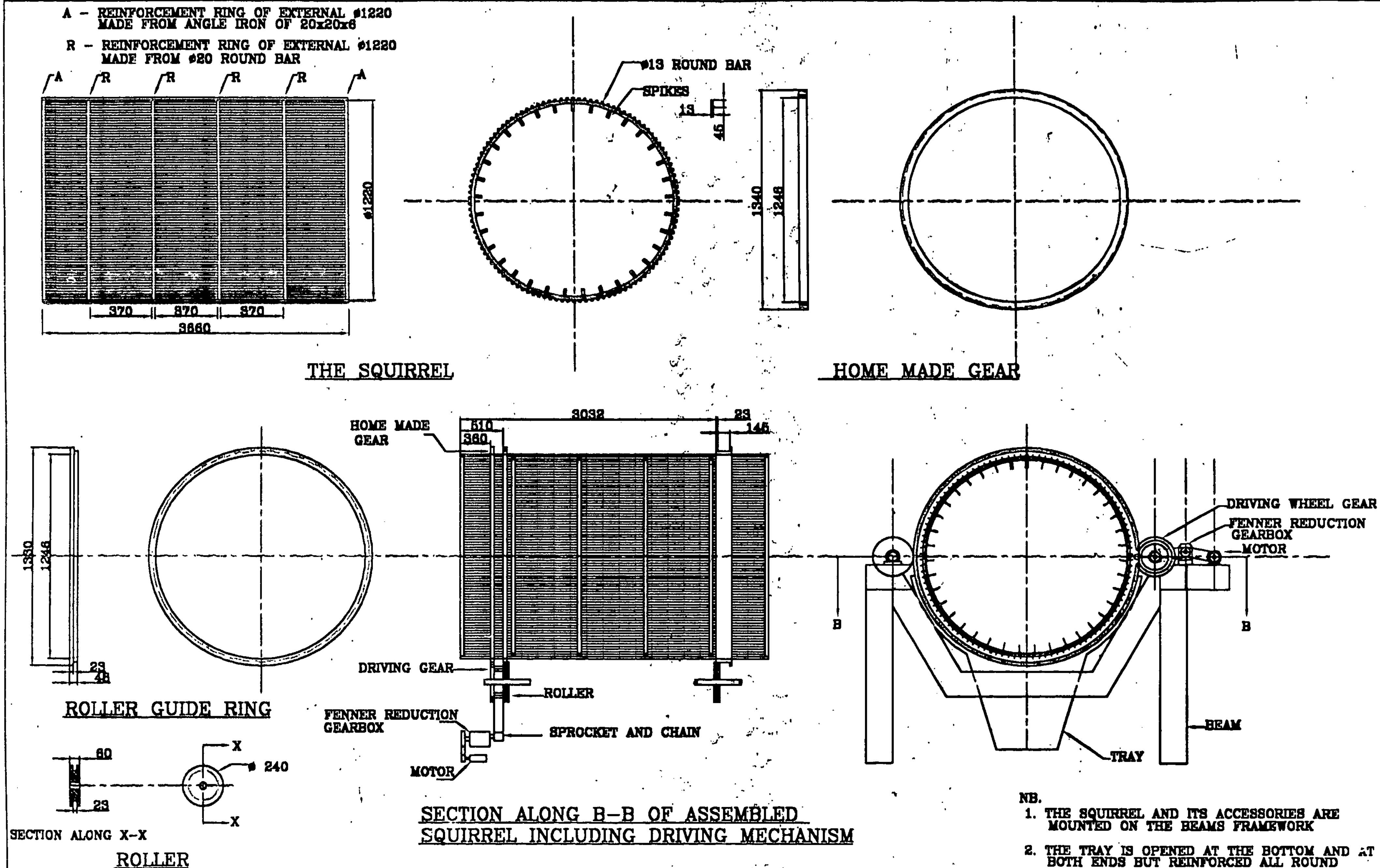
ASSEMBLY OF THE SQUEEZER
[NB: Hidden details not shown]



AN END ELEVATION OF THE ASSEMBLED SQUEEZER SHOWING THE DRIVING MECHANISM AND CHAIN TENSIONER

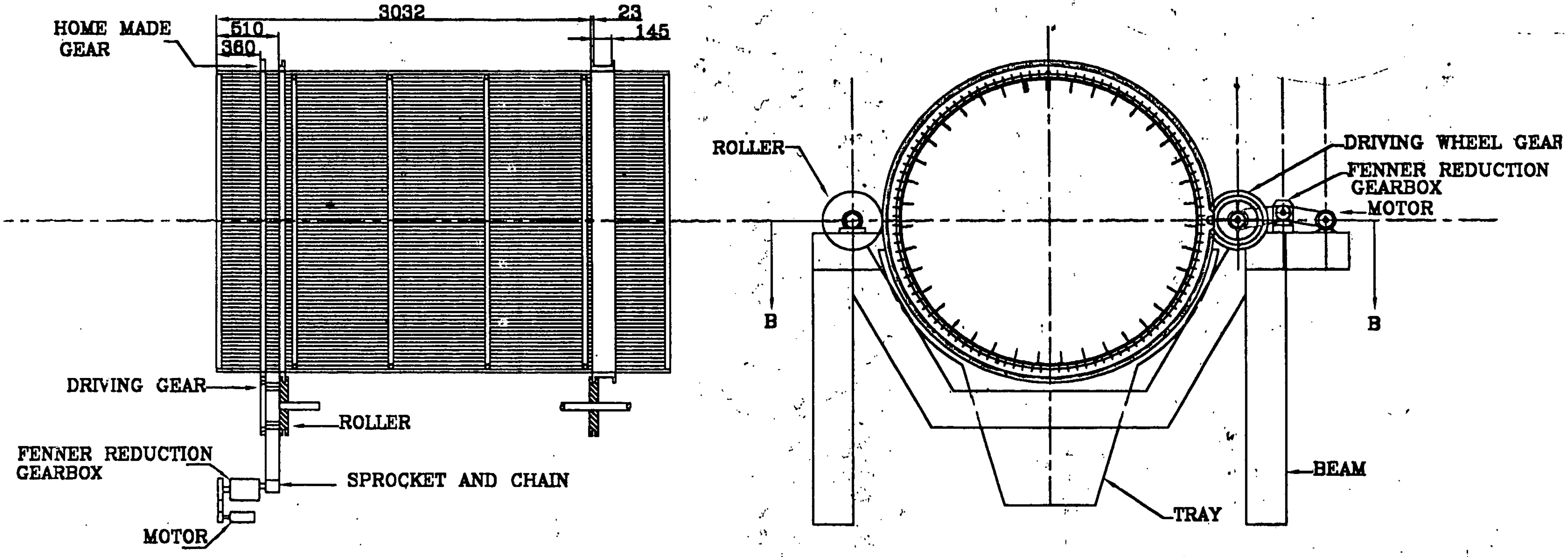


NOTES 1. All dimensions are in mm unless otherwise stated	KILIFI PLANTATIONS LIMITED	DATE: NOVEMBER 2001 PART NAME: SQUEEZING UNIT	SCALE: 1:10



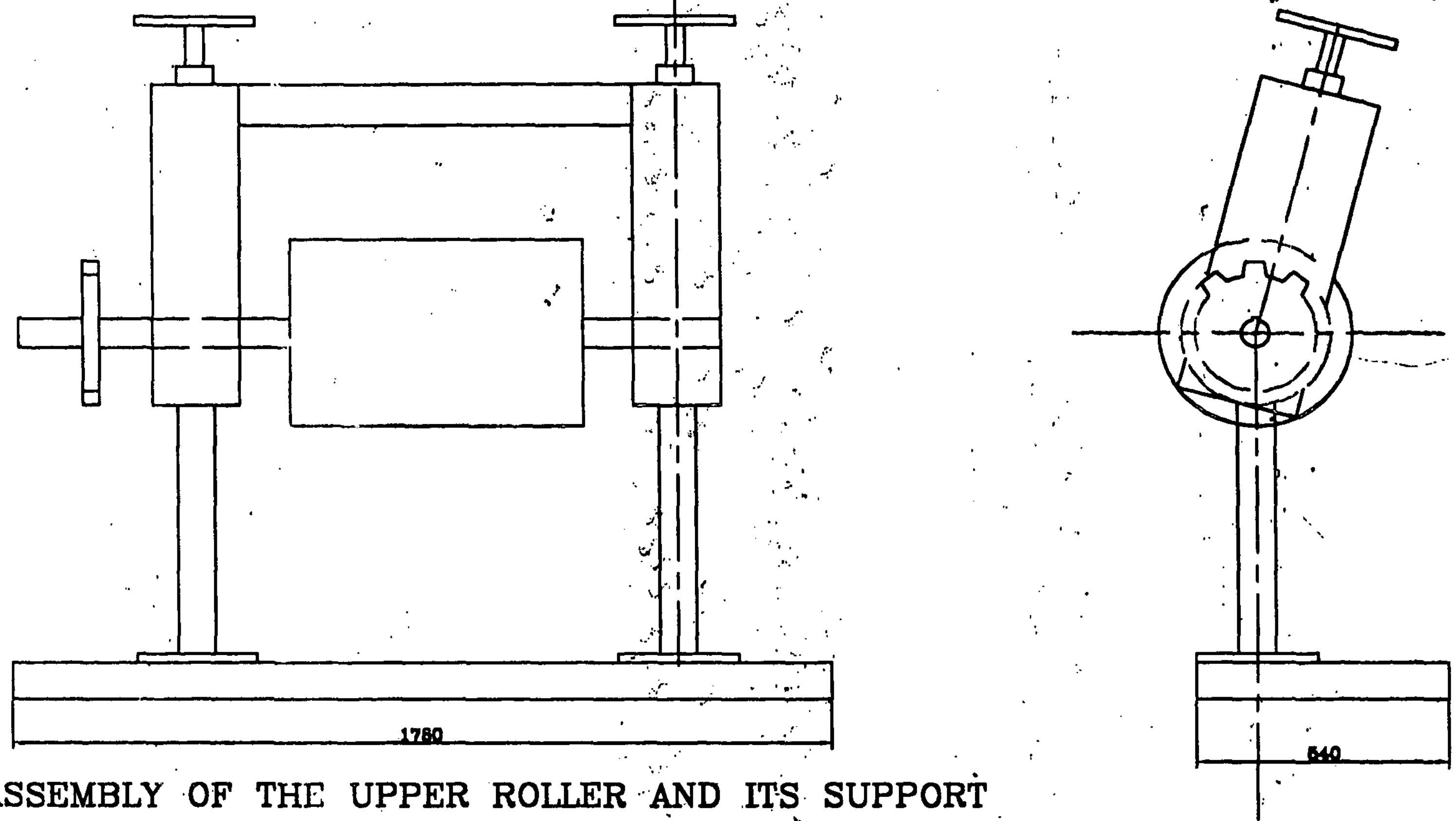
NB.
1. THE SQUIRREL AND ITS ACCESSORIES ARE MOUNTED ON THE BEAMS FRAMEWORK
2. THE TRAY IS OPENED AT THE BOTTOM AND AT BOTH ENDS BUT REINFORCED ALL ROUND

NOTES 1. All dimensions in mm unless otherwise stated 2. Length of squirrel is drawn using a scale of 1:20	KILIFI PLANTATIONS LIMITED	DATE: NOVEMBER 2001 PART NAME: THE SQUIRREL	SCALE: 1:10

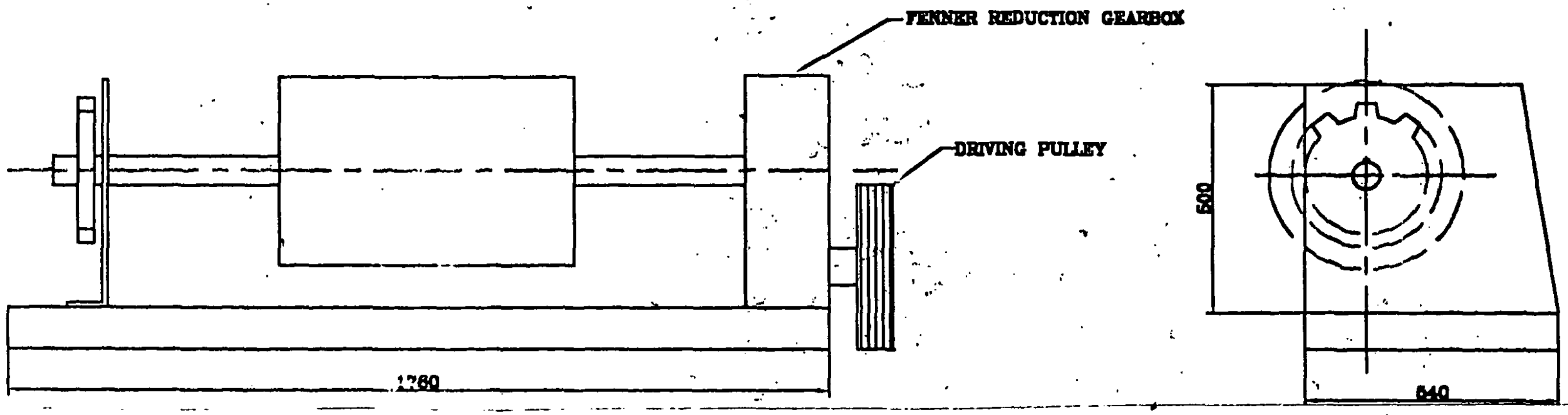


SECTION ALONG B–B OF ASSEMBLED SQUIRREL INCLUDING DRIVING MECHANISM

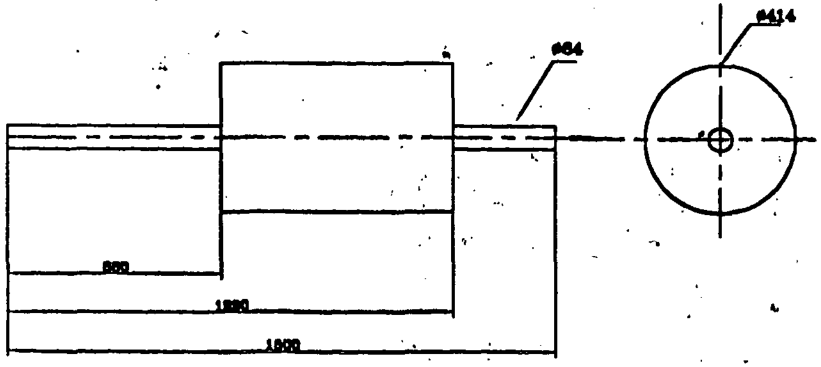
NB.
1. THE SQUIRREL AND ITS ACCESSORIES ARE MOUNTED ON THE BEAMS FRAMEWORK
2. THE TRAY IS OPENED AT THE BOTTOM AND AT BOTH ENDS BUT REINFORCED ALL ROUND



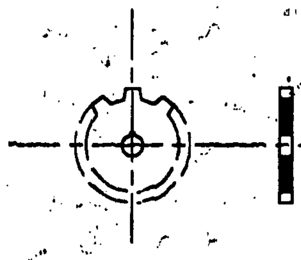
ASSEMBLY OF THE UPPER ROLLER AND ITS SUPPORT



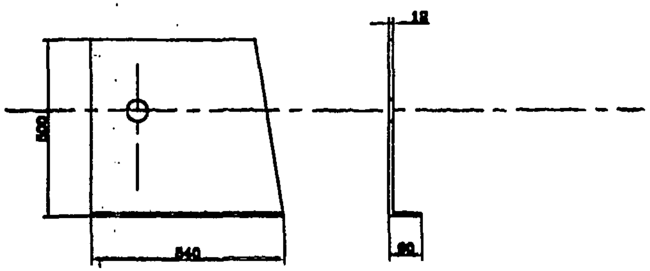
ASSEMBLY OF THE LOWER ROLLER AND ITS SUPPORT



SQUEEZING ROLLER (2 OFF)



ROLLERS DRIVING SPROCKET (2 OFF)



LOWER ROLLER SUPPORT (2 OFF)

2. ANIMAL FEEDING TRIALS

2.1 Introduction

Farmers in the tropics have limited resources for feeding their ruminant livestock. The main feedstuffs available are natural pastures, agro-industrial by-products and crop residues. Bogas (or bagasse as is referred to elsewhere; Preston and Leng, 1987) is a residue of fibre extraction from sisal (*Agave sisalana).* This can be used as manure for crop production or for livestock feeding. Where the animals are kept close to the source of bogas and it is available continuously, it can be fed fresh. It can also be ensiled to supplement dry season feeding.

The growing sisal industry in Mexico, South America and Africa generates growing amounts of by-products. Casso and Castro (1998) reviewed utilization of sisal by-products in Mexico. The review indicated that drying or ensiling where fermentation is completed in 10 days could preserve the pulp. The review also indicated that the main limitation to the productivity of animals fed sisal by-products was intake and that supplementation with molasses, protein and forages resulted in improved productivity. The review also reported studies that showed that ensiled sisal pulp appeared to be a poor source of fermentable organic matter, and that there was little advantage gained from ensiling sisal pulp where fresh bagasse was available. The authors of the review concluded that for reasonable animal performance, sisal waste should be fed together with a source of rumen undegradable protein, a source of readily available energy like molasses and a source of fibre to ensure optimal rumen function.

The earliest recorded use of sisal waste in Kenya was by Frank (1957) where cattle were supplemented with sisal waste. A study by Rodeseth (1965) showed that when Boran beef cattle were fed fresh sisal waste as a supplement to natural pastures during the dry season they maintained a better body condition than the non-supplemented group.

Bogas has been used for cattle feeding since the mid 1960s in Kilifi Plantations. This has been used to supplement natural grass silage fed to the cows during the dry season which can last up to 8 eight months. There has been many quantitative and qualitative developments made in use of bogas in Kilifi Plantations over the years. The objective

of the current study was to record, quantity and qualify the experience for the benefit of all the potential sisal producers and livestock keepers.
The study involved goats, sheep, beef steers and dairy cows.

2.2 Materials and Method

2.2.1 Description of the buildings

The animals were housed in well-ventilated stalls with individual feeding and watering facilities. The structures were made of blocks, iron roofed and a concrete floor, which had a slope to allow drainage of urine and wastewater used for cleaning. The structures are shown in Annex A.

2.2.2 Animals, treatments and trial period

For each of the trials, healthy animals were selected as follows:

Goats

The small East African goat was used for the study. The goat is mainly a browser, which depends on shrubs for its feed. A total of 42 one-month old entire male goats were selected for the study. These were divided into three groups whose initial mean weights were 20.5 ± 0.9, 19.1 ± 1.1 and 18.0 ± 0.7 for the fresh bogas, ensiled bogas and the Panicum diet respectively. The diet composition is shown in Table 2.1.
Half the feed was offered every morning after removing and weighing the refused feed. The other half was added in the afternoon. The concentrate was offered in a different trough (Plate 2.1).
The amount offered daily (0.58 kg DM) was at least 48% above the estimated daily intake (0.30 kg) for a goat weighing 12 kg and gaining 0.10 kg daily to allow for *ad libitum* feeding. Clean water and a mineral lick were available at all times to the animals, which were weighed monthly.
The treatment diets were offered to the animals for six months from 29 September 1999 to 31 March 2000.

Table 2.1 Composition [kg dry matter (DM)] of diets fed to sheep and goats

	Treatment Groups		
Ingredient	**Control**	**Fresh bogas**	**Ensiled bogas**
Panicum infestum	0.40	0.2	0.2
Fresh bogas	-	0.2	-
Ensiled bogas	-	-	0.2
Maize bran	0.09	0.09	0.09
Wheat bran	0.09	0.09	0.09
Total DM	**0.58**	**0.58**	**0.58**
Cost/animal/day (US$)	0.01	0.01	0.01
Metabolisable energy (MJ/kgDM)	7.9	8.1	8.1
Crude protein (g/kgDM	114	102	102

Sheep

A total of 30, 10-month old Dorper sheep were used for the experiment. The mean weight at the start of the experiment per treatment group was 21.5 ± 0.63, 20.5 ± 0.9 and 25.2 ± 0.5 kg for the fresh bogas, ensiled bogas and the Panicum diet respectively. Fourteen of the Sheep were fed on fresh bogas, 13 on ensiled bogas and 14 on the Panicum diet. The diet composition was similar to the one fed to goats (Table 2.1). They were offered treatment diets for six months from 11 December 1999 to 11 June 2000. Water and a mineral lick were available at all times and all the other procedures were as for the goats.

Beef

Three groups of 10 beef steers aged between 5-7 months and weighing an average 83 ± 3, 84 ± 3 and 89 ± 3 kg for the fresh bogas, ensiled bogas and the Panicum diet respectively were used for the study. They were of mixed genotypes of Friesian, Sahiwal and their crosses. The composition of the treatment diets is shown in Table 2.2. The animals were offered treatment diets for nine months starting on 29 September 1999 to 30 June 2000.

The feeds were offered in two equal proportions in the morning and afternoon. The amount offered daily (8.3 kg) was at least 14% above the estimated daily requirement (7.3 kg) for a 200 kg steer gaining 1 kg daily. Refused feed was removed before fresh feed was added in the morning. Clean water was provided at all times and the animals were weighed every three weeks.

Table 2.2 Composition (kg DM) of diets fed to beef steers

	Treatment Group		
Ingredient	**Control**	**Fresh bogas**	**Ensiled bogas**
Panicum infestum	3.60	1.00	1.00
Sisal boles	0.50	1.13	1.13
Cane molasses	0.60	0.23	0.23
Fresh bogas	-	1.80	-
Ensiled bogas	-	-	1.80
Maize bran	0.51	1.85	0.85
Maize germ meal	0.44	0.35	0.35
Wheat bran	2.73	2.64	2.64
Cotton seed cake	0.18	0.28	0.28
Urea	0.04	0.07	0.07
Total DM	**8.60**	**8.35**	**8.35**
Cost/steer/day (US$)	0.36	0.37	0.37
Metabolisable energy (MJ/kgDM)	9.20	9.50	9.50
Crude protein (g/kg)	135	141	141

Dairy Cows

The dairy cows were selected from a herd grazing natural pastures in Kilifi plantations. Their parity ranged from one to three and they were assigned treatment diets during their first to fifth month in lactation. It was proposed to start the experiment when cows had not reached peak production (3-4 months) but this was not possible. Except for five cows which calved between September and October 1999, all the others calved within a period of three months (June- August 1999).

The cows were assigned and randomised to the three treatment diets on the basis of genotype and current yield. Although this was aimed at having similar genotypes and milk yield at the start of the experiment, the average milk yield of cows receiving ensiled bogas was lower (8.6 kg) than the other two groups (10.1 and 10.3 for the control and fresh bogas respectively). A summary of the lactation parameters and genotypes of the dairy cows is shown in Table 2.3. The composition of the diets is shown in Table 2.4.

Table 2.3 Summary of lactation traits, means and ranges, and genotypes of dairy cows fed three different diets

Diet	No. of cows	No. of lactation	Stage of lactation (months)	Milk yield in first week of experiment (kg/d)	Genotypes		
					Friesian	Sahiwal	Crosses
Fresh bogas	12	1-3	1-4	10.3 (6.9-14.6)	5	2	5
Ensiled bogas	10	1-2	1-4	8.6 (5.4-10.9)	4	5	1
Panicum (control)	9	1-2	2-5	10.1 (8.1-12.1)	2	2	5

Table 2.4 Composition (kg DM) of diets fed to the cows

	Treatment Group		
Ingredient	**Control**	**Fresh bogas**	**Ensiled bogas**
Panicum/Kilifi Plantation silage	7.00	3.5	3.50
Sisal boles	0.25	0.25	0.25
Ensiled bogas	-	-	2.52
Fresh bogas	-	2.52	-
Cane molasses	1.13	1.13	1.13
Maize bran	1.31	1.31	1.31
Maize germ meal	1.32	1.32	1.32
Wheat bran	0.88	1.76	1.76
Copra cake	0.44	0.44	0.44
Cotton seed cake	0.93	0.93	0.93
Urea	0.06	0.06	0.06
Maclick plus	0.30	0.30	0.30
Limestone	9.80g	0.10	0.10
Total DM	**13.61**	**13.62**	**13.62**
Cost/cow/day (US$)	0.62	0.61	0.61
ME (MJ/kg DM)	9.80	10.0	10.0
Crude protein (g/kg)	102	107	107

The diet was at least 13% more than the estimated dry matter intake (12.1 kg per day) for a cow weighing 425 kg, yielding 15 kg of milk daily with no weight change to allow for *ad libitum* feeding. The Panicum, sisal bole and bogas were offered in a different feed trough from the concentrate. Clean water was offered at all times. The cows were hand milked twice daily at 4.00 and 15.00 hrs. The experiment was carried out over a period of 33 weeks starting on 30 October 1999 to 31 July 2000.

2.3 Results

All classes of animals consumed all the concentrate. Left over forage was difficult to quantify due to spillage from the trough and tramping. It was therefore difficult to determine DM intake. An attempt was made to determine intake for the cows, which had minimal spillage. Live weight data is reported for sheep, goats and steers while DM intake and milk yield is reported for the cows.

2.3.1 Sheep and goats

The growth performance of both species on all the three diets was poor. It was decided that the results did not warrant formal analyses of variance. Means were calculated for initial body weight, final body weight and weight-change during the experiment, together with their standard errors..

Out of the 42 goats at the start of experiment, nine died from various causes as shown in Table 2.5. Four out of the nine deaths were due to lactic acidosis. This was because the goats preferred to eat the concentrate first leaving the forage part of the diet. Three of the sheep also died of acidosis. A mixed diet for these two types of animals may have been a better option to avoid this problem. The other major cause of death was starvation and some of the animals that survived refused to eat and hence the low live weight gains. Unlike the goats, sheep gained some weight during the last two months of the experiment (Fig 2.1 and 2.2). This may have been a result of the sheep acclimatizing to the experimental conditions. The sheep were not weighed in March and data for this month is extrapolated in the figure. Live-weight changes and causes of death are shown in Table 2.5.

The poor performance of both the sheep and goats and lack of records for sheep in March and June made it difficult to make conclusions on the suitability of feeding them on sisal bogas. The initial live weight of the sheep fed Panicum was relatively higher than for the other groups and remained high throughout the experiment. The initial live weight of the goats was different for the three groups and the data does not give any indications of treatment differences. Statistical analyses of the data were not carried out because of the high mortality and lack of acclimatization to the experimental conditions. The raw data is given in Annex B to E.

Fig 2.1. Live weights (kg) for sheep fed fresh bogas, ensiled bogas or Panicum

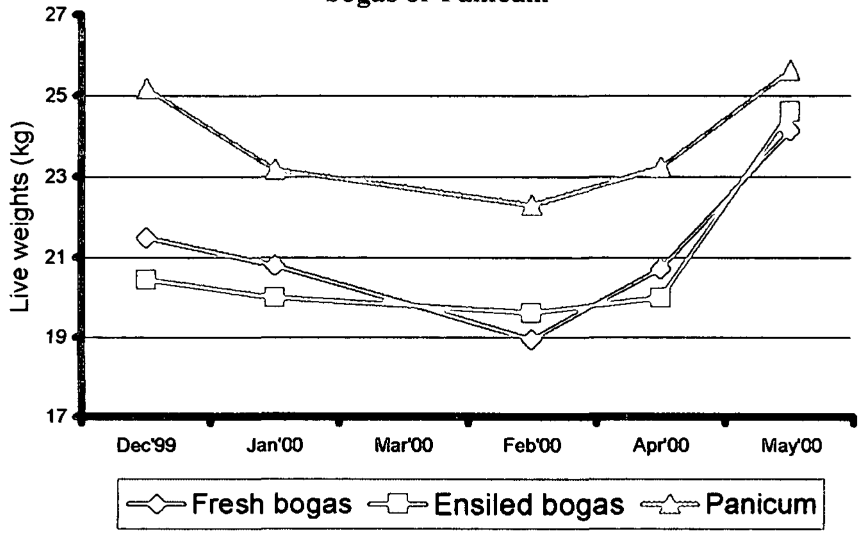


Fig 2.2 Live weights (kg) for goats fed fresh bogas, ensiled bogas or panicum

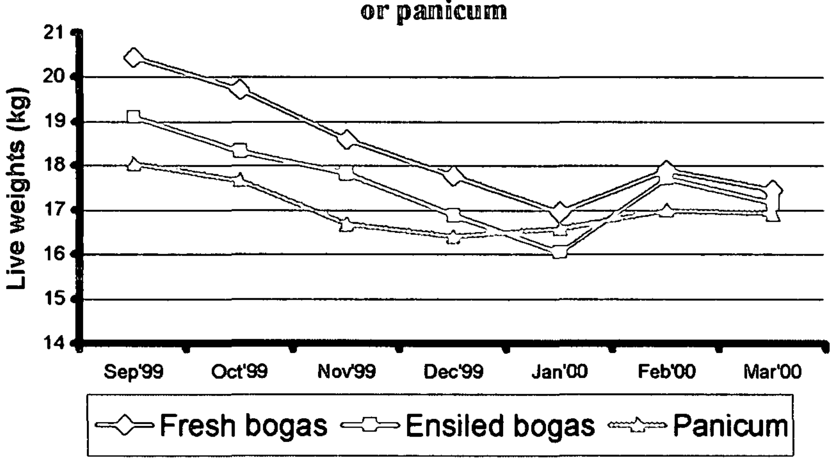


Table 2.5 The performance of sheep and goats fed different diets

	Number at the start	Number that died and cause	Number that survived	Initial weight (kg)	Weight gain (kg)
Sheep					
Fresh bogas	14	1 acidosis	13	21.5 ± 0.6	2.7 ± 0.6
Ensiled bogas	13	1 acidosis	12	20.5 ± 0.9	4.2 ± 0.6
Panicum control	14	2 asphyxiated 1 acidosis	11	25.2 ± 0.5	0.5 ± 0.3
Goats					**Weight loss (kg)**
Fresh bogas	14	1 starvation 1 acidosis 1 pneumonia	11	20.5 ± 0.9	3.0 ± 0.9
Ensiled bogas	14	1 starvation 1 acidosis 5 pneumonia	9	19.1 ± 1.1	1.9 ± 1.1
Panicum	14	2 acidosis 1 leg fracture	11	18.0 ± 0.7	1.1 ± 0.7

Beef cattle

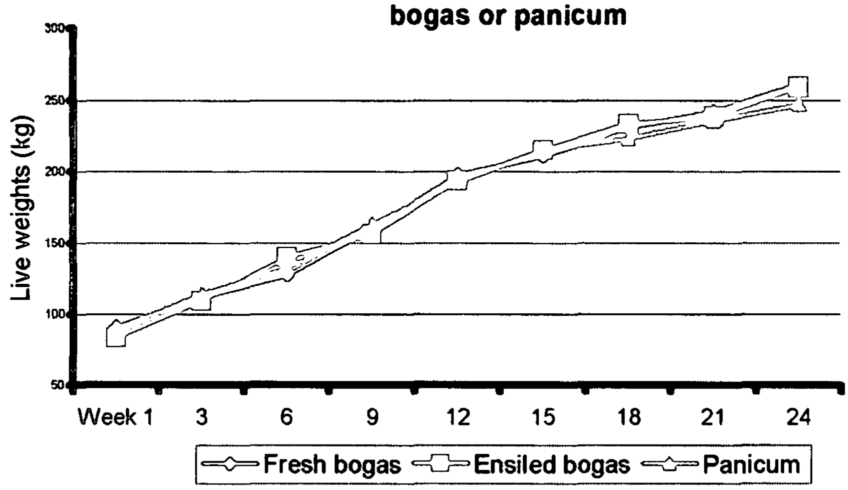
The animals were in good health and none died throughout the experiment. Growth rates were calculated for each animal by linear regression of body weight on week of measurement. Mean values of growth rate, initial and final body weights were calculated for each dietary treatment together with their standard errors. Means were similar and analyses of variance was not necessary (Table 2.6).

The average growth rate was statistically similar between the three groups. Figure 2.3 shows the 3-weekly live weights. Growth rate was linear (7.2 ± 0.2 kg/week) throughout the experiment.

Table 2.6 Growth rate of steers fed different diets over 24 weeks.

	Number	Initial weight (kg) (week 1)	Final weight (kg) (week 24)	Average growth rate (kg/week)
Fresh bogas	10	83 ± 3	239 ± 9	6.9± 0.44
Ensiled bogas	10	84 ± 3	260 ± 8	7.6 ± 0.37
Panicum	10	89 ± 3	247 ± 8	7.0 ±0.25

Fig 2.3 Live weights (kg) for steers fed fresh bogas, ensiled bogas or panicum



2.3.3 Dairy cows

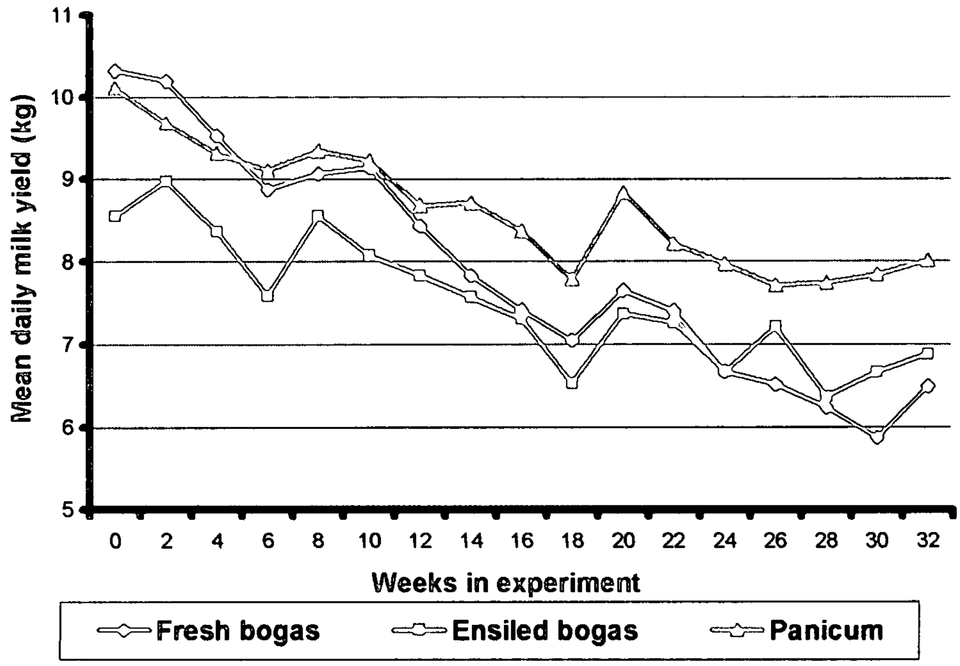
Cows fed ensiled bogas had a lower initial yield than the other groups and therefore milk yield at the start of the experiment was used as a covariate in milk yield analysis. The decline in milk yield for each cow was calculated by linear regression of milk yield on week of experiment. Effects of other factors like lactation number, stage of lactation and genotype were also examined but none were found to be significant. Four cows did not acclimatize to the experiment and were removed. One of the cows on ensiled bogas had low milk yield (1.3 kg/day). This is why the numbers per treatment were not the same. Eight of the animals suffered from ailments ranging from abscesses, hind limb weakness and foot rot. Six of the animals were from the fresh bogas treatment while seven of the cows fed fresh bogas were dried before 32 weeks in experiment. Similarly, three of the cows fed ensiled bogas and two fed the control diet were dried off before the end of the experiment. The mean daily DM intake for cows fed bogas was significantly ($P<0.01$) lower than that of cows fed the control diet. The control group would have been expected to produce more milk than cows fed bogas. Although the effect of diet on live weights and body condition was not quantified cows fed bogas were generally weak and this may have been associated with the low DM intakes. Average milk production for cows fed fresh bogas tended to be less than for the other two treatments (Table 2.7). The 0.5 kg difference in milk production was not statistically significant ($P>0.05$).

Table 2.7 Mean average milk yield and decline in cows fed over 33 weeks

Treatment diet	No. of cows	Mean DM Intake (kg/d)	Mean milk yield (kg/d)[a]	Mean decline in milk yield (kg/day[a]	No. of cows with clinical ailments[b]	No. dried off before 32 weeks in experiment
Fresh bogas	12	4.3	7.8	0.115	6	9
Ensiled bogas	10	4.4	8.3	0.097	2	3
Panicum	9	7.0	8.3	0.072	0	2
Average SED[a]		0.24	0.50	0.0220		

[a] average standard error of difference between each bogas feed and the control.

Fig. 2.4 Mean daily milk yield (kg) of cows fed fresh bogas, ensiled bogas or panicum



The decline in milk yield per week for the cows fed bogas also tended to be lower than that of cows fed the control diet (0.097 litres/day). Fig. 2.4 shows the daily average milk yield for every fortnight. By the end of the experiment, the group fed fresh bogas had only 3 cows left while the group fed ensiled bogas had seven cows. The treatment differences were however not significant because cows with ailments were dried off as early as the 14th week from the bogas treatment. In practical terms, this would lead to loss in total production. Over the 33 weeks experimental period, the cows fed bogas produced less total milk than cows on each of the other diets.

The fresh sisal bogas had deleterious effect on performance and was unable to sustain milk production. Ensiling it led to an improvement in performance. This would therefore be the preferred form of bogas, which can also be stored for use during the dry period.

2.4 Conclusions and practical implications

Bogas is not as good as natural pastures nutritionally but can be used as an additional source of fodder or as a "replacement' to non-existent fodder during the dry season. The

The constraints associated with the use of sisal waste as feed for ruminants relate partly to the organic acids mainly lactic and oxalic (Preston and Leng, 1987). Naseveen and Harrison, (1981) found that cattle fed sisal waste developed acidosis and barely maintained body weight. Bogas used in the current studies had high lactic and oxalic acids (1 and 5.2% in DM respectively).

From these studies, it is evident that none of the diets used were suitable for the sheep and goats. The weight gained by sheep was negligible over the six- months while the goats lost weight in all the treatments. It is therefore difficult to make any conclusions on use of sisal bogas for sheep and goats. It might have been better to feed the bogas under free grazing with no sources of readily available carbohydrates (maize bran and wheat bran) since shoats seem to be more prone to acidosis than the other livestock. It is not clear from the study whether acidosis was associated with bogas or the bran

The steers gained about 1 kg daily, which was expected from the diet offered. There were no differences between the control and bogas diets. Where bogas is available, it can be used for feeding steers either in the fresh or ensiled form. A number of the dairy cows did not acclimatize to the diets and 12 of the animals were dried off before 32 weeks in the experiment. The short lactation would translate into low lactation milk yields and loss of income for the farmer. The average decline in milk yield tended to be higher for the animals fed bogas compared to those on Panicum. This was however not statistically significant and it can be concluded that there was no significant difference in milk persistency between cows fed bogas diets and the control.

The bogas diets used in these studies were however not suitable for lactating cows due to the associated ailments and the short lactation. These diets cannot be recommended for lactating cows. Further studies are required to establish the effect of bogas on rumen fermentation and nutrient metabolism.

2.5 References

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Preston, T. R. and R. A. Leng. 1987. Matching ruminant production systems with available resources in the tropics and sub-tropics. CTA, Penambul Books, Armidale

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2.6 Plates and Annexes

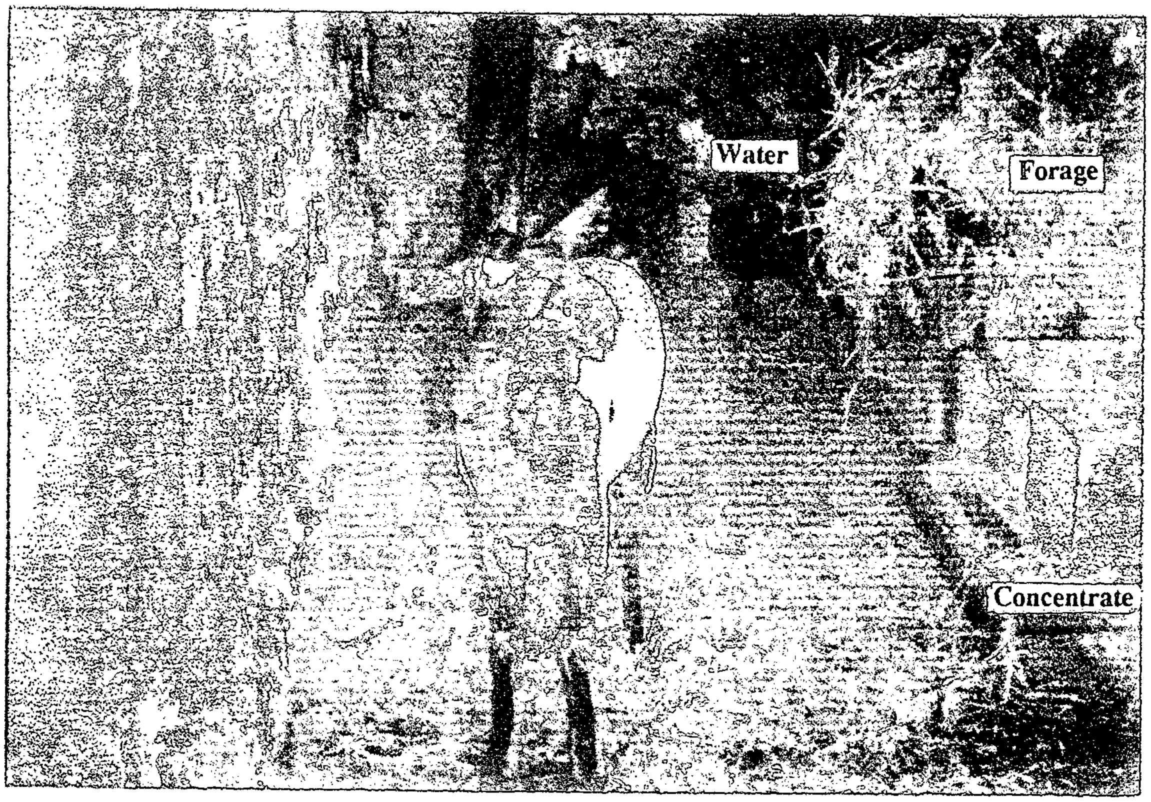


Plate 2.1 Feeding facilities for the goats

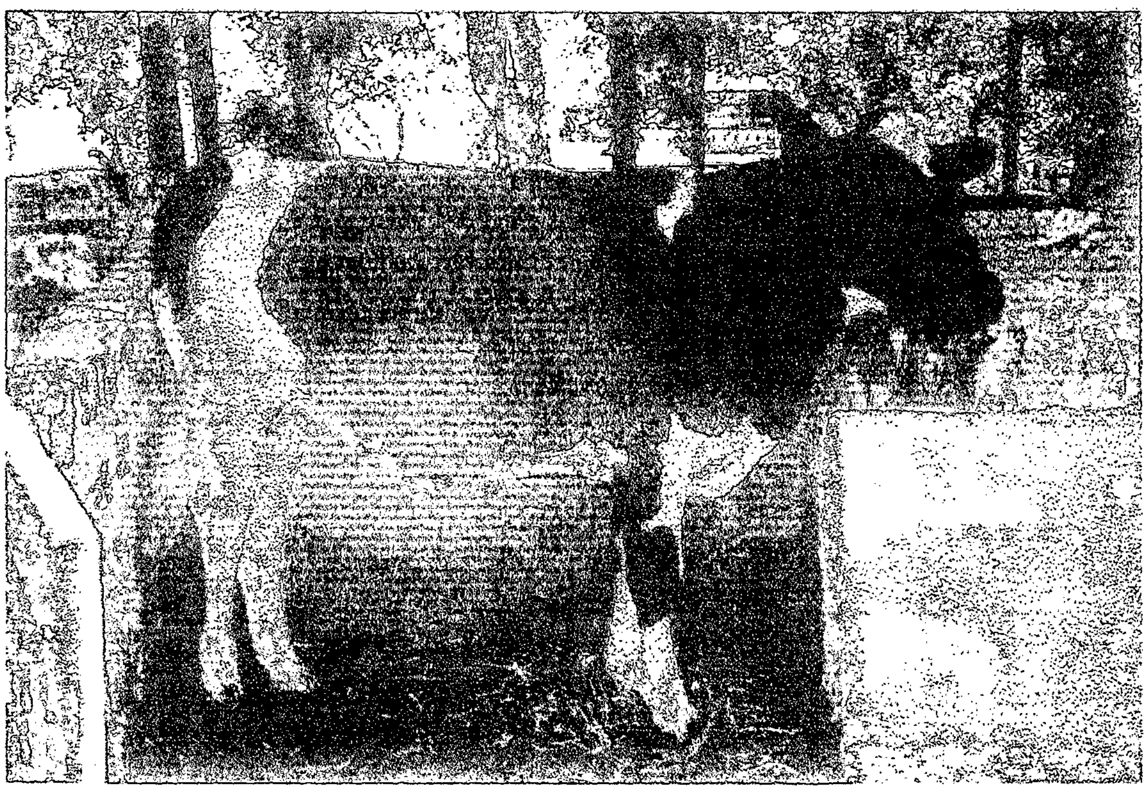


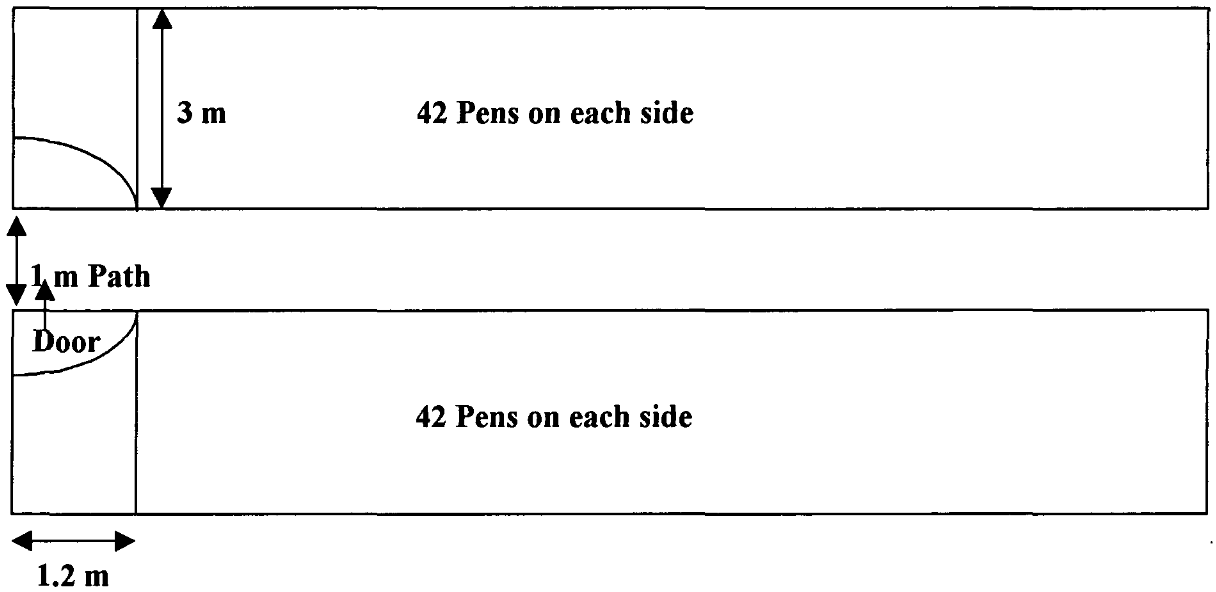
Plate 2.2 A Friesian steer

Plate 2.3 A Sahiwal steer

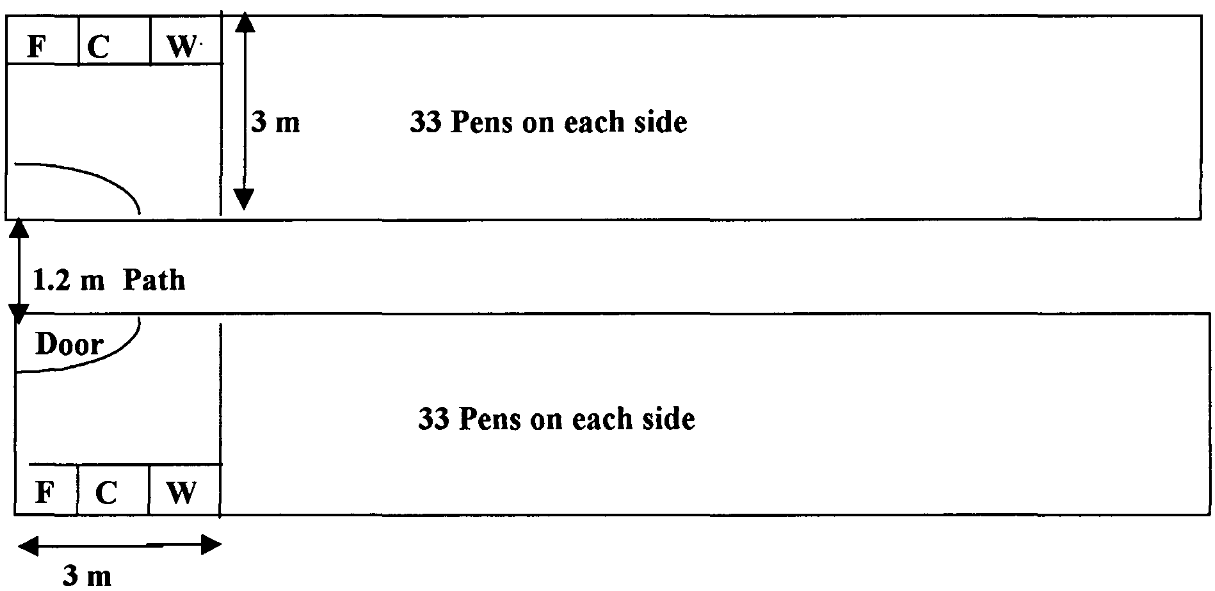
Plate 2.4 A Crossbred cow

Annex A. Stalls used to house the experimental animals

A. SHEEP AND GOAT PENS



B. BEEF AND DAIRY COW PENS



F fodder, **C** concentrate, **W** water troughs

NB
Store and milking parlour located close to the cow pens

Drawing not to scale

Annex B. Values used to calculate means reported for sheep

Animal No.	Treatment Group	Initial weight (kg)	Average weight (kg)	weight gain (kg)
KSO1	Fresh bogas (A)	22.0	22.3	5.0
KSO2	A	25.0	23.5	1.0
KS03	A	24.0	24.1	3.0
KS04	A	20.5	20.5	3.5
KS05	A	24.0	22.4	1.0
KS06	A	24.0	23.0	3.0
KS07	A	21.0	19.4	2.0
KS08	A	19.0	20.1	4.0
KS09	A	20.0	21.6	5.0
KS11	A	19.0	19.3	4.0
KS12	A	21.0	22.4	5.0
KS13	A	20.0	18.7	-1.0
KS14	A	20.0	18.7	-1.0
KS15	A	23.0	22.0	2.5
KS16	Ensiled bogas (B)	20.0	19.4	3.0
KS18	B	20.0	22.0	7.0
KS19	B	14.0	16.2	8.0
KS21	B	20.5	21.9	5.5
KS22	B	24.0	21.2	1.0
KS23	B	24.0	24.6	4.0
KS24	B	23.0	22.9	4.0
KS25	B	19.0	19.7	3.0
KS26	B	21.0	21.8	4.0
KS27	B	16.0	18.7	6.0
KS28	B	21.0	20.9	2.0
KS29	Panicum (C)	24.0	24.3	3.0
KS30	C	26.0	26.1	4.0
KS31	C	27.0	27.0	2.0
KS32	C	22.0	21.3	3.0
KS34	C	24.0	23.1	-0.5
KS35	C	25.0	22.1	-3.0
KS36	C	26.0	23.0	-2.0
KS37	C	24.0	23.4	2.0
KS38	C	27.0	25.1	-1.0
KS39	C	27.0	24.1	1.0
KS40	C	25.0	23.5	1.5

Annex C. Live weights (kg) recorded for sheep from which reported mean values were calculated.

Sheep No.	KS01	KS02	KS03	KS04	KS05	KS06	KS07	KS08	KS09	KS11	KS12	KS13	KS14
Group	A	A	A	A	A	A	A	A	A	A	A	A	A
Dec 1999	22.0	25.0	24.0	20.5	24.0	24.0	21.0	19.0	20.0	19.0	21.0	20.0	20.0
Jan 2000	22.5	23.5	23.8	20.5	20.5	22.2	20.0	18.2	21.2	18.5	21.8	19.0	19.0
Feb	19.0	20.0	21.5	18.5	20.5	20.0	15.0	19.0	21.0	17.0	20.0	17.5	17.5
Apr	21.0	23.0	24.0	19.0	22.0	22.0	18.0	21.5	21.0	19.0	23.0	18.0	18.0
May	27.0	26.0	27.0	24.0	25.0	27.0	23.0	23.0	25.0	23.0	26.0	19.0	19.0

Sheep	KS15	KS16	KS18	KS19	KS21	KS22	KS23	KS24	KS25	KS26	KS27	KS28
Group	B	B	B	B	B	B	B	B	B	B	B	B
Dec	23.0	20.0	20.0	14.0	20.5	24.0	24.0	23.0	19.0	21.0	16.0	21.0
Jan	21.0	19.0	21.0	15.5	22.5	19.0	24.0	21.5	18.0	21.0	16.5	21.0
Feb	20.5	18.5	21.0	14.5	19.0	19.0	23.0	20.0	21.0	19.0	21.0	19.0
Apr	20.0	16.5	21.0	15.0	21.5	19.0	24.0	23.0	18.5	23.0	18.0	20.5
May	25.5	23.0	27.0	22.0	26.0	25.0	28.0	27.0	22.0	25.0	22.0	23.0

Sheep	KS29	KS30	KS31	KS32	KS34	KS35	KS36	KS37	KS38	KS39	KS40
Group	C	C	C	C	C	C	C	C	C	C	C
Dec	24.0	26.0	27.0	22.0	24.0	25.0	26.0	24.0	27.0	27.0	25.0
Jan	23.5	24.5	26.5	20.5	22.5	22.0	23.5	23.0	24.0	21.5	23.5
Feb	23.0	23.0	24.0	19.5	23.0	21.5	20.0	22.5	24.0	22.0	23.0
Apr	24.0	27.0	28.5	19.5	22.5	20.0	21.5	21.5	24.5	24.0	22.5
May	27.0	30.0	29.0	25.0	23.5	22.0	24.0	26.0	26.0	26.0	23.5

Annex D. Values used to calculate means reported for goats

Animal No.	Group	Initial weight (kg)	Average weight (kg)	Weight loss (kg)
KG01	A	24.0	21.6	2.0
KG03	A	17.0	18.6	+3.0 (gain)
KG04	A	26.0	20.1	9.0
KG05	A	20.0	16.9	5.0
KG06	A	18.0	16.1	2.0
KG08	A	19.0	18.6	0.0
GK09	A	19.0	17.1	3.0
KG10	A	22.0	19.8	3.0
KG11	A	20.0	19.4	4.0
KG12	A	25.0	21.4	4.0
KG13	A	15.0	12.7	4.0
KG15	B	25.0	21.7	3.0
KG18	B	19.0	18.1	2.0
KG19	B	17.0	15.4	4.0
KG22	B	15.0	17.5	+3.0
KG23	B	22.0	17.5	6.0
KG24	B	18.0	17.6	0.0
KG25	B	21.0	16.8	6.5
KG26	B	20.0	19.0	0.0
KG28	B	15.0	14.8	+1.0
KG29	C	19.0	19.1	0.0
KG32	C	20.0	17.1	5.0
KG33	C	21.0	19.6	1.0
KG34	C	15.0	15.1	+0.5
KG36	C	17.0	16.2	1.5
KG36	C	14.0	15.1	+4.0
KG38	C	18.0	16.9	1.5
KG39	C	20.0	18.4	2.0
KG40	C	20.0	19.7	0.0
KG41	C	20.0	18.4	2.0
KG44	C	14.0	11.9	4.0

Annex E. Body weights recorded for goats from which reported mean values were calculated.

Goat No.	KG01	KG03	KG04	KG05	KG06	KG08	KG09	KG10	KG11	KG12	KG43
Group	A	A	A	A	A	A	A	A	A	A	A
Sep	24.0	17.0	26.0	20.0	18.0	19.0	19.0	22.0	20.0	25.0	15.0
Oct	23.5	17.0	25.0	19.5	17.5	18.5	18.0	21.0	19.0	24.0	14.0
Nov	20.6	17.8	23.0	17.0	17.5	18.6	17.5	20.0	18.5	20.0	14.0
Dec	20.0	19.0	20.0	16.0	15.0	18.0	16.5	19.0	20.0	19.0	13.0
Jan	20.0	19.5	14.0	15.0	14.5	18.0	16.0	18.0	20.0	19.5	12.0
Feb	21.0	20.0	15.5	15.5	14.5	19.0	17.0	19.5	22.0	21.0	12.0
Mar	22.0	20.0	17.0	15.0	16.0	19.0	16.0	19.0	16.0	21.0	11.0

Goat No.	KG15	KG18	KG19	KG22	KG23	KG24	KG25	KG26	KG28
Group	B	B	B	B	B	B	B	B	B
Sep	25.0	19.0	17.0	15.0	22.0	18.0	21.0	20.0	15
Oct	24.0	18.5	17.0	15.0	19.0	16.0	21.0	20.0	14.5
Nov	22.0	18.0	16.5	16.0	20.0	16.0	19.0	19.0	14.0
Dec	20.0	18.0	15.0	18.0	16.0	17.0	15.0	18.0	15.0
Jan	16.0	18.0	14.5	19.5	14.5	18.0	13.0	17.0	14.0
Feb	23.0	18.0	14.5	21.0	15.0	20.0	14.0	19.0	15.0
Mar	22.0	17.0	13.0	18.0	16.0	18.0	14.5	20.0	16.0

Goat No.	KG29	KG32	KG33	KG34	KG35	KG36	KG38	KG39	KG40	KG41	KG44
Group	C	C	C	C	C	C	C	C	C	C	C
Sep	19.0	20.0	21.0	15.0	17.5	14.0	18	20.0	20.0	20.0	14.0
Oct	19.0	19.5	21.0	14.5	17.0	13.0	17.5	20.0	20.0	19.0	14.0
Nov	18.0	18.0	18.0	14.0	16.0	13.0	17.5	19.0	19.0	18.0	13.0
Dec	19.0	17.0	18.0	15.0	15.5	15.0	16.5	18.0	18.5	17.0	11.0
Jan	20.0	16.0	19.0	15.0	15.0	16.0	16	16.5	20.0	18.5	10.5
Feb	19.5	14.0	20.0	16.5	16.5	17.0	16.5	17.5	20.5	18.0	11.0
Mar	19.0	15.0	20.0	15.5	16.0	18.0	16.5	18.0	20.0	18.0	10.0

Annex F. Live weight (kg) and growth rate (kg/week) for steers used for statistical analysis

Animal No.	Group	Weight Week 1	Weight Week 24	Growth rate
J252	A	95	300	9.181
J406	A	105	265	7.858
J230	A	97	250	7.182
J256	A	95	270	7.819
J312	A	87	260	8.257
J390	A	94	245	5.862
J472	A	75	270	8.446
J258	A	96	270	8.266
J248	A	97	285	8.055
J574	A	70	195	4.503
J232	B	97	290	8.090
J314	B	86	260	7.713
J582	B	75	280	8.162
J452	B	81	220	5.436
J468	B	78	270	8.781
J282	B	75	275	8.769
J414	B	80	275	8.466
J288	B	86	260	7.562
J284	B	97	250	7.078
J320	B	83	215	5.785
J504	C	82	250	7.454
J404	C	78	250	7.263
J210	C	95	235	6.373
J336	C	92	260	7.567
J272	C	101	270	6.952
J498	C	83	210	6.114
J266	C	90	280	8.090
J304	C	85	235	6.658
J228	C	103	270	7.777
J576	C	77	210	5.550

Annex G. **Body weights recorded for steers from which values were calculated for statistical analysis**

Steer No.	J252	J406	J230	J256	J312	J390	J472	J258	J248	J574
Group	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**
Week 1	95	105	97	95	87	94	75	96	97	70
3	130	109	118	127	107	107	99	108	129	88
6	126	150	120	130	125	120	125	105	125	150
9	150	175	148	150	160	160	168	140	165	179
12	255	185	195	220	210	170	180	195	220	150
15	240	210	220	220	230	190	210	220	220	150
18	255	255	235	250	250	180	240	230	250	170
21	280	275	235	250	255	200	245	250	250	185
24	300	265	250	270	260	245	270	270	285	195

Steer No.	J232	J314	J582	J452	J468	J282	J414	J288	J284	J320
Group	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**
Week 1	97	86	75	81	78	75	80	86	97	83
3	123	114	103	89	116	101	104	124	120	99
6	230	150	128	126	125	130	130	136	125	120
9	129	175	150	158	155	155	169	165	159	145
12	230	200	185	140	210	200	200	215	200	160
15	268	235	210	155	230	220	225	220	215	175
18	255	250	240	170	255	240	240	240	235	215
21	280	250	215	195	265	255	250	250	240	190
24	290	260	280	220	270	275	275	260	250	215

Steer No.	J504	J404	J210	J336	J272	J498	266	J304	J228	J576
Group	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**
Week 1	82	78	95	92	101	83	90	85	103	77
3	104	103	125	107	134	95	129	119	139	86
6	139	130	130	148	120	130	135	128	120	145
9	170	175	164	159	149	168	160	150	160	180
12	185	180	190	220	210	150	200	200	220	170
15	205	215	210	250	230	175	240	205	245	175
18	255	225	225	190	180	255	240	215	255	195
21	230	225	235	270	250	200	255	235	255	205
24	250	250	235	260	270	210	280	235	270	210

Annex H. Values used for statistical analysis for dairy cattle

Cow No.	Treatment group	Breed	Initial milk yield (kg)	Calving date	Month of lactation	Lactation number	Ave. milk yield (kg)	Ave. decline (kg/w)	Weeks milked	Disease
E408	A	Cross (C)	13.0	21/09/1999	1	2	8.6	0.195	33	1
E581	A	Friesian (F)	10.0	16/08/1999	2	2	8.8	0.187	27	1
F729	A	F	12.9	25/07/1999	3	1	11.1	0.086	21	1
E933	A	F	8.3	18/06/1999	4	1	7.8	0.096	17	
E277	A	C	14.6	20/10/1999	0	2	11.2	0.208	28	1
E113	A	F	10.7	27/09/1999	1	3	7.9	0.133	33	
G309	A	Sahiwal (S)	10.4	10/07/1999	4	1	8.0	0.104	26	
D403	A	F	8.4	25/07/1999	3	3	8.6	0.022	14	
E141	A	C	11.7	01/07/1999	4	1	8.7	0.123	33	1
E929	A	C	9.0	23/07/1999	3	1	7.7	0.077	32	1
D615	A	C	8.0	14/08/1999	2	2	7.2	0.103	24	
G609	A	S	6.9	05/09/1999	2	1	3.5	0.113	32	
E583	B	F	10.9	25/08/1999	2	2	10.3	0.147	33	
F553	B	F	9.3	25/07/1999	3	1	8.9	0.056	33	
E985	B	F	9.0	03/08/1999	3	2	7.3	0.086	33	
F139	B	S	7.4	05/07/1999	4	1	6.2	0.097	33	
F743	B	S	8.9	03/07/1999	4	1	8.2	0.05	27	
F343	B	S	8.0	14/07/1999	3	1	8.1	0.034	33	1
F933	B	S	7.6	14/09/1999	1	1	7.5	0.015	33	
E267	B	F	9.4	31/07/1999	3	2	7.8	0.089	28	
D271	B	S	9.6	05/08/1999	3	2	7.1	0.154	33	1
E371	B	C	5.4	14/06/1999	4	2	2.9	0.152	25	
E657	C	F	11.9	05/06/1999	5	2	8.4	0.139	33	
E983	C	F	8.7	03/07/1999	4	1	8.4	0.112	24	
F065	C	C	9.4	21/07/1999	3	1	7.8	0.07	33	
E763	C	C	11.8	04/07/1999	4	2	11.7	0.004	33	
F495	C	S	10.4	27/08/1999	2	1	8.8	0.061	33	
E5.7	C	S	8.2	25/06/1999	4	2	8.1	0.047	17	
F293	C	C	8.1	12/07/1999	4	1	7.5	0.098	33	
E855	C	C	10.4	10/07/1999	4	1	7.8	0.081	33	
F145	C	C	12.1	19/08/1999	2	2	8.9	0.067	33	

Annex I. Milk yields recorded for dairy cattle from which values were calculated for statistical analysis.

Cow No.	E407	E581	F729	E933	E277	E113	G309	D403	E141	E929	D615	G609
Group	A	A	A	A	A	A	A	A	A	A	A	A
Week 1	13.0	10.0	12.9	8.3	14.6	10.7	10.4	8.4	11.7	9.0	8.0	6.9
2	12.9	10.7	12.4	8.1	14.9	10.3	9.0	8.0	10.6	8.7	8.0	4.5
3	13.0	12.7	12.6	9.0	13.6	10.7	9.1	9.6	12.0	9.3	9.0	6.1
4	11.1	11.0	12.4	8.6	13.9	8.1	9.0	8.4	11.0	9.0	7.8	5.0
5	12.7	10.9	11.1	8.1	12.6	8.9	9.0	7.9	10.4	9.1	7.6	5.0
6	11.6	8.9	11.0	7.4	12.6	8.7	8.1	9.0	9.7	9.1	7.3	4.6
7	10.7	8.4	10.4	7.9	12.3	8.9	8.1	9.7	8.4	8.7	6.9	4.4
8	11.0	9.3	8.9	7.6	11.7	8.7	8.9	8.6	10.4	9.6	8.3	4.0
9	11.3	10.9	10.3	8.6	12.6	9.6	9.1	8.6	8.9	7.2	9.0	4.5
10	9.1	11.3	11.0	8.0	12.1	9.7	8.6	9.0	9.9	6.3	8.4	3.6
11	9.7	11.0	11.0	8.4	12.7	8.9	8.3	8.6	9.7	9.0	7.9	7.3
12	10.7	9.7	10.5	7.7	11.2	8.7	8.1	9.0	9.1	8.9	8.0	2.9
13	8.6	9.6	12.0	7.0	11.3	8.0	7.9	7.9	8.3	7.3	6.8	3.3
14	7.4	8.0	11.4	7.4	10.9	8.3	7.3	7.9	7.6	7.7	6.3	2.9
15	7.0	8.3	11.6	8.4	10.9	8.3	7.3		7.5	7.0	7.0	3.7
16	7.6	8.7	11.0	6.6	10.9	7.3	7.3		7.9	5.0	6.7	3.9
17	7.0	7.6	10.9	6.2	9.9	8.3	7.1		8.1	5.5	6.5	3.2
18	6.6	5.5	9.0		10.4	7.4	5.9		7.9	5.9	4.4	2.1
19	7.4	7.1	11.3		9.9	7.3	7.1		9.3	7.3	6.9	2.3
20	3.4	7.3	11.0		12.0	8.8	7.3		10.0	9.7	8.3	2.0
21	4.7	7.0	9.6		10.3	7.4	7.0		7.7	10.1	7.4	2.1
22	6.1	7.6			10.9	8.4	8.0		9.3	9.3	7.0	2.4
23	7.3	7.3			8.9	7.6	8.0		8.4	7.9	7.0	2.0
24	6.9	7.6			9.6	8.0	6.9		7.7	7.4	3.5	2.0
25	7.0	6.5			7.7	7.6	7.1		8.1	7.8		2.0
26	7.2	7.4			8.4	5.1	7.1		7.6	7.0		2.6
27	7.5	6.5			8.6	5.4			6.9	6.9		3.6
28	8.9				9.2	5.6			6.7	6.0		2.6
29	7.4					5.9			7.6	6.5		2.5
30	7.3					5.9			7.6	5.6		2.7
31	6.8					5.8			7.0	7.4		2.7
32	7.6					5.7			7.4	6.1		2.7
33	7.3					7.3			6.9			

Cow No.	E583	F553	E985	F139	F743	F343	F933	E267	D271	E371
Group	B	B	B	B	B	B	B	B	B	B
Week 1	10.9	9.3	9.0	7.4	8.9	8.0	7.6	9.4	9.6	5.4
2	12.7	10.4	8.4	7.3	9.7	9.0	7.6	8.5	8.4	5.5
3	12.7	11.0	8.4	8.3	9.8	10.0	8.4	9.4	8.4	5.5
4	11.9	9.4	8.0	7.5	7.6	9.0	7.5	8.5	8.6	5.1
5	12.3	10.1	7.9	7.9	8.8	8.0	7.8	8.5	8.9	4.1
6	11.2	8.1	8.0	7.1	9.1	7.0	6.8	7.6	8.3	3.3
7	10.9	8.3	7.7	6.6	7.8	8.0	6.3	8.3	8.0	3.5
8	13.0	9.9	9.0	7.5	7.8	9.0	8.5	8.9	8.8	4.0
9	12.1	10.3	9.1	7.4	8.8	8.0	8.5	9.0	7.6	3.8
10	12.4	10.7	8.7	7.1	8.1	8.0	7.6	8.4	7.4	3.0
11	11.6	9.1	8.1	7.0	7.8	8.0	7.8	8.8	10.0	1.9
12	11.9	9.3	8.0	8.1	8.9	8.0	7.8	8.1	9.4	2.3
13	11.3	8.1	7.9	6.3	8.3	8.0	7.4	7.6	8.1	1.9
14	10.9	9.0	7.6	7.4	8.1	9.0	7.5	7.9	6.3	2.0
15	10.9	8.9	7.9	5.1	9.1	8.0	8.0	7.8	7.3	2.8
16	11.1	9.0	7.0	6.1	7.4	8.0	7.1	7.9	8.6	2.0
17	10.6	10.1	6.1	5.4	8.0	7.0	6.6	7.6	8.5	2.0
18	8.3	5.0	4.1	2.8	6.1	9.0	6.4	6.1	5.6	2.0
19	10.4	9.0	6.9	6.3	8.0	10.0	7.4	7.9	7.4	2.0
20	11.3	10.3	7.1	6.3	8.8	7.0	7.8	7.6	8.4	2.0
21	8.9	8.8	6.9	6.3	8.1	7.8	7.5	7.4	7.2	2.0
22	9.0	8.0	6.7	5.4	7.5	8.0	8.0	6.9	7.1	2.0
23	10.3	9.1	7.6	5.8	8.6	11.0	7.6	7.1	7.6	1.9
24	9.3	8.3	6.7	5.4	7.8	7.0	7.4	6.6	6.4	1.9
25	8.9	8.1	6.6	6.0	7.0	7.0	7.6	7.1	6.4	2.0
26	8.6	8.3	7.3	6.8	7.6	8.0	8.4	7.1	6.8	
27	8.1	7.4	5.7	4.9	8.1	7.0	8.1	6.8	4.8	
28	7.9	8.3	5.7	4.0		8.0	7.8	6.5	3.7	
29	7.7	7.3	6.3	5.6		6.0	6.6		4.3	
30	8.1	8.6	6.4	4.8		8.0	7.1		4.9	
31	8.2	9.0	5.4	4.5		8.0	6.5		3.8	
32	9.4	8.4	6.4	5.0		8.0	7.1		4.0	
33	8.4	9.0	7.1	5.3		7.0	6.9		4.3	

Cow No.	E657	E983	F065	E763	F495	E507	F293	E855	F145
Group	C	C	C	C	C	C	C	C	C
Week 1	11.9	8.7	9.4	11.8	10.4	8.2	8.1	10.4	12.1
2	11.6	8.9	8.3	11.9	10.2	8.4	8.3	10.1	9.9
3	10.6	9.7	7.5	11.8	9.7	8.7	9.7	7.9	11.0
4	10.3	9.3	8.5	11.8	9.0	6.8	8.3	8.2	10.8
5	9.4	9.6	9.0	11.7	9.3	8.0	8.3	9.3	10.0
6	8.7	8.1	9.1	11.9	9.7	9.9	8.3	8.9	7.6
7	9.3	9.3	9.0	11.5	9.1	8.6	8.6	8.3	8.0
8	9.8	9.8	8.8	11.5	9.3	8.2	8.3	9.3	9.5
9	10.4	9.6	9.4	11.4	8.7	7.9	9.4	8.0	8.9
10	9.4	9.3	7.3	11.9	8.3	8.1	7.1	8.0	9.6
11	10.4	9.4	8.6	12.0	10.3	9.3	8.2	8.1	10.7
12	10.1	8.7	7.3	11.6	8.3	8.3	9.3	8.4	9.3
13	7.7	7.8	8.0	11.7	9.0	7.3	7.3	7.5	8.5
14	9.0	7.9	8.6	11.7	8.6	8.1	7.0	7.4	8.6
15	8.9	7.7	8.4	11.8	9.0	8.0	8.3	8.0	9.7
16	7.9	8.3	8.0	11.4	9.3	7.6	8.3	9.1	8.3
17	7.5	7.5	6.5	11.5	10.2	7.0	7.3	7.0	8.0
18	6.1	6.1	6.7	11.6	7.6		5.7	6.6	6.0
19	7.7	7.4	9.1	11.7	8.3		7.6	7.1	9.3
20	8.1	8.0	7.9	11.8	9.9		8.3	7.1	9.0
21	8.6	8.2	7.2	11.8	10.0		8.4	8.2	8.8
22	7.0	7.0	7.1	11.5	9.9		6.4	8.9	9.0
23	7.6	6.9	6.7	11.7	9.0		6.9	6.7	9.1
24	6.7	7.3	5.9	11.7	8.4		7.6	7.9	9.1
25	7.0		6.6	11.7	7.4		6.6	6.9	8.9
26	7.0		7.5	11.6	6.5		7.0	6.5	7.7
27	8.1		6.9	11.8	7.4		7.1	6.9	6.0
28	7.4		8.0	11.8	8.3		5.9	7.1	8.9
29	6.4		7.0	12.1	6.4		5.3	5.9	7.9
30	6.5		7.3	11.9	7.5		5.2	6.5	8.2
31	7.4		7.2	12.0	9.0		6.0	6.2	8.8
32	6.4		6.4	11.9	9.0		5.9	7.3	9.1
33	7.3		6.7	11.8	8.0		5.9	8.1	8.3