THE NUTRITIVE VALUE OF TREATED MAIZE COBS

By

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DECLARATION

a) This thesis is my original work and has not been presented for a degree in any other University.

Francesca N. Nang'ole

b) This thesis has been submitted for examination with our approval as University Supervisors.

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DEDICATION

"Dedicated to all those who in any way helped towards the completion of this work".

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A B S T R A C T

Two experiments were conducted at Kitale National Agricultural Research Station to study the effect of grinding and chemical treatment on the nutritive value of maize cobs.

In Experiment I the digestibility of treated maize cobs was studied using Romney Marsh wether sheep in a 2 x 3 factorial design. Maize cobs were ground through 10 and 6 mm screen sizes. Three chemical treatments were applied to each grinding and these were:

1. sodium hydroxide (4.5 g per 100 g cob dry matter)

2. magadi soda (9.0 g per 100 g cob dry matter)

3. distilled water (Control).

Cobs were treated for 24 hours using one litre of solution to one kilogram of maize cobs.

In vivo digestion coefficients of crude protein and ether extract were lowered ($P < 0.01$) by finer grinding of the maize cobs. Finer grinding did not affect ($P > 0.05$) in vivo digestibility of dry matter, crude fibre, CWC, ADF and cellulose. Chemical treatment of maize cobs improved ($P < 0.01$ or $P < 0.05$) in vivo digestibility of dry matter, crude fibre, ether extract, CWC, ADF and cellulose. In vivo dry matter digestion coefficients were 44.68, 54.15 and 61.57 percent for rations containing maize cobs treated

with water, NaOH and magadi soda respectively and were different ($P< 0.05$) from each other. The increase in *in vivo* digestibility of crude fibre, CWC and cellulose due to treatment of maize cobs with magadi soda was higher ($P< 0.01$) than on the control and NaOH treated cobs. *In vivo* ADF digestion coefficients for control, NaOH and magadi soda treated cobs were different ($P< 0.05$) from each other. Chemical treatment lowered ($P< 0.01$) the *in vivo* digestibility of crude protein. *In vivo* digestibility of crude protein was 28.02, 16.98 and 18.17 percent for rations based on control, NaOH and magadi soda treated cobs respectively. *In vivo* crude protein digestibility was higher ($P< 0.01$) on control cobs than on cobs treated with NaOH and magadi soda.

The interaction between grinding and chemical treatment of maize cobs affected ($P< 0.01$) *in vivo* digestibility of crude protein and ether extract. *In vivo* digestibility of dry matter was marginally affected ($P \simeq 0.05$) by the same interaction. *In vivo* digestibility of crude fibre, CWC, ADF and cellulose were not affected ($P> 0.05$) by the interaction between grinding and chemical treatment of maize cobs.

In Experiment II rations based on maize cobs treated with water, NaOH and magadi soda were fed *ad libitum* to young dairy cattle grazing on Nandi Setaria/Silver Leaf Desmodium pasture. Pasture quality and animal performance were monitored.

Total weight gains as percent of the initial weight were 29.72, 40.87 and 42.02 for cattle fed rations containing maize cobs treated with water, NaOH and magadi soda respectively. Total weight gain as a percent of initial weight was higher ($P< 0.05$) on rations containing NaOH and magadi soda treated cobs than on the ration containing control cobs. Average daily gains were 0.38, 0.48 and 0.50 kg for animals fed rations with control, NaOH and magadi soda treated cobs respectively and were not significantly ($P> 0.05$) different from each other. Maize cob intake per animal per day was 3.35, 5.11 and 2.56 kg dry matter when animals were fed rations containing maize cobs treated with water, NaOH and magadi soda respectively. During the first month of the experimental period there were no differences in weight gain patterns between the three experimental groups of animals indicating a requirement for a long adaptation period to chemically treated maize cobs.

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1. INTRODUCTION

The main cause of protein deficiency diseases in certain parts of Kenya is the short supply of animal protein. Kenya's annual population growth rate is 3.9 percent whereas the production of animal protein is increasing at a rate of 1.4 percent per year (Economic Survey, 1978). The population pressure in areas of high agricultural potential has greatly limited grazing land available for animal production. It is therefore, becoming more important to find alternative and cheaper ways in which animal production can thrive without competing directly with crop production. Utilization of crop residues for ruminant livestock feeding has been advocated by various authors (Beeson and Perry, 1952; Tascenco, Isar and Cristea, 1974; Jackson, 1977, 1978; Kevelenge, 1978). Ruminant animals are able to utilize highly fibrous feeds through microbial digestion in the rumen. Cellulose in plant fibre is hydrolysed by rumen bacteria to form volatile fatty acids which are absorbed in the blood stream for various metabolic functions, namely in fat and energy metabolism. (Crampton and Harris, 1969). Utilization of crop residues for ruminant feeding would release the bulk of grains and their milling by-products for human and monogastric livestock.

Maize crop residues form one of the major classes of crop by-products under Kenyan farming conditions. Cultivation of

hybrid maize, since it was introduced in 1963, has increased tremendously especially on small scale farms. Total land under maize in 1978 was 436,876 ha, 93 percent of which was on small scale farms. The expected yield was 900 000 tonnes of grain and 400 000 tonnes of cobs, the latter being a crop residue, which until recently has been a waste by-product. The problem of disposal of maize cobs has been magnified by the increase in production. Small scale farmers generally use maize cobs as fire wood.

A factory at Eldoret in Uasin Gishu District of the Rift Valley Province, is utilizing maize cobs for extraction of furfural, from the core of the cob, for use in making buttons. But transport costs are so high that farms located 40 kilometers or more outside Eldoret cannot sell cobs to the factory profitably. It will be equally interesting to look into the possibility of utilizing the by-product of furfural extraction coming out of the factory as a ruminant feed.

For a long time, the simplest and most common way of dealing with crop residues has been burning them in fields. Burning leads to destruction of certain physical and chemical properties of the soil. These include loss of inorganic nitrogen, sulphur and organic matter. This leads to the loss of soil fertility and the crumb structure which is attributed to the organic matter content of the soil (Ahn,

1973). Useful biological organisms are also destroyed. Besides, burning leads to environmental pollution.

Feeding crop residues to livestock is practised in only a few cases. The quality and supply of digestible material in tropical pastures during dry seasons and peaks of rainy seasons is too low to maintain reasonable growth and milk yields in cattle (Musangi and Soneji, 1967; Mugerwa, Lawrence and Christensen, 1974). Cobs could be fed to livestock at such times to maintain store condition in beef cattle and avoid, in part, a severe depression in milk production in dairy cattle. Small scale farmers who practise zero-grazing could use cobs as a dry season feed when little herbage is available. Cobs could serve as a source of roughage in complete rations for ruminant livestock (Beeson and Perry, 1952). However, cobs, like all other crop residues, have a low digestibility coefficient which is related to the high lignin content (Jackson, 1977) Roughage digestibility varies inversely with the degree of cellulose lignification (Mugerwa et al., 1974). Lignification of plants increases with maturity (Drapala, Raymond and Crampton, 1947), so that crop residues from mature plants have very high lignin content in the cell walls. Lignin acts as a physical barrier between cellulose and rumen bacteria, which lowers roughage digestibility (Baker and Harris, 1947). Factors which might affect digestibility and nutritive value of maize cobs are physical, chemical and microbial treatments.

The objectives of this study were, therefore:

a) to study the effect of treatment with sodium hydroxide (NaOH) or magadi soda ($NaCO_3.NaHCO_3.2H_2O$) on the nutritive value of maize cobs ground into different particle sizes,

b) to study the growth of young grazing Friesian cattle supplemented with such treated cobs.

2. LITERATURE REVIEW

2.1 Introduction

Maize (Zea mays) is the most important cereal crop in Kenya and was first introduced in the sixteenth or seventeeth century by Portuguese traders. Cultivation was restricted to the Coastal strip until European settlers introduced varieties better suited to the inland environment.

Maize belongs to the botanical family Poaceae, sub-family Panicoideae. It is a grass with a single solid stem which grows to a height of 2 to 5 metres depending on variety. Male and female flowers are borne separately on the same stalk, and seeds are permanently enclosed in bracts which are known as ears or husks. Inside the husks, seeds are arranged in rows on the cob. At harvesting husks are removed to leave the grain-on-cob, which is then shelled to give 70 to 80 percent grain and 20 to 30 percent cob by weight.

2.2 Chemical composition and digestibility of maize cobs

Burroughs, Gerlaugh, Schalk, Silver and Kunkle (1945) reported that maize cobs contained on average 91.3 percent dry matter, 33.5 percent crude fibre, 2.01 percent ash and

44.2 percent nitrogen free extracts. In a series of digestion comparisons with four steers each, the average TDN value of maize cobs was found to be 51.6 percent, which suggested that maize cobs for cattle were 64 percent as valuable as the maize grain as a source of energy for fattening beef cattle. Tascenco *et al.* (1974) found maize cobs to contain 2.47 percent crude protein, 2065 kcal of digestibile energy and 1870 kcal of metabolizable energy per kilogram of dry matter. Cobs had a lower crude protein, digestible energy and metabolizable energy contents than either stovers or whole ears. Digestible crude protein of cobs was equal to that of stover but lower than that of whole ears.

One kilogram of maize cobs was reported to be 0.5 food units and to contain 2 g digestible protein (Nadazdin, Dzinic, Burgerski, Pavlovie, Zaklan and Handzic, 1975). The *in vivo* and *in vitro* dry matter digestibility by sheep of rations containing 81 to 65 percent maize cobs was 37 to 47 percent and 39 to 45 percent respectively (Orb, Gil, Verde and Cappelleti 1971).

2.3 Maize cobs as a livestock feed

Before 1945, the nutritive value of maize cobs as fed in corn-and-cob meal to fattening beef cattle had been a disputed question for a long time. Some feedlot data showed that cobs were of little or no value whereas others showed that cobs were as valuable as legume hay or slightly less

valuable than the maize grain itself when fed to beef cattle (Otis, 1904; Mumford, 1905; Allison, 1917; Vaughan, 1927; Gerlaugh, 1928; Peters, 1933; Thalman and Cathcart, 1934; Gerlaugh and Rogers, 1936; King, 1939; 1940).

In a feedlot experiment, consisting of eight comparisons, using a total of 192 cattle, maize cobs replacement value for maize grain averaged 62 percent (Burroughs et al., 1945). Rakes (1969) also found no adverse effect on dairy cattle when 41 percent of the dairy ration consisted of ground maize cobs. However, Orb et al. (1971), using 81 to 65 percent maize cobs in rations containing linseed oil meal and urea, found that the average daily gains of Aberdeen-Angus bullocks fed the rations was 679 g with least and 383 g with most cobs. Intake of rations increased from 7.00 to 7.75 kg DM per day as the amount of cobs in the ration decreased.

Several workers have compared maize cobs with other roughages. Beeson and Perry (1952) found maize cobs satisfactory as a roughage whether supplemented with soy bean oil meal, urea, distiller's solubles and urea, brewer's yeast or alfalfa meal. Fries, Lassister, Seath and Rust (1955) compared maize cobs and cotton seed hulls to clover-timothy hay as roughages for dairy heifers. When roughages were fed at equal rates, average daily gains for heifers fed maize cobs, hay and cotton seed hulls were 0.42, 0.35

and 0.31 kg respectively. When fed ad libitum, average daily gains for maize cobs, hay and cotton seed hulls were 0.30, 0.30 and 0.36 kg respectively. McCoy, Olson and Reed (1965) reported that maize cobs were inferior to high quality long grass hay as a source of roughage. Hibbs and Conrad (1978) compared maize cobs to alfalfa and soy bean flakes as roughages in high roughage pelleted rations for calves. Greater pellet consumption and lowered feed efficiency were observed on cob pellets. Lowered digestibility of cob rations was compensated for by increased intake of dry matter. Ground cobs could be used successfully instead of either alfalfa or soy bean flakes as a major roughage in balanced high roughage pelleted diets for calves.

Nadazdin et al. (1975) studied the possibility of producing complete feed mixtures from maize stover and cobs. The food unit value and the amount of digestible crude protein dropped as the amount of dried maize stover and cobs in complete feed mixtures increased. Feed mixtures with varying proportions of maize stalks and cobs could serve primarily to feed sheep and less productive categories of stock during winter (Nadazdin et al., 1975).

Maize cobs may be more suited to beef production than milk production. Hill, Hatcher, Lundiquist and Crowl (1953) conducted an experiment in which alfalfa silage and alfalfa hay replaced maize cobs. Milk production was lowest and

weight gain highest in cows fed maize cobs as the only roughage. The drop in milk production did not appear to be due to insufficient energy intake. In another experiment Graf and Lengel (1953) replaced 50 percent by weight of alfalfa-grass hay in a ration with ground maize cobs. Cows fed rations containing maize cobs produced 10 kg less milk and gained 2.73 kg more in weight than cows fed rations containing no cobs. However, Emery, Brown and Thomas (1964) found that feeding maize cobs was better than commercial alfalfa meal for supporting milk fat production and maintaining feed intake.

2.4 Some factors affecting the nutritive value of maize cobs

2.4.1 Grinding

Studies generally indicate improved nutritive value of low quality roughages due to grinding. Rodrigue and Allen (1960) found that grinding hay in a ration composed of two parts hay and one part concentrate by weight produced an earlier initial excretion of hay residues in faeces in cows. Change in excretion time was statistically significant. Excretion of finely ground hay was more rapid than that of unground hay throughout the experimental period. The most marked effect on digestibility of nutrients of ground roughages was the highly significant decline in *in vivo* digestibility of fibre and/or cellulose as a

result of grinding hay. The decline was mainly responsible for the highly significant decrease in dry matter digestion. In vivo digestibility of ether extract was lowered by medium to fine grinding. Finer grinding of hay resulted in greater depression of in vivo digestibility of total ration and faster rate of excretion. The larger depression in cell-wall constituents (CWC) digestibility was associated with a marked decrease in milk fat percentage.

Dehority and Johnson (1961) studied the effect of ball-milling on in vitro cellulose digestibility. Amount of cellulose digested increased with ball-milling time, the increase being greater in more mature and more lignified Timothy hay. Beardsley (1964) also got more response from grinding and pelleting of poor quality material than from grinding high quality hay. Animal performance was improved due to grinding and pelleting. Much of the improved performance appeared to be due to grinding. From figures compiled for different forages, Beardsley (1964) concluded that digestibility of individual nutrients in forages may be altered by grinding, but the net effect is small. Digestibility of crude fibre is reduced. However, the lowered digestibility is more than compensated for by increased voluntary intake, resulting in an overall increased intake of digestible nutrients. Burt (1966) found that when all or part of the long barley straw in a ration was replaced by ground pelleted whole rations,

liveweight gain was significantly improved, which indicated a marked response in energy value due to processing of the straw.

Studies with sheep by Weston and Hogan (1967) showed that grinding of roughages led to 50 percent increases in consumption. The rate of flow of digesta from the rumen was unaffected, but the rate of flow from the abomasum was higher with ground roughages. Sheep spent less time eating and ruminating when roughages were ground. With an aim of separating the effects of grinding per se from those associated with increased intake of roughages permitted by grinding, Hogan and Weston (1967) fed chopped hay at 90 percent of the ad libitum intake, ground hay at the same level as chopped hay and ground hay ad libitum. Results showed that grinding per se produced little change in relative importance of the stomach and small intestine as sites of digestion. Grinding reduced the in vivo digestibility of wheaten hay mainly by reducing digestibility of the cell walls.

Campling (1969) reported that intake of low protein roughages such as straw is controlled partly by physical factors which operate through limits imposed by the capacity of the reticulo-rumen and extent of delay of food in these organs, and especially by the rate of breakdown of digesta in the rumen. Presenting a ruminant animal with ground roughage which readily passes out of the

reticulum results in greater voluntary intake. Limitation is imposed by the small size of the reticulo-omasal orifice. Increases in voluntary feed intake tend to be greatest with roughages containing high levels of CWC (Campling, 1969).

Grinding through different fine screen sizes appears to have no effect on the nutritive value of roughages. Pickard, Swan and Lamming (1969) worked with barley straw ground through screen sizes 0.16, 0.47 and 0.77 cm and at 15 or 30 percent straw in the diet. No significant differences in performance of young cattle due to particle size or the proportion of straw in the diet were observed. Gharib, Goodrich, Meiske and El Serafy (1975) also found that dry matter digestibility of poplar bark was not enhanced by finer grinding.

Lamming, Swan and Clarke (1966) substituted maize by milled barley straw at 0, 10, 20, 30, 40 and 50 percent in the diet and found that there was a reduction in growth rate as the amount of straw in the diet increased. Differences in growth rate were not significant up to thirty percent straw in the diet. As the amount of straw in the diet increased, digestibility was depressed, feed efficiency declined and intake of ration increased up to the level of 20 percent straw in the diet. Similar results were obtained by Kay, MacDearmid and Massie (1970) using ground straw to replace cereals at 0, 30 and 50 percent in rations. As the proportion of straw in the diet increased

there was lowered dry matter digestibility, growth rate, killing out percentage and carcass gains. However, increased feed intake and alimentary tract fill were observed.

2.4.2 Chemical treatment

Use of alkali to break the ligno-cellulose bonds and improve the nutritive value of low quality roughages has been studied since the beginning of the century. Kellner and Kohler (1900) prepared "fodder cellulose" by boiling rye straw under pressure in a solution containing sodium hydroxide (NaOH) and several other alkali salts and reported digestibility coefficients of organic matter and crude fibre as 88 and 96 percent respectively, compared to the original material whose digestibility would have been less than 50 percent. Godden (1920) described work done by Lehmann around 1904. Lehmann boiled 100 kg straw in 200 kg water with 2 to 4 kg caustic soda for six hours under pressure. The product was washed with water to remove free alkali. Digestibility of straw was increased by about 50 percent.

Using the same method, Woodman and Evans (1947) produced "fodder cellulose" from wheat straw boiled under pressure in 6 percent NaOH solution, washed and dried. In vivo dry matter digestibility with sheep was 74 percent. Such studies, lasting over 40 years, showed that delignification could be used to convert low quality forages to feeds of high energy availability. Straw was soaked in 1.5 percent NaOH solution at a ratio of eight parts solution to one

part straw for a minimum of four hours at atmospheric pressure and temperature, drained and washed with running water to remove free alkali (Beckman, 1921). The resultant "straw pulp" was fed in wet condition and was not as digestible as Kellner's "fodder cellulose" because of the milder treatment conditions, but digestibility doubled compared to untreated material. The effectiveness of the Beckmann process was subsequently confirmed by Ferguson (1942) and Sen, Ray and Talapatra (1942). However, treatment costs were still high; large volumes of water were required; and 25 percent of the original dry matter was lost (Saxena, Otterby, Donker and Good, 1971). Straw treated by this method has usually been more expensive than conventional feeds and consequently has rarely been used.

Lampila (1963) modifed the Beckmann's process by reducing the amount of water for both treating and washing the straw and by doubling the NaOH concentration used. Straw treated this way had digestion coefficients of 62 to 63 percent for organic matter and 87 to 91 percent for crude fibre. A total of only 7 litres of water per kilogram dry straw was used and less nutrients were washed off compared to the Beckmann process. A still simpler method of treatment was introduced by Wilson and Pigden (1964). Sodium hydroxide solution was sprayed on straw and the moist product fed to animals without this being washed. *In vitro* digestibility of straw treated in this way was about 70 percent. *In vivo* digestibility was lower

than *in vitro* digestibility, presumably because of the adverse effect of sodium hydroxide on rumen fermentation. Increase up to 7 g NaOH per 100 g straw dry matter linearly increase enzyme and *in vitro* digestibility and reduce cell-wall constituents. Digestibility with sheep increases as the level of NaOH increases up to 4 to 5 g per 100 g of straw dry matter. Higher levels of NaOH produce no further increase in *in vivo* digestibility. Unreacted NaOH has no effect on animals.

Other chemicals for treatment of low quality roughages have been studied. Chandra and Jackson (1971) found sodium carbonate (Na_2CO_3) to be relatively ineffective but a mixture of half Na_2CO_3 and half NaOH was almost as effective as an equal weight of pure NaOH. Sodium sulphite and Sodium sulphide were much less effective than sodium hydroxide. Gharib *et al.* (1975) found calcium hydroxide, ($Ca(OH)_2$) to be much less effective because of its low solubility and slow rate of reaction. When $Ca(OH)_2$-treated poplar bark was left to stand for 150 days, digestibility was increased as much as the material treated with NaOH. Waller and Klopfenstein (1975) found a mixture of NaOH (3 percent) and $Ca(OH)_2$ (1 percent) more effective than NaOH alone (4 percent) in promoting daily gains and feed efficiency in lambs and yearling heifers fed maize cobs. Chlorine was found to be very effective in increasing *in vitro* dry matter digestibility of roughages (Chandra and Jackson, 1971). Hydrogen peroxide (H_2O_2) has also been

found to increase *in vitro* dry matter digestibility of roughages (Chandra and Jackson, 1971). Potassium and ammonium hydroxides improved *in vitro* dry matter and organic matter digestibility of wheat straw (Braman and Abe, 1977). Sodium hydroxide has proved to be the most effective and easy to apply of all the chemicals studied (Jackson, 1977).

2.4.2.1 Effect of alkali treatment on chemical composition of roughages

Crampton and Maynard (1938) partitioned carbohydrates into three components; a highly digestible fraction, an indigestible fraction (lignin) and cellulose. Cellulose digestibility was suggested to vary inversely with the degree or nature of cellulose lignification. Baker and Harris (1947) suggested that lignin acts as a physical barrier between cellulose and rumen cellulolytic bacteria by encrusting on the cellulose. It was noted that histochemical reactions of structural cellulose were masked in lignified structures. Reaction was resumed and digestibility greatly increased after chlorination or treatment with alkaline sulphate or sulphate lyes. Van Soest (1964) put forward four theoretical explanations on how lignin reduces digestibility of plant materials namely: the encrustation of lignin on cellulose; formation of indigestible lignin-carbohydrate complexes; the formation of lignin-carbohydrate compounds in the plant cell-walls; and the presence of molecular complexes due to hydrogen bonding or other attractive forces.

Lignin content of roughages is reduced by alkali treatment. Chandra and Jackson (1971) found that the lignin content of maize cobs was reduced by 26 percent when treated with 10 g NaOH per 100 g of cobs. Lignin content of poplar bark was reduced by treatment with 9 or 12 g NaOH per 100 g bark (Gharib et al., 1975). Feist, Baker and Tarkow (1970) noted that response of hard woods to NaOH treatment varied inversely with the lignin content of treated material. The optimum value for improving digestibility of hard woods was 5 to 6 g NaOH per 100 g wood. Baker (1973) found digestibility of wood pulp to depend upon how much of the original lignin had been removed, but not on the method of removal. Baker, Mahaupt and Spino (1973) found that chemically treated pulp, which was highly delignified and bleached with chemicals, had a higher in vitro digestibility and supported more fungal growth than mechanically processed pulp from the paper industry.

Results compiled by Jackson (1977) showed that apart from lignin, hemicellulose and silica were removed by treatment with 12 to 16 g NaOH per 100 g roughage. Cellulose was not affected by the same treatment. Braman and Abe (1977) found Acid detergent fibre (ADF), Acid detergent lignin (ADL), CWC and hemicellulose to decrease with increasing concentration of NaOH, KOH or NH_4OH for treatment of wheat straw. Concentration of crude protein, ash and ADF increased while hemicellulose decreased with increasing duration of

treatment. McManus (1978) found that NaOH and ethylen-diamino-triacetate (EDTA) removed a fraction of the cell-wall ash and increased cell-wall digestibility with increasing application to brewer's grain and mature grasses. Cell-wall constituents and ADF were reduced. Saxena et al. (1971) had earlier reported a reduction in CWC and ADF of oat straw due to alkali treatment.

2.4.2.2 Effect of chemical treatment on intake, digestibility and animal performance

Improvement in intake, digestibility and animal performances as a result of chemical treatment of low quality roughages has been observed by many workers. Alkali treatment of oat straw improved in vivo CWC and ADF digestibility and in vitro dry matter digestibility (Saxena et al., 1971). Significant improvement in feed consumption, liveweight gains, feed utilization efficiency and carcass quality were reported by the same workers. Singh and Jackson (1971) spray-treated chaffed or ground wheat straw with 0, 3.3, 6.7 and 10 percent NaOH at 1000 litres of solution per tonne. Intake was highest at 3.3 percent NaOH, then declined at higher levels of NaOH. Nitrogen, phosphorus and calcium retention were not adversely affected up to 3.3 percent NaOH treatment. Carmona and Greenhalgh (1972) compared chopped or milled barley straw soaked or sprayed with alkali. Soaking followed by washing caused losses in organic matter

of 28 and 32 percent for 1.5 and 3.0 percent NaOH treatment respectively. Dry matter digestibility was not significantly affected by the treatment. Dry matter intake tended to be higher for milled-sprayed straw.

Jayasuriya and Owen (1975) carried out four experiments to determine the effect of treatment of barley straw with NaOH solution and subsequent neutralization with hydrochloric acid on the digestibility and intake by sheep. Chopped straw was treated with 4.5 or 9.0 g NaOH in 200 or 800 ml water per 100 g straw, and after 24 hours, neutralized with HCl and left to stand for a further 24 hours before feeding in a maintenance diet with 35 percent concentrate. Organic matter digestibility of straw improved by 8 and 11 units after treatment with 200 ml of solution containing 4.5 and 9.0 g NaOH respectively. Volume of solution had no effect on digestibility. When treated straw was fed ad libitum, the highest intake was for the treatment with 200 ml of solution of 4.5 g NaOH per 100 g straw. Treatment with 9.0 g NaOH gave significantly lower intake. In vitro dry matter digestibility was found to increase with increasing volume up to 120 ml of solution per 100 g straw. But response to successive increments of water declined progressively. When straw was treated with 4.5, 6.75 or 9.0 g NaOH in 30, 60 or 120 ml water per 100 g straw increasing volume of water from 30 to 60 ml per 100 g of straw significantly improved in vivo dry matter digestibility

at 4.5 and 6.75 g NaOH per 100 g straw. Response to increased levels of NaOH was less and inconsistent.

Gharib et al. (1975) studied the effect of temperature and concentration of NaOH on composition and in vitro true dry matter digestibility of poplar bark. While in vitro true dry matter digestibility was improved by NaOH treatment, time and temperature did not seem to have any significant effect on the digestibility of poplar bark. However, McManus (1978) found that digestion of brewer's grain was improved by treatment with NaOH and NH_4OH, and that temperature improved reaction. Sodium hydroxide and EDTA decreased the organic matter fraction of mature forages especially CWC, ADF and lignin components. It was concluded that alkalis increased dry matter digestibility by degrading cell-walls.

Javed and Donefer (1970) fed NaOH-treated oat straw to fattening lambs in rations containing 77.5 to 85 percent treated straw and 7 to 10 percent molasses. Growth rates on treated straw approached those obtained with the control alfalfa ration. Bramann and Abe (1977) reported improved average daily gains (ADG), dry matter intake and digestibility of both dry matter and crude fibre by beef cattle when ground wheat straw was treated with NaOH, but nitrogen retention was lowered and carcass parameters unaffected. Addition of urea to the treated straw lowered ADG.

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2.4.2.3 Chemical treatment of maize cobs

Maize cobs appear to respond to chemical treatment better than most other low quality roughages. In an experiment done by Jones and Klopfenstein (1967) a 4 percent alkali treatment dissolved a portion of the cell-walls and lignin of maize cobs but not of alfalfa stems. *In vitro* disappearance of dry matter was improved from 49.7 percent on control to 54.5 percent on treated cobs. Klopfenstein and Woods (1970) conducted one digestion study and two growth trials with lambs to study the effect of combinations of NaOH and potassium hydroxide (KOH) for treatment of maize cobs and wheat straw. Wheat straw was treated with 4 or 5 percent of combinations of NaOH and KOH to produce Na:K ratios of 1:1 or 1:2 at each level of treatment. Organic matter digestibility of control, 4 percent and 5 percent hydroxide-treated straws were 43.4, 57.6 and 60.4 percent respectively. Straws treated with hydroxide to form Na:K ratios of 1:1 and 1:2 had dry matter digestibility of 60.3 and 57.6 percent respectively. In the first lamb growth trial, hydroxide treatment of straws increased gains from 0 g for lambs fed control rations to 90 g per day for lambs fed treated straw rations. In the second growth trial, lambs were fed maize cobs treated with 4 percent NaOH and KOH to produce Na:K ratios of 2:1, 1.5:1, 1:1 and 1:1.5. Hydroxide treatment of cobs increased average daily gains from 54 g for the control lambs to 156 g for those fed treated maize cob rations. The Na:K ratio had only a slight effect on animal performance. Rounds, Klopfenstein,

Waller and Messersmith (1976) found NaOH and KOH to be equally effective on equimolar basis for treatment of maize cobs.

Chandra and Jackson (1971) compared several delignifying agents used in various paper-making processes for their ability to remove lignin and increase digestibility of several roughages in laboratory experiments using the spray method. At the rate of 10 g of chemical per 100 g of roughage the lignin content of maize cobs was reduced by 26 percent and *in vitro* dry matter digestibility increased by more than 100 percent. Klopfenstein, Bartling and Woods (1967) found HCl to improve dry matter digestibility of maize cobs and other roughages. Also a 4 percent H_2O_2 treatment on dry matter basis reduced lignin content of cobs and improved *in vitro* dry matter digestibility.

Later, Klopfenstein, Krause, Jones and Woods (1972) studied the use of hydroxides and peroxides and mixtures of the two in treatment of low quality roughages. Ground maize cobs were treated with 4 percent NaOH, 4 percent sodium peroxide (Na_2O_2) or 4 percent NaOH plus 3 percent H_2O_2. *In vitro* dry matter digestibility was significantly improved by all chemical treatments, and there was no significant difference among chemicals. Treatment did not affect ADF content, but reduced ADL and CWC contents of the cobs. Sodium peroxide had a greater effect than NaOH in reducing CWC. However, addition of H_2O_2 to NaOH did not reduce CWC any further. Sodium hydroxide treatment significantly

improved *in vivo* dry matter digestibility. Sodium peroxide treatment produced a further increase above NaOH treatment. Nitrogen retention was better in lambs consuming treated cobs. Chemical treatment of cobs caused an increase in digestibility of a greater magnitude than that found with alfalfa stems. The increase appeared to be due to delignification since lignin content of NaOH - and Na_2O_2-treated cobs was reduced, but that of alfalfa stems was not affected.

Waller and Klopfenstein (1975) used NaOH, $Ca(OH)_2$, NH_4OH and a combination of the three chemicals to treat maize cobs. The highest daily gains and the lowest feed per gain ratio were obtained on the 3 percent NaOH plus 1 percent $Ca(OH)_2$ treated rations. In another study, Klopfenstein (1975) reported that treatment of cobs with 3 percent NaOH plus 1 percent $Ca(OH)_2$ gave greater weight gains and higher digestibility of dry matter in beef cattle than untreated cobs. Similar results were obtained by Rounds *et al.* (1976). Maize cobs were soaked for 24 hours in NaOH or KOH or $Ca(OH)_2$ or a combination of the alkalis, then dried. *In vitro* dry matter digestibility was higher with 5 percent NaOH and KOH than 4 percent of the hydroxides individually. Calcium hydroxide was not effective alone. Lambs given cobs treated with 4 percent NaOH gained 118 g daily against 145 g daily for those fed cobs treated with 3 percent NaOH and 1 percent $Ca(OH)_2$. Intake was always reduced by treatment of cobs with NH_4OH solution.. Gains and feed efficiency were also poorer, except when only half

the cobs in the ration were treated with NH_4OH and the other half with $Ca(OH)_2$ plus NaOH.

Soper, Owen and Nielsen (1977) fed maize cobs treated with 3 percent NaOH and 1 percent $Ca(OH)_2$ at 0, 12 or 23 percent of maize silage rations dry matter and replacing part of the cracked maize in the diet to give crude fibre contents of 12, 16 or 20 percent. When cobs were fed at 23 percent of ration dry matter, intake was highest, but milk yield lowest. Intake of dry matter and net energy for milk production were highest in rations containing no cobs. Milk fat, averaging 3.68 percent, was not affected by the amount of cobs. Milk protein was 3.34, 3.24 and 3.11 percent for 0, 12 and 23 percent cobs respectively. General performance favoured rations with low levels of cobs.

Koers, Woods and Klopfenstein (1970) conducted a series of trials to determine the effect on animal performance and ration digestibility of ensiling maize stover and maize cobs with 4 g NaOH per 100 g roughage dry matter. Two lots of six steers each were fed either untreated or treated stover silages ad libitum. Average daily gains were significantly improved from 0.30 to 0.41 kg by stover treatment. In a growth trial with maize cobs, 5 individually fed steers were assigned to treatments. Treatments were a control ration and treated cob rations neutralized with 1, 2 or 3 percent KCl added on dry matter basis. Average daily gains were 0.30, 0.72, 0.73 and 0.73 kg; feed required per unit gain was 14.3, 7.1, 7.6 and 7.8 respectively for the

four treatments. The increased gain and reduced feed per gain ratio for steers fed treated rations were significantly different from the control rations. Dry matter, organic matter and true dry matter digestibility were not significantly affected by treatments. Steers fed treated rations lost significantly less nitrogen compared to those fed control rations. Rumen pH was significantly reduced and total volatile fatty acids (VFA) significantly increased for steers fed treated rations compared to those fed control rations.

Djafar and Hussain (1976) studied the effect of chemical and heat treatment on the nutritive value of saw dust and maize cobs. The feeding value of saw dust and maize cobs treated with 3 percent NaOH with or without heating was compared to that of untreated materials. Chemicals and chemical plus heat treatments significantly increased feed intake and digestibility of dry matter, crude protein crude fibre and energy. Treated saw dust and maize cobs could replace 28 percent of other roughages in ruminant rations.

3. MATERIALS AND METHODS

3.1 Introduction

Two experiments were conducted at Kitale National Agricultural Research Station to study the effect of grinding and chemical treatment on the nutritive value of maize cobs. In experiment I the digestibility of treated maize cobs was studied using Romney Marsh wether sheep. Cobs were ground through 10 and 6 mm screen sizes. Three chemical treatments were applied to each grinding. Treatments were sodium hydroxide (4.5 g per 100 g cob dry matter), magadi soda (9 g per 100 g cob dry matter) and distilled water (control).

In Experiment II treated maize cobs were fed to young dairy cattle grazing on Nandi Setaria/Silver Leaf Desmodium pasture and live weight gain was monitored.

3.2 Experiment I

To study the effect of grinding and chemical treatment on the digestibility of maize cobs.

3.2.1 Animals

A flock of 26 adult Romney Marsh wether sheep were fed ad libitum on good quality legume-grass hay, maize based concentrates and mineral supplements. All the sheep were dewormed a month before the start of the experiment using Nilverm[1].

[1] Wellcome Kenya Limited.

The animals were numbered 1 to 26. For every treatment, five sheep were picked using random number tables. Randomisation was repeated till a fairly uniform liveweight distribution between treatment groups was obtained. Reserve sheep were selected in a similar way. The purpose of this last group was to serve as a ready source of sheep for replacement of experimental animals that might fall sick or die. The animals used in the experiment are shown in Table 3.1.

TABLE 3.1: LIVEWEIGHTS OF SHEEP USED IN THE DIGESTIBILITY STUDY

A (NaOH)		B (Magadi)		C (Control)	
Animal Number	Liveweight (kg)	Animal Number	Liveweight (kg)	Animal Number	Liveweight (kg)
2	35.0	17	37.0	19	38.0
7	40.0	10	42.0	5	41.5
18	43.5	12	44.5	22	45.0
13	48.0	21	53.0	15	53.0
20	56.0	11	59.0	1	58.5
Mean±SE	44.5±8.0	-	47.1±8.8	-	47.2±8.4

The experiment was carried out in a corrugated iron roofed house whose walls were made up of wooden rail guards to allow free movements of air. Animals were kept in individual metabolism cages fitted with 26 gauge galvanized iron pans for urine collection. The sheep were held in position using collars and chains. A 2 x 3 factorial lay out in a completely randomized design was used. There were six treatment combinations and five animals per treatment. The experiment was split into two digestibility series, based on particle size.

Treatment of cobs was done everyday at 08.00 hours. The method used was similar to that used by Klopfenstein et al. (1972). One litre of solution was required for treatment of 1 kg of air dry cobs. Little portions of the solution were added to ground cobs at a time and mixed thoroughly using metal forks. The treatments increased moisture content of cobs to about 50 percent. The control cobs were treated similarly with distilled water. Total faecal and urine output per animal per day were recorded during the sample collection period. Animals were weighed at the beginning and end of each digestibility series using an Avery weighbridge.

3.2.2 Feeds

Maize cobs were obtained from Kenya Seed Company. Grains that escaped machine threshing were sorted out. Cobs were ground in a hammer mill fitted with either a 10 mm or

a 6 mm screen and were used in the first and second digestibility series respectively. Cobs were from different maize varieties and from different farms. Variation in nutritional value of cobs due to variety, location and agronomic practices was expected (Jackson, 1977). An estimated number of bags of cobs to last one digestibility series was, therefore, mixed before starting to get more uniform material. Cobs were sampled at the time of mixing.

TABLE 3.2: SOLUTIONS USED IN THE TREATMENT OF COBS

Composition	Solutions		
	A	B	C
NaOH flakes (g)	-	405.0	-
Magadi (98% $NaHCO_3$) (g)	-	-	810.0
Water (l)	10.0	10.0	10.0
Total (l)	10.0	10.0	10.0

Chemicals were weighed in tared beakers and transfered quantitatively to graduated plastic buckets containing about six litres of distilled water. The contents were stirred thoroughly using a glass rod and volume made up to 10 litres. Solutions were made in bulk and stored in plastic containers at room temperature.

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Chemicals were weighed in tared beakers and transfered quantitatively to graduated plastic buckets containing about six litres of distilled water. The contents were stirred thoroughly using a glass rod and volume made up to 10 litres. Solutions were made in bulk and stored in plastic containers at room temperature.

A mixture of molasses, urea, phosphorus and vitamins (MUM[1]) was used as a nitrogen supplement and Maclick plus[2] as a mineral supplement to the cobs. Ration compositions are shown in Table 3.3

3.2.3 Feeding

Feeding was done twice daily at 09.00 and 15.00 hours. Initially 2 kg of wet ration was allowed for each sheep daily. After 4 days, the day's ration was estimated from the previous day's intake plus 10 percent to cater for any possible increased feed intake. The amount was fed in two equal portions, one in the morning and the rest in the afternoon. Water was offered ad libitum.

Weights of feeds offered and feed refusals were taken in order to calculate daily feed intake. Volumes of water offered and water left were taken to estimate water intake per sheep per day.

3.2.4 Sample collection

An adjustment period of 15 days in both digestibility studies was allowed before samples were collected for 6 consecutive days.

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[1]Kenya Molasses Cattle Feeds

[2]Wellcome Kenya Limited

TABLE 3.3: RATION COMPOSITION

Ration	10 mm cobs			6 mm cobs		
Ingredient	1	2	3	4	5	6
Control cobs, kg	87.5	-	-	87.5	-	-
NaOH treated cobs, kg	-	87.5	-	-	87.5	-
Magadi soda treated cobs, kg	-	-	87.5	-	-	87.5
MUM, kg[1]	10.3	10.3	10.3	10.3	10.3	10.3
Maclick, kg[1]	2.2	2.2	2.2	2.2	2.2	2.2
Total, kg	100.0	100.0	100.0	100.0	100.0	100.0

[1]Supplements were added to the treated cobs just before feeding. The rates were estimated for the five sheep in each treatment as recommended by the manufacturers. The sheep were each offered 200 g of MUM and 30 g of Maclick per day. A dry matter intake of 1.2 kg per sheep was assumed.

Faeces were collected in faecal collection bags fitted to harnesses. Bags were emptied and changed, at 08.30 and 17.30 hours daily. During sample collection period, evening's faecal collection were kept in airtight plastic containers. These were bulked together with the following day's morning collection, mixed thoroughly and weighed to determine the total output over 24 hours period per animal. Ten percent sample of the total faeces was taken to the laboratory and preserved with 3 percent H_2SO_4, 1 percent toluene and 96 percent ethyl alcohol for later analysis.

Urine was collected from the metal pans using bottles and funnels. During sample collection period, 10 ml of 50 percent HCl was added to each urine collection bottle to trap ammonia. Individual urine output over a 24 hour period was measured, 10 percent of which was taken to the laboratory and preserved with 2 drops of 1 percent toluene for later analysis.

Fresh feed samples of 200 g each were taken from every dietary treatment and the whole amount of feed refusals per animal were taken for analysis daily.

3.2.5 Preparation of samples for laboratory analyses

Samples of feed offered and feed refusals were dried in a forced draught oven at 60°C for 72 hours after each day's collection. Bulking was done over six days collection period per ration in the case of fresh feed samples and per animal in the case of refusals.

Preserved faecal samples were put in an airtight container (one per sheep) and bulked over six days sample collection period. Containers were kept in the deep freezer throughout the period . At the end of the sampling period a fresh sample of faeces per animal was retained for nitrogen analysis. The rest of the faeces was dried in a forced draught oven at 60^{o}C for 72 hours.

Preserved urine samples were bulked in bottles (one per animal) over the 6-day collection period. The bulking bottles were kept in a deep freezer till required for analysis.

3.3 Experiment II

To study the growth patterns of young grazing Friesian cattle supplemented with treated maize cobs.

3.3.1 Animals

A group of nine steers and nine heifers balanced for age and liveweight was selected from the Friesian herd. The average age and weight of selected animals were 9 months and 110.5 kg respectively. Selected animals were randomly allocated to treatments using random number tables. Steers and heifers were allocated to treatments seperately. Randomisation was repeated till differences in age and weight between groups was minimized. Liveweights of animals used in this experiment are shown in Table 3.4.

TABLE 3.4: AGE AND LIVEWEIGHTS OF ANIMALS USED IN THE GROWTH STUDY

Treatment A (Control)			Treatment B (NaOH)			Treatment C (magadi soda)		
Animal No.	Age (months)	Liveweight (kg)	Animal No.	Age (months)	Liveweight (kg)	Animal No.	Age (months)	Liveweight (kg)
H 44	5.75	105.5	H 33	8.75	116.8	H 32	10.50	112.3
H 40	7.00	102.3	H 37	7.50	110.5	H 34	10.50	109.1
H 28	11.50	119.1	H 2	9.50	107.3	H 27	11.75	121.4
H 45	5.25	107.7	H 42	6.75	102.7	H 31	10.50	94.1
H 41	7.00	125.0	H 36	8.00	98.6	H 26	12.50	115.9
H 30	10.50	123.3	H 35	8.00	114.1	H 29	11.50	101.4
Mean± SD	7.8±2.6	113.8±9.8		8.1±1.0	108.3±6.9		10.9±1.4	109.0±9.9

Animals were dewormed using Nilverm[1] two weeks before the start of the experiment and once during the experiment. Spraying against ticks was done weekly. Animals were weighed at the start of the experiment and every two weeks thereafter. Average daily gains, feed intake and other performance parameters were calculated for each animal.

3.3.2 Feeds

3.3.2.1 Maize cobs

Cobs ground through 10 mm screen were used in this study. Treatment of cobs was carried out as described in Experiment I. Treated cobs were then used to make mixed rations A (Control), B (NaOH-treated) and C (Magadi soda-treated). Ration mixing was done as described in Experiment I. Maclick and MUM were added to treated cobs at 20 g and 200 g per kg of air-dry cobs respectively. Mixed rations were offered to each treatment group of animals ad libitum on pasture every day at 09.00 hours. Amounts of feed offered and feed refused were recorded to estimate daily feed intake. Samples of treated cobs, mixed rations and feed refusals were taken from each treatment at the start of the experiment and every two weeks during the experimental period. These samples were dried seperately in a forced draught oven at 60^{o}C for 72 hours, ground in a Wiley Mill through 1 mm screen, bulked at the end of the experiment and subsampled for further laboratory analyses.

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[1] Tetramizole hydrochloride .

3.3.2.2 Pasture

Three grazing fields of 0.4 hectares each, labelled 11b, 11C-1 and 11C-2, were used. Pasture composition was predominantly Nandi Setaria (Setaria sphacelata) and Silver Leaf Desmodium (Desmodium uncinatum). Fields were rested for about three months and top-dressed with calcium ammonium nitrate (CAN) at the rate of 70 kg per hectare three weeks before grazing. A black polythene shade, measuring 2 x 4 metres was put up in each field to protect supplemental feeds from rains and sunshine. Animal groups A, B and C were grazed in fields 11C-1, 11b and 11C-2 respectively at the start of the experiment, and were rotated between fields every two weeks. Grazed pastures were sampled at the start of the experiment and every two weeks thereafter during the whole experimental period. Samples were obtained from six randomly thrown 1 m^2 quadrants in each field by clipping all grass 7.5 cm above the ground within a quadrant. Clipped pasture samples were weighed and bulked per field. Two subsamples of 500 g each were saved for laboratory analysis. Subsamples were dried in a forced draught oven at 60^{o}C for 72 hours cooled and weighed. Dried samples were ground in a Wiley Mill through a 1 mm screen and bulked per field over the whole experimental period.

3.4 Chemical Analyses

3.4.1 Proximate analysis

Methods of analysis used were according to standard procedures (A.O.A.C. 1975). All analyses were done in triplicate.

In the determination of dry matter, about 1 g of the sample was weighed into tared aluminium dishes and oven-dried at 105°C for 6 hours.

Crude protein was determined using the macro-Kjeldahl method. About 5 g of the preserved wet faeces or about 1 g of air dry sample was weighed in triplicate into Kjeldahl flasks (a fourth flask served as a blank). Selenium (Se) catalyst tablet and 25 ml of concentrated sulphuric acid (H_2SO_4) were added to the flasks. The contents were boiled to oxidize nitrogen into ammonium sulphate $[(NH_4)_2SO_4]$. Ammonia was distilled off using aliquots of 50 percent NaOH into a measured amount of boric acid, which was then titrated against standard hydrochloric acid. The amount of nitrogen obtained was multiplied by the factor 6.25 to get the crude protein content expressed as a percentage.

In determining ash, about 1 g of the sample was weighed into tared silica dishes, ashed in a muffle furnace at 600°C for 3 hours, cooled and weighed.

For ether extract determination about 1.0 g of material was weighed and transferred into paper Soxhlet thimbles. The thimbles and contents were placed into a Soxhlet extractor and previously tared collecting flasks attached. Continuous extraction by di-ethyl ether proceeded for 12 hours after which thimbles were removed. The ether in the flasks was allowed to evaporate before the flasks were oven dried at 105°C for about 2 hours, then cooled and weighed. Ether-extract was expressed as percentage of the original dry weight of the sample.

Crude fibre was determined by boiling exactly 1.0 g of moisture and fat free sample first in 25 ml of 2.05 N sulphuric acid solution added to about 200 ml of boiling water for exactly 30 minutes being stirred occasionally. The sample-acid mixture was filtered using glass wool. The residue was washed three times with distilled water, then 25 ml of 1.78 N NaOH solution was added and volume made up to about 200 ml with boiling water and boiled for exactly 30 minutes. The residue was filtered and washed as before then transferred, using distilled water, to a specially prepared silica dish and finally washed with about 15 ml of 95 percent ethyl alcohol. The residue was dried at 105^{o}C for 4 hours, cooled, weighed and ignited in a muffle furnace at 600^{o}C for two hours. The contents were cooled to room temperature and re-weighed. Crude fibre was calculated as the loss in weight on ignition.

3.4.2 Analyses of Structural Components

For the determination of cell-wall constituents (CWC), about 1 g of the sample was placed in a refluxing Berzelius 600 ml beaker. A 100 ml of cold neutral detergent solution, 2 ml decalin and 0.5 g sodium sulphite were added. The mixture was heated to boil in 5-10 minutes, refluxed for one hour and filtered into previously tared 50 ml sintered glass crucibles with coarse porosity. The residue was washed twice with boiling water and repeatedly with acetone until it removed no colour. The crucibles were then oven-dried at

100°C overnight, cooled and weighed. Cell-wall constituents were reported as weight of residue expressed as a percentage of original dry sample weight.

Acid detergent fibre (ADF) was determined by placing about 1 g of the sample in a refluxing Berzelius beaker. A 100 ml cold acid detergent solution and 2 ml decalin were added. The mixture was heated to boil in 5-10 minutes, refluxed for 1 hour and filtered into previously tared 50 ml sintered glass crucibles with coarse porosity. Contents were washed twice with hot water, then with acetone, and oven-dried at 100°C overnight, cooled and weighed. Acid-detergent fibre was determined as the weight of the residue expressed as a percentage of original dry sample weight.

Hemicellulose (HC) was reported as the difference between cell-wall constituents and acid-detergent fibre.

Permanganate lignin was determined on acid detergent fiber. Crucibles containing acid-detergent residues were placed into a shallow enamel pan. About 25 ml of combined saturated potassium permanganate ($KMnO_4$) and buffer solution (in the ratio 2:1 v/v) was added into each crucible. A short glass rod in each crucible was used to break up lumps and stir contents. At the end of 90 minutes the crucibles were removed from the pan, filtered without washing then filled with demineralising solution twice, lasting about 5 minutes each. The contents were washed twice with 80 percent ethanol, and twice with acetone. Crucibles were oven-dried

at 100°C overnight, cooled and weighed. Lignin was calculated as loss in weight from acid-detergent fiber expressed as a percentage of the original dry sample weight.

The contents of crucibles after determination of permanganate lignin were ashed at 550°C for about 4 hours in a muffle furnace. Crucibles were then cooled and weighed. Cellulose was calculated as the loss in organic matter upon ashing expressed as a percentage of original dry sample weight.

To the crucible contents, after determining cellulose was added about 4 ml of 48 percent hydrobromic acid. Acid was filtered off after two hours and contents washed with acetone and filtered, before oven-drying at 100°C for about 8 hours, placed in muffle furnace for 2 hours at 550°C, cooled and weighed. Silica was calculated as the weight of the residue after hydrobromic acid treatment and expressed as a percentage of the original dry sample weight.

3.4.3 Mineral analysis

Calcium was determined at 422.7 nm wavelength by atomic absorption spectrophotometry using a Perkin-Elmer-Model 303 fitted with an air acetylene flame (Perkin-Elmer, 1971). The vanadium phosphomolybdate colorimetric method was used for phosphorus determination. Optical density was determined using Beckman model B spectrophotometer with 1 x 10 cm optical cells at 450 nm wavelength. Sodium was determined by the method of flame photometry.

3.4.4. In vitro digestibility of dry matter and organic matter

Dry matter digestibility of samples was determined *in vitro* by the Tilley and Terry (1963) two-stage *in vitro* rumen fermentation technique.

Rumen fluid was obtained from a healthy Hereford x Boran cross steer, fitted with a permanent rumen fistula based at the University Farm, Kabete. The steer was about four years old. The animal was fed on good quality *Chloris gayana* hay in the morning about three hours before rumen liquor collection was done.

Rumen ingesta drawn from the animal was transferred into a two-litre Thermos Flask, previously flushed with warm ($40^{o}C$) water. Finally the rumen ingesta was transferred to the forage evaluation laboratory of the Department of Animal Production, University of Nairobi.

In the laboratory cheese-cloth was used to squeeze rumen fluid from the ingesta into a beaker kept in a water-bath at $40^{o}C$, and carbon dioxide (CO_2) was bubbled gently through the rumen fluid.

McDougall's artificial saliva was prepared in two parts: first part was made by dissolving in one litre of distilled water, 9.8 g sodium bicarbonate ($NaHCO_3$); 7.0 g disodium hydrogen orthophosphate ($NaHPO_4.7H_2O$); 0.57 g potassium chloride (KCl); 0.47 g sodium chloride (NaCl) and 0.12 g

magnesium sulphate ($MgSO_4.7H_2O$). The second part was prepared by dissolving 4.0 g calcium chloride ($CaCl_2$) in 100 ml. Just before use, 1 ml of the 4 percent $CaCl_2$ solution was added per litre of the buffer.

Artificial saliva and rumen fluid were mixed in a ratio of 4:1 (v/v) in a flask connected to carbon dioxide (CO_2) cylinder. Carbon dioxide was bubbled through the media continuously.

To about 0.5 g of forage sample placed into a 100 ml rumen fermentation test tube, 2 ml of distilled water was added to wet all particles. Fifty ml of rumen inoculum was added from the dispensing burette, after which the tube was flushed with carbon dioxide and closed with the rubber stopper fitted with a Bunsen valve for gas release. Tubes were shaken to mix the media with forage particles and transferred into an oven set at 40°C for incubation for 48 hours. The contents were shaken 3-4 times during the incubation period. After incubation tubes were removed, centrifuged, decanted and 50 ml of distilled water, 6 ml 20 percent HCl and 2 ml pepsin solution added in order. Tubes were put back in the incubator for a further 48 hours, being shaken 3-4 times a day. Tube contents were transferred to tared Gooche crucibles, filtered and washed three times with hot distilled water. Crucible and contents were dried at 105°C overnight, cooled and weighed. In vitro dry matter disgestibility was calculated as the loss in dry matter during incubation. Crucibles were ashed in a

muffle furnace at 500°C for 3 hours, cooled and weighed. *In vitro* organic matter digestibility was calculated as loss in organic matter during incubation.

3.4.5 Statistical analyses

All data in Experiment I and II were subjected to analysis of variance (Steel and Torrie, 1960) and differences between means were compared using the Duncan's multiple range test (1955).

4. RESULTS

4.1 Effect of chemical treatment on chemical composition of maize cobs

There was a general reduction in dry matter content of the cobs from 96.71 to 94.74, 93.51 and 93.30 percent when cobs were treated with water, NaOH and magadi soda respectively (Table 4.1). Crude fibre decreased from 45.68 to 44.40 and 42.63 percent when cobs were treated with NaOH and magadi soda respectively but was unaffected after treatment of cobs with water.

There was a sharp decline in CWC, ADF and hemicellulose when cobs were treated with NaOH and magadi soda. Sodium hydroxide and magadi soda reduced hemicellulose content of cobs by 54 and 22 percent respectively. Cellulose content was reduced from 45.34 percent in untreated cobs to 42.54 percent by treatment of cobs with magadi soda. Lignin content of cobs was increased from 11.67 percent to 12.16 percent by treatment of cobs with water and reduced to 9.63 percent by NaOH treatment, but was not affected by magadi soda treatment. There was an increase in silica content of cobs from 0.51 to 1.10 after treatment of cobs with NaOH. Water and magadi soda treatment did not greatly increase the silica composition of cobs. Phosphorus content of cobs was increased by all treatments. Sodium content was greatly increased by treatment of cobs with NaOH and magadi soda. There was no apparent increase in calcium content of the treated cobs.

TABLE 4.1: CHEMICAL COMPOSITION OF TREATED AND UNTREATED MAIZE COBS (DM BASIS)

Component	Untreated cobs	Water-treated cobs	NaOH-treated cobs	Magadi soda treated cobs
Proximate composition (%)				
Dry matter	96.71	94.74	93.51	93.30
Organic matter	98.67	98.45	93.36	91.20
Crude protein	1.72	1.52	1.83	1.78
Crude fibre	45.68	45.38	44.40	42.74
Ether extract	1.23	1.31	1.56	1.55
Ash	1.33	1.55	6.64	8.80
Nitrogen-free extract	50.04	50.24	45.57	45.13
Van Soest composition (%)				
Cell wall constituents	70.55	71.02	60.52	65.34
Cell contents	29.45	28.98	39.48	34.66
Acid detergent fibre	57.01	56.61	53.85	54.14
Hemicellulose	13.54	14.41	6.67	11.20
Cellulose	45.34	44.45	44.22	42.54
Lignin	11.67	12.16	9.63	11.60
Silica	0.51	0.67	1.10	0.64
Mineral composition (%)				
Calcium	Trace[1]	Trace	Trace	Trace
Phosphorus	Trace	0.004	0.02	0.01
Sodium	0.01	0.01	5.00	6.50

[1] Concentration too low to be detected by atomic absorption spectrophotometry.

The composition of rations used in the *in vivo* digestibility of maize cobs is shown in Table 4.2. The rations differed in the concentration of organic matter, total ash, CWC, hemicellulose, silica and sodium. Rations were, however, isonitrogenous, and similar in calcium and phosphorus content. The composition of the other chemical constituents did not show marked differences.

4.2 Experiment I

4.2.1 Effect of grinding (particle size) on digestibility of maize cobs

In vitro dry matter digestibility was affected ($P< 0.01$) by grinding. Mean *in vitro* dry matter digestibility coefficients were 42.44 and 50.97 percent for rations containing 10 mm and 6 mm cobs respectively (Table 4.3). *In vitro* dry matter digestibility was higher ($P< 0.01$) on rations containing 6 mm cobs than on rations containing 10 mm cobs.

Grinding affected ($P< 0.01$) *in vivo* digestibility of crude protein. Mean *in vivo* crude protein digestion coefficients were 23.70 and 18.78 percent on rations with 10 and 6 mm cobs respectively (Table 4.3). *In vivo* digestibility of crude protein on rations containing 6 mm cobs was lower ($P< 0.01$) than on rations with 10 mm cobs. *In vivo* digestibility of ether extract was lowered ($P< 0.01$) by finer grinding. *In vivo* digestion coefficients for ether

TABLE 4.2: CHEMICAL COMPOSITION OF THE RATIONS USED IN THE IN VIVO DIGESTIBILITY STUDY WITH SHEEP (DM BASIS)

Particle size	10 mm cobs			6 mm cobs		
Ration	1	2	3	4	5	6
Proximate composition (%)						
Dry matter	51.54	51.92	48.62	47.59	46.96	46.89
Organic matter	94.37	89.81	88.01	95.55	91.26	86.34
Crude protein	4.12	3.80	3.82	3.70	3.46	3.91
Crude fibre	40.02	37.11	37.53	48.85	49.39	46.89
Ether extract	0.52	0.64	0.70	0.57	0.95	1.08
Ash	5.63	10.19	11.99	4.45	8.74	13.66
Nitrogen-free extract	49.71	48.26	45.96	42.43	37.46	34.46
Van Soest composition (%)						
Cell-wall constituent	82.67	72.62	77.70	85.82	77.66	75.96
Cell content	17.33	27.38	22.30	14.18	22.34	24.04
Acid detergent fibre	51.08	46.75	48.51	51.65	52.84	51.81
Hemicellulose	31.59	27.87	29.19	34.18	24.83	24.15
Cellulose	40.39	36.60	37.79	42.13	45.11	42.83
Lignin	10.69	10.15	10.72	9.52	7.73	8.98
Silica	1.06	1.45	0.86	0.09	0.27	0.12
Mineral composition (%)						
Calcium	0.50	0.54	0.52	0.59	0.40	0.76
Phosphorus	0.19	0.18	0.18	0.23	0.19	0.27
Sodium	0.20	5.00	6.42	0.26	4.70	6.10

TABLE 4.3 EFFECT OF GRINDING ON IN VITRO AND IN VIVO DIGESTIBILITY OF DRY MATTER AND NUTRIENTS (MEAN ± S.E.)

Component	10 mm cobs	6 mm cobs
In vitro digestibility (%)		
Dry matter	42.44[a] ± 0.75	50.96[b] ± 2.02
Organic matter	49.12 ± 1.45	50.24 ± 1.84
In vivo digestibility (%)		
Dry matter	51.76 ± 1.68	55.18 ± 3.08
Crude protein	23.70[a] ± 1.04	18.78[b] ± 2.85
Crude fibre	58.67 ± 1.99	59.51 ± 2.73
Ether extract	47.12[a] ± 5.97	15.40[b] ± 2.94
Cell-wall constituents	55.05 ± 2.04	59.00 ± 2.75
Acid detergent fibre	53.32 ± 1.53	56.08 ± 2.48
Cellulose	58.16 ± 1.82	60.01 ± 2.36

Means in same row with different letter superscripts were significantly ($P < 0.05$) different.

extract were 47.12 and 15.40 percent for rations with 10 and 6 mm cobs respectively (Table 4.3).

Particle size did not significantly ($P > 0.05$) affect *in vitro* digestibility of organic matter and *in vivo* digestibility of dry matter, crude fibre, CWC, ADF and cellulose. However, slight improvement in *in vivo* digestibility of dry matter, CWC and ADF on rations based on 6 mm cobs were noted.

4.2.2 Effect of chemical treatment on digestibility of maize cobs

In vitro dry matter digestibility was improved ($P < 0.05$) by chemical treatment of cobs. The highest improvement was when cobs were treated with NaOH. *In vitro* digestion coefficients of dry matter were 41.94, 47.85 and 47.77 percent on rations containing cobs treated with water, NaOH and magadi soda respectively (Table 4.4). *In vitro* dry matter digestibility was higher ($P < 0.05$) on rations containing cobs treated with NaOH and magadi soda than on the ration containing control cobs. However, the difference in *in vitro* dry matter digestibility between the two chemical treatments was not significant ($P > 0.05$). *In vitro* digestibility of organic matter was improved ($P < 0.01$) by chemical treatment of the cobs. *In vitro* organic matter digestion coefficients were 42.64, 54.63 and 51.43 percent for the rations containing cobs treated with water, NaOH and magadi soda respectively and were different ($P < 0.01$) from each other.

In vivo dry matter digestibility was increased ($P < 0.01$) by chemical treatment of maize cobs. *In vivo* dry matter digestion coefficients were 44.68, 54.16 and 61.57 percent for rations containing cobs treated with water, NaOH and magadi soda respectively (Table 4.4). *In vivo* dry matter digestion coefficients for the three chemical treatments were different ($P < 0.05$) from each other.

In vivo digestibility of crude protein was reduced ($P < 0.01$) by chemical treatment of maize cobs. *In vivo* crude protein digestion coefficients were 28.02, 16.98 and 18.71 percent for the rations containing control, NaOH and magadi soda treated cobs respectively (Table 4.4). *In vivo* crude protein digestibility was higher ($P < 0.01$) on rations containing control cobs than on rations containing cobs treated with NaOH and magadi soda. However, the difference in *in vivo* digestibility of crude protein between NaOH and magadi soda treatments was not statistically significant ($P > 0.05$).

Chemical treatment of maize cobs changed ($P < 0.01$) *in vivo* digestibility of crude fibre. *In vivo* crude fibre digestion coefficients were 55.89, 53.34 and 68.04 percent on rations containing cobs treated with water, NaOH and magadi soda respectively (Table 4.4). *In vivo* digestibility of crude fibre due to treatment of cobs with magadi soda was significantly ($P < 0.01$) higher than when cobs were treated with water and NaOH. The difference in *in vivo* digestibility

TABLE 4.4: EFFECT OF CHEMICAL TREATMENT ON THE IN VITRO AND IN VIVO DIGESTIBILITY OF DRY MATTER AND NUTRIENTS (MEAN ± S.E.)

Component	TREATMENTS		
	Control	NaOH	Magadi
In vitro digestibility (%)			
Dry matter	41.94^{a} ± 1.59	47.85^{b} ± 1.94	47.77^{b} ± 2.19
Organic matter	42.64^{a} ± 1.32	54.63^{b} ± 0.84	51.43^{c} ± 1.12
In vivo digestibility (%)			
Dry matter	44.68^{a} ± 1.63	54.16^{b} ± 1.97	61.57^{c} ± 2.70
Crude protein	28.02^{a} ± 2.21	16.98^{b} ± 2.82	18.71^{b} ± 1.70
Crude fibre	55.89^{a} ± 1.72	53.39^{a} ± 2.22	68.04^{b} ± 2.25
Ether extract	16.46^{a} ± 5.22	49.38^{b} ± 9.03	26.44^{c} ± 8.36
Cell-wall constituents	51.01^{a} ± 2.09	55.06^{a} ± 2.35	64.98^{b} ± 2.70
Acid detergent fibre	53.04^{a} ± 1.24	47.97^{b} ± 1.31	63.09^{c} ± 2.00
Cellulose	57.21^{a} ± 1.66	53.37^{a} ± 1.50	66.67^{b} ± 2.36

Means in same row with different letter superscripts were significantly ($P < 0.05$) different.

of crude fibre between the control and NaOH treatments was not significant ($P > 0.05$).

In vivo digestibility of ether extract was significantly ($P < 0.01$) improved by chemical treatment of cobs. *In vivo* digestion coefficients of ether extract were 16.46, 49.38 and 26.44 percent for rations containing cobs treated with water, NaOH and magadi soda respectively (Table 4.4). *In vivo* digestibility of ether extract was significantly improved by NaOH ($P < 0.01$) and magadi soda ($P < 0.05$) treatment of cobs.

Chemical treatment of maize cobs significantly ($P < 0.01$) improved *in vivo* digestibility of CWC. *In vivo* CWC digestibility coefficients were 51.01, 55.06 and 64.98 percent for the rations containing cobs treated with water, NaOH and magadi soda respectively (Table 4.4). The improvement in *in vivo* digestibility of CWC due to treatment of cobs with magadi soda was significant ($P < 0.01$). The difference in *in vivo* CWC digestibility between the control and NaOH treatments was not significant ($P > 0.05$).

In vivo digestibility of ADF was significantly ($P < 0.05$) changed by chemical treatment of maize cobs. Digestion coefficients of ADF were 53.04, 47.97 and 63.09 percent for the rations containing cobs treated with water, NaOH and magadi soda respectively (Table 4.4). The differences in *in vivo* digestibility of ADF between the three treatments were significant ($P < 0.05$).

In vivo digestibility of cellulose was significantly ($P< 0.01$) affected by chemical treatment of maize cobs. *In vivo* digestion coefficients of cellulose were 57.21, 53.37 and 66.67 percent for the rations containing cobs treated with water, NaOH and magadi soda respectively (Table 4.4). *In vivo* digestion of cellulose on magadi soda treated cobs was higher ($P< 0.01$) than on the control and NaOH treatments of cobs. The difference in *in vivo* cellulose digestibility between the rations containing control and NaOH treated cobs was, however, not significant ($P> 0.05$).

4.2.3 Effect of grinding and chemical treatment on digestibility of maize cobs.

The interaction between grinding and chemical treatment of the maize cobs was significant ($P< 0.01$) with respect to *in vivo* digestibility of crude protein and ether extract. *In vivo* crude protein digestion coefficients were 23.37 and 32.70; 23.82 and 9.43; 24.54 and 14.21 percent on rations containing 10 and 6 mm cobs treated with water, NaOH and magadi soda respectively. *In vivo* crude protein digestion coefficients were depressed on rations containing 6 mm cobs treated with NaOH and magadi soda. *In vivo* ether extract digestion coefficients were 30.85 and 20.04; 78.64 and 23.41; 32.17 and 19.51 percent for rations containing 10 and 6 mm cobs treated with water, NaOH and magadi soda respectively. *In vivo* ether extract digestibility was lower on rations

containing maize cobs ground through 6 mm and treated with water, NaOH and magadi soda than on the rest of the rations (Table 4.5).

In vitro and in vivo dry matter digestibility were marginally ($P \simeq 0.05$) affected by the interaction between grinding and chemical treatment of cobs. In vitro organic matter digestibility, and in vivo digestibility of crude fibre, CWC, ADF and cellulose were not significantly ($P > 0.05$) affected by the interaction between grinding and chemical treatment of maize cobs.

4.3 EXPERIMENT II

Rations used in the Friesian cattle feeding trial differed in the composition of organic matter, ether extract, total ash, nitrogen free extract, CWC, hemicellulose, silica and sodium. There were similarities between rations in crude fibre, ADF and phosphorus concentrations (Table 4.6). The composition of the grazed pasture during the experimental period is shown in Table 4.7.

4.3.1 Effect of chemical treatment of maize cobs on cattle performance

Performance data of the grazing cattle supplemented with treated and untreated maize cobs are shown in Table 4.8. Total weight gain expressed as a percentage of the initial weight was improved ($P < 0.05$) when cattle were fed on rations containing chemically treated cobs. The highest improvement

TABLE 4.5: EFFECT OF INTERACTION BETWEEN GRINDING AND CHEMICAL TREATMENT ON IN VITRO AND IN VIVO DIGESTIBILITY OF DRY MATTER AND NUTRIENTS

Particle size	10 mm cobs			6 mm cobs			SE
Chemical treatment	Water	NaOH	Magadi soda	Water	NaOH	Magadi soda	
In vitro digestibility (%)							
Dry matter	40.43	43.73	43.17	44.20	54.03	54.67	0.55
Organic matter	41.70	55.05	50.60	44.05	54.00	52.68	0.43
In vivo digestibility (%)							
Dry matter	46.04	53.14	56.09	43.32	55.18	67.04	1.27
Crude protein**	23.37	23.82	24.54	32.70	9.43	14.21	0.58
Crude fibre	56.68	53.64	65.68	55.09	53.03	70.40	1.52
Ether extract**	30.85	78.64	32.17	20.04	23.41	19.51	2.14
Cell-wall constituents	51.99	53.20	59.90	50.02	56.94	70.05	1.73
Acid detergent fibre	53.65	46.90	59.41	52.43	49.04	66.78	0.70
Cellulose	57.70	53.33	63.46	56.73	53.41	69.88	1.18

**P< 0.01

TABLE 4.6: CHEMICAL COMPOSITION OF RATIONS USED IN THE FRIESIAN CATTLE GROWTH STUDY (DM BASIS)

Particle size	10 mm cobs		
Rations	A	B	C
Proximate composition (%)			
Dry matter (as fed)	45.68	46.66	49.40
Organic matter	95.12	90.18	89.04
Crude protein	3.61	3.22	2.89
Crude fibre	41.16	41.18	40.79
Ether extract	2.16	1.55	1.50
Ash	4.88	9.82	10.96
Nitrogen-free extract	47.73	44.23	43.86
Van Soest composition (%)			
Cell-wall constituents	84.43	73.57	79.80
Cell contents	15.57	26.43	20.20
Acid detergent fibre	49.64	50.44	49.46
Hemicellulose	34.79	23.31	30.34
Cellulose	38.36	41.13	37.23
Lignin	11.28	9.31	12.23
Silica	0.86	1.18	0.30
Mineral composition (%)			
Calcium	0.44	0.57	0.64
Phosphorus	0.27	0.24	0.29
Sodium	0.80	4.80	6.30

TABLE 4.7: PROXIMATE AND MINERAL COMPOSITION OF GRAZED PASTURES THROUGHOUT THE STUDY PERIOD (DM BASIS)

Component	Content (%)
Proximate composition	
Organic matter	91.52
Crude protein	8.80
Crude fibre	38.34
Ether extract	3.25
Ash	8.48
Nitrogen-free extract	41.15
Mineral composition	
Calcium	0.30
Phoshporus	0.23
Sodium	0.03

TABLE 4.8 PERFORMANCE OF GRAZING DAIRY CATTLE SUPPLEMENTED WITH RATIONS BASED ON TREATED AND UNTREATED MAIZE COBS[1]

	Rations		
	A	B	C
Number of animals	6	6	5
Initial weight (kg)	118.8± 4.0	109.4±4.8	112.3±4.8
Final weight (kg)	154.3± 7.4	154.2±7.5	159.4±10.2
Total weight gain (kg)	35.5± 4.4	44.8±3.3	47.2±7.3
Total weight gain (% initial weight)	29.7^{a}[2] ±3.2	40.9^{b}±2.1	42.0^{b}±6.0
Average daily gain (kg)	0.38±0.05	0.48±0.04	0.50±0.08
Total feed intake (kg DM)	314.49	480.34	240.97
Average cob intake per day (kg DM)	3.35	5.11	2.56
Relative feed efficiency (Feed/gain)	8.85	10.94	5.12

[1]Rations A, B and C were based on 10 mm cobs treated with water, NaOH and Magadi soda.

[2]Means in same row with different letter superscripts were significantly ($P< 0.05$) different.

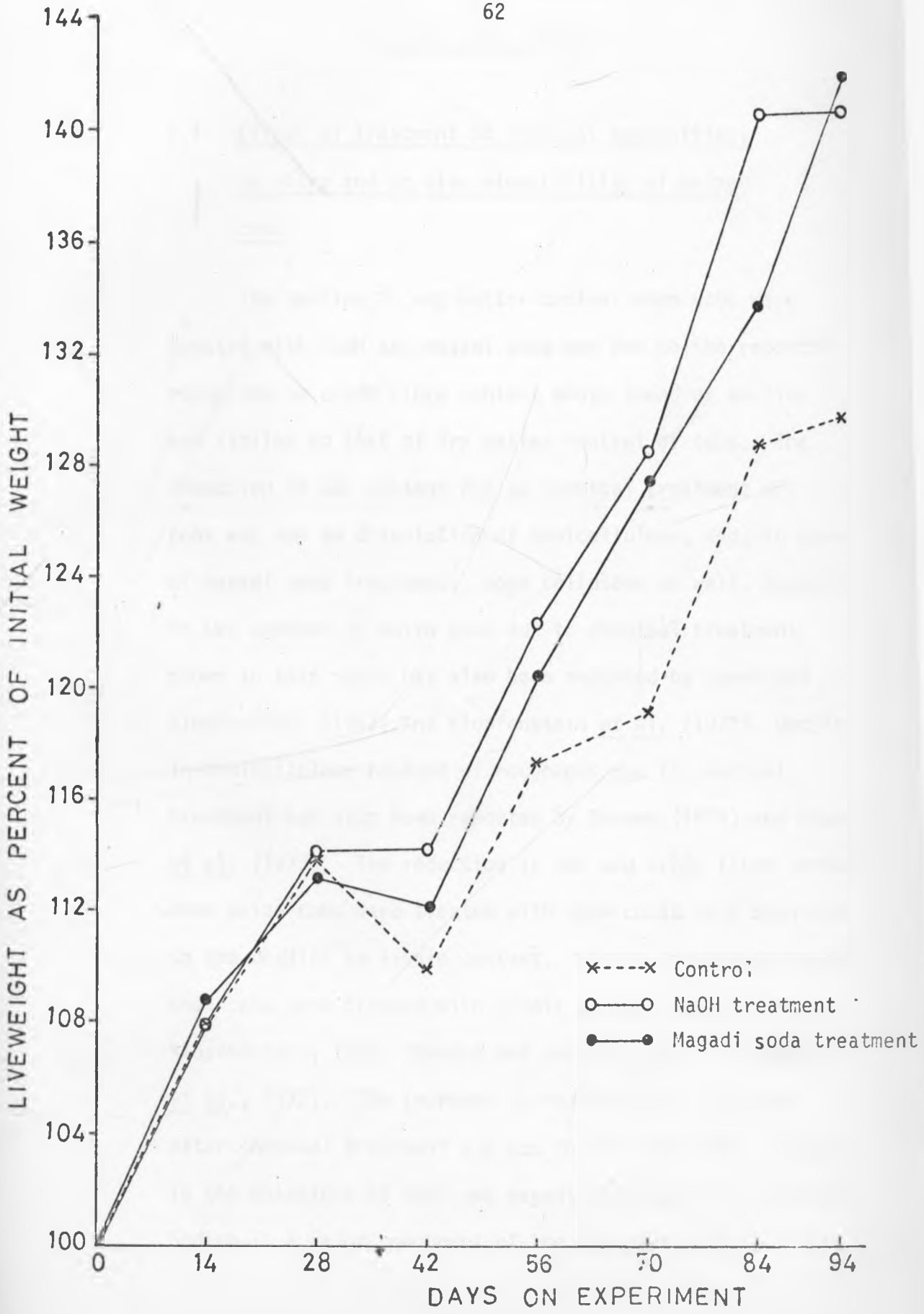
was obtained from cattle fed rations containing cobs treated with magadi soda. Weight gains as a percentage of initial weight were 29.72, 40.87 and 42.02 percent for cattle fed rations A, B and C respectively. Total weight gain as percent of initial weight was higher ($P< 0.05$) on rations containing treated cobs (B and C) than the ration (A) containing control cobs. However, the difference in weight gain as percent of initial weight between the two chemical treatments (B and C) was not significant ($P> 0.05$).

Chemical treatment of cobs did not significantly ($P> 0.05$) affect average daily gains of cattle. However, the highest ADG was recorded when cattle were fed rations containing cobs treated with magadi soda. Average daily gains were 0.38, 0.48 and 0.50 kg for animals supplemented with rations A, B and C respectively.

Feed intake per animal per day was increased from 3.35 kg dry matter on control ration (A) to 5.11 kg dry matter on the ration containing NaOH treated cobs (B), but intake was reduced to 2.56 kg dry matter on the ration based on magadi soda treated cobs (C). Rations based on NaOH treated cobs were more readily accepted than rations based on cobs treated with water and magadi soda. Feed per unit gain was increased from 8.85 on the ration with control cobs to 10.94 on the ration with NaOH-treated cobs, but dropped to 5.12 for animals fed rations containing cobs treated with magadi soda.

When liveweights of the animals were expressed as percent of the initial weights and plotted graphically (Figure 1), animals fed chemically treated cobs were found to gain weight faster than animals fed control cobs. However, it was noted that during the first month of the experimental period, there were no differences in weight gain patterns between the three experimental groups of animals.

Fig. 1.: Growth patterns of grazing dairy cattle supplemented with treated and untreated maize cobs.


144
140
136
132
128
124
120
116
112
108
104
100
LIVEWEIGHT AS PERCENT OF INITIAL WEIGHT
0
14
28
42
56
70
84
94
DAYS ON EXPERIMENT
Control
NaOH treatment
Magadi soda treatment

5. DISCUSSION

5.1 Effect of treatment on chemical composition, in vitro and in vivo digestibility of maize cobs

The decline in dry matter content when cobs were treated with NaOH and magadi soda was due to the recorded reduction in crude fibre content whose trend of decline was similar to that of dry matter content of cobs. The reduction in CWC content due to chemical treatment of cobs was due to dissolution of hemicellulose, and, in case of magadi soda treatment, some cellulose as well. Reduction in CWC content of maize cobs due to chemical treatment shown in this study has also been reported by Jones and Klopfenstein (1967) and Klopfenstein et al. (1972). Decline in hemicellulose content of roughages due to chemical treatment has also been reported by Sharma (1974) and Gharib et al. (1975). The reduction in ADF and crude fibre content when maize cobs were treated with NaOH could have been due to the decline in lignin content. Lignin content decreased when cobs were treated with alkali solution (Jones and Klopfenstein, 1967; Chandra and Jackson, 1971; Klopfenstein et al., 1972). The increase in sodium content of cobs after chemical treatment was due to the high level of sodium in the solutions of NaOH and magadi soda used for treatment. Sodium is a major component of the two chemicals.

Improvement in *in vitro* dry matter digestibility with finer grinding has also been observed by Dehority and Johnson (1961). And reductions in *in vivo* digestibility of crude protein and ether extract due to finer grinding is in agreement with the findings of Rodrigue and Allen (1960), Weston and Hogan (1967) and Hogan and Weston (1967). Increases in *in vivo* digestibility of dry matter, CWC and ADF due to grinding of cobs contradict previous reports by Rodrigue and Allen (1960) and Hogan and Weston (1967).

In vitro digestibility of dry matter and organic matter was improved by chemical treatment of cobs. Similar results have been reported by Jones and Klopfenstein (1967) Klopfenstein *et al.* (1967), Chandra and Jackson (1971) and Klopfenstein *et al.* (1972). Chemical treatment improved *in vivo* dry matter digestibility of cobs. This findings was in agreement with earlier reports by Koers *et al.* (1975) and Djafar and Hussain (1976) who treated maize cobs with alkaline chemicals and obtained improved *in vivo* digestibility of dry matter. The increase in *in vivo* digestibility of dry matter could not be associated with delignification since the lignin content of cobs treated with magadi soda was not altered. Gaillard (1962) stated that high lignin in forages was not always associated with low digestibility. However, silica content of cobs treated with NaOH was increased, and may have been responsible for lowering *in vivo* dry matter digestibility as compared to

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cobs treated with magadi soda. Silica concentration has been associated with low digestibility of forages (Van Soest and Jones, 1968).

In vivo digestibility of crude protein was reduced by chemical treatment of cobs. The observation is contrary to the findings of Djafar and Hussain (1976), who reported improved in vivo digestibility of crude protein when maize cobs were treated with 3 percent NaOH. In vivo digestibility of crude fibre, CWC and ADF was improved by treatment of maize cobs with magadi soda. These results were in agreement with the findings of Djafar and Hussain (1976). Saxena et al. (1971) reported improved in vivo digestibility of CWC due to alkali treatment of oat straw. The increase in in vivo digestibility of cellulose due to treatment of cobs with magadi soda was perhaps responsible for the similar increases in in vivo digestibility of CWC, ADF and crude fibre.

Finer grinding followed by chemical treatment lowered in vivo digestibility of crude protein and ether extract, but marginally improved in vitro and in vivo dry matter digestibility. Similar results have been obtained by Carmona and Greenhalgh (1972) working with milled straw treated with alkali compared to similarly treated chopped straw.

5.2 Effect of chemical treatment of cobs on performance of cattle

Weight gain in dairy cattle was improved by chemical treatment of maize cobs. The improvement was possibly due to improved digestibility of dry matter, espeacially the fibre fraction as a result of chemical treatment of maize cobs. The sodium content in chemically treated rations was greatly increased by treatment of maize cobs. The high sodium content in the rations containing chemically treated cobs could have been partly responsible for the improved weight gains since the sodium content of the pasture was lower (0.03 percent) than the requirement for growing dairy cattle (NRC, 1972). The improved ADG when animals were fed rations containing cobs treated with NaOH (ration B) and magadi soda (ration C) was in agreement with the findings of Koers et al. (1970) and Tubei (1980) who reported improved ADG when animals were fed chemically treated maize cobs. Since in this study the animals were also grazing, the weight gains recorded could not be attributed to the maize cob rations only. However, the improvement in weight gains on rations B and C was definitely due to the nutritional superiority of the chemically treated maize cobs.

Feed intake was improved by treatment of maize cobs with NaOH, probably due to high levels of sodium in the ration. Optimum sodium supplementation has been shown to increase feed intake by animals (Crampton and Harris, 1969;

Aitken, 1976). Djafar and Hussain (1976) and Tubei (1980) also found chemical treatment to increase intake of maize cobs. Reduced intake of ration C (based on cobs treated with magadi soda) could have been due to the fact that the high levels of magadi soda used in treatment (9 g/100 g DM) rendered the ration unpalatable.

Relative feed efficiency measured as feed per unit gain, was lowered by NaOH treatment of maize cobs. The lowered feed efficiency due to NaOH treatment of cobs contradicts the findings of several workers. Koers et al. (1970), Waller and Klopfenstein (1975), Djafar and Hussain (1976) and Rounds et al. (1976) have all reported improved feed efficiency as a result of chemical treatment of maize cobs. Feed efficiency was improved by treatment of maize cobs with magadi soda. Since feed intake on rations containing maize cobs treated with magadi soda was low, feed utilization was probably improved. Generally, low feed intake increases feed utilization efficiency (Crampton and Harris, 1969). It is interesting to note that although cattle fed on cobs treated with magadi soda consumed less cobs, their ADG was the highest of the three groups. The higher ADG may have been partly due to the high feed efficiency recorded, and partly due to the fact that cattle on such rations grazed more than other groups to satisfy a constant volume of rumen contents (Stanley Price, 1977). Grazing had a superior crude protein content, hence the high ADG.

During the first month of the experimental period, there were no differences in weight gain patterns between the three experimental groups of animals. This showed that animals required an adjustment period of not less than one month before they adapted to the chemically treated rations. Hence superiority of the chemically treated cob rations was shown after the adaptation period. Similar results were obtained by Tubei (1980) when he fed ammonia treated maize cobs to ram lambs.

6. CONCLUSIONS

Within limits of the experimental conditions and procedures employed, the results of this study lead to the following conclusions:

1. Chemical treatment of maize cobs decreased the concentration of DM, CF, CWC and hemicellulose. In case of NaOH and magadi soda treatment, lignin and cellulose were reduced respectively.

2. Finer grinding of maize cobs improved ($P< 0.05$) *in vitro* and *in vivo* digestibility of dry matter, but reduced ($P< 0.01$) *in vivo* digestibility of crude protein.

3. Chemical treatment of maize cobs with NaOH and magadi soda improved ($P< 0.05$) *in vitro* digestibility of dry matter, and *in vivo* digestibility of dry matter, crude fibre, CWC, ADF and cellulose, but reduced ($P< 0.01$) *in vivo* digestibility of crude protein.

4. Treatment of maize cobs with magadi soda proved superior ($P< 0.05$) to NaOH treatment in improving the *in vivo* digestibility of dry matter, crude fibre, CWC, ADF and cellulose.

5. Both magadi soda and NaOH were effective in improving the nutritive value of maize cobs when fed to young dairy cattle. Average daily gains were 0.38, 0.48 and 0.50 kg on rations containing cobs treated with water, NaOH and magadi soda respectively. However the cattle required a period of adaptation to chemically treated cobs of not less than one month before differences in growth rates due to chemical treatments could be observed.

7. SCOPE FOR FURTHER STUDY

These research results indicate that further work should be undertaken using the following guidelines:

1. evaluation of chemically treated maize cobs as a dry season feed compared to conventional fodder crops;

2. effect of protein supplementation on the utilization of chemically treated maize cobs; and

3. the value of maize cobs as a carrier for molasses, urea and minerals (MUM).

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APPENDIX A

TABLE 1.A: WEIGHT GAIN DATA OF CATTLE IN EXPERIMENT II

Treatment	Animal No.	Intial wt. (kg)	Final wt. (kg)	Total gain (kg)	Total gain (% initial wt.)	
	H44	110.0	146.5	36.5	33.1	0.
	H40	110.0	143.0	33.0	30.2	0.
A	H28	127.5	177.5	50.0	39.3	0.
(Control)	H45	112.5	134.0	21.5	19.4	0.
	H41	128.0	170.5	42.5	32.9	0.
	H30	125.0	154.5	29.5	23.5	0.
	Mean ± SE	118.8±4.0	154.3±7.4	35.5±4.4	29.7±3.2	0.
	H33	123.5	174.5	51.5	41.2	0.
	H37	112.5	150.5	38.0	33.5	0.
B	H2	115.5	170.5	55.0	47.6	0.
"	H42	99.0	137.5	38.5	38.5	0.
(NaOH)	H36	94.5	134.0	39.5	41.8	0.
	H35	111.0	158.0	47.0	42.6	0.
	Mean ± SE	109.4±4.8	154.2±7.5	44.8±3.3	40.9±2.1	0.
	H32	120.0	186.5	66.5	55.3	0.
	H34	108.5	170.5	62.0	56.9	0.
C	H27	121.5	158.0	36.5	30.3	0.
(Magadi	H31	95.5	124.0	28.5	30.0	0.
soda)	H36	116.0	158.0	42.0	36.5	0.
	Mean ± SE	112.3±4.8	159.4±10.2	47.2±7.3	42.0±6.0	0.

TABLE 2.A. DRY MATTER INTAKE AND FAECAL OUTPUT OVER THE COLLECTION PERIOD FOR ANIMALS USED IN EXPERIMENT I (g/Day)[1]

10 mm cobs						6 mm cobs					
Control		NaOH		Magadi soda		Control		NaOH		Magadi soda	
Intake	Output	Intake	Output	Intake	Output	Intake	Output	Intake	Output	Intake	Output
475	226	727	304	513	161	697	369	1000	587	334	89
631	460	871	346	318	206	1064	673	732	346	546	165
1010	543	508	315	343	137	912	480	597	216	563	321
816	441	587	194	444	206	593	330	1296	358	485	134
856	371	598	346	554	205	799	392	842	546	441	112
Mean 758	408	658	301	434	183	813	449	893	411	474	164

[1]A total of 30 animals was used, five for each treatment. Figures indicate DM intake and faecal output per animal.