Quality of Forage Cereal and Grasses Treated with Municipal and Industrial Wastes

Fisseha Itanna1 and Bruce Coulman2


An experiment was undertaken at Addis Ababa and Kerabu Hurbu in Ethiopia, to examine the forage quality parameters of oats (Avena sativa L.), an introduced forage cereal, and two indigenous warm season grass species, Rhodesgrass (Chloris gayana, cv. Callide) and Setaria (Setaria sphacelata, cv. Kazungula). These grasses were grown on a site (Akaki) treated with industrial effluent, and on two other sites (Peacock Park and Kolfe) treated with municipal effluent. The same species were grown at Kerabu Hurbu (check site), where no chemical waste or fertilizer was applied. Warm season grasses grown at sites receiving municipal waste had lower neutral detergent fiber (NDF) and acid detergent fiber (ADF), and higher crude protein (CP) concentrations than those grown at the sites receiving either industrial waste or no fertilizer. The Rhodes and Setaria grasses at the industrial waste site of Akaki had lower CP concentrations than at Kerabu Hurbu suggesting a negative effect of the industrial wastes on forage quality. Both Rhodes and Setaria grasses had lower ADF, but the former had higher (%) CP than oat. In conclusion, municipal wastes appear to be an excellent nutrient source for the production of high quality forage, so long as other toxic substances are eliminated.

Keywords: Industrial wastes, Municipal wastes, Indigenous grass species, Forage quality, Ethiopia.

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INTRODUCTION

Crop residues and grasses are the major sources of livestock feed in Ethiopia. These sources are generally low in nutritive value, mainly due to poor management conditions. In the last few decades, research has been carried out on the assessment of forage quality evaluation and improvement of local pasture grasses and legumes as well as the adaptation of improved exotic forage species.

Cool-season forages from the temperate zone are said to be intrinsically higher in both protein and digestibility than warm-season grasses of the tropics (Minson 1990). Forage quality of tropical grasses can be improved through addition of adequate nutrients that can increase the carrying capacity, higher than temperate grasses. Despite the adaptability of both warm- and cool-season grasses in the highlands of the tropics, there is more reliance on the warm season forages in developing countries for livestock production (Hacker and Jank 1998).

The common oat (Avena sativa L.) is a cool-season cereal forage, which was introduced to Ethiopia in the late 1960s, and is now grown in the central highlands. The grains are used as food, brewing or as a commodity, and the straw for animal feed and thatching (Mengistu 1997). It grows well on a wide range of soils, from high to low pH and from dry to relatively water logged conditions better than most of the other cereals.

Rhodesgrass (Chloris gayana, Kunth), is an indigenous warm season grass, which is widely grazed by animals and also grows on a wide range of soil types, but requires good fertility for high productivity (Mengistu 1997). It is among the best grass species adapted to semi-arid environment (Kusekwa et al. 1989) and when cut at optimum growth stages, it can produce large amounts of forage per hectare with high nutritive value (Mero and Uden, 1998). The cultivar ‘Callide’ is a tetraploid late flowering, robust and leafy than the other two widely grown ecotypes, ‘Pioneer’ and ‘Katambora’ (Hacker and Jank 1998). Holstein-Friesian cows grazing on nitrogen fertilized Callide pastures have been reported to produce about 3500 kg milk year1, if supplemented with other feed (Cowan et al., 1985).

Setaria (Setaria sphacelata, (Schum.) Stapf and C. E. Hubb. ex M. B. Moss) is also an indigenous warm season grass, which is used both for erosion control and as a forage crop in Ethiopia. It grows on a wide range of soils and tolerates water logging (Mengistu 1997). Setaria, like many other tropical grasses, originated in Africa (Dwivedi, et al. 1999). It has received attention from breeders since the 1950s in other parts of the world. Some of the ecotypes from the highlands of East Africa are reported to have a desirable attribute of retaining green leaf in a light to moderate frost conditions. The tetraploid cultivar ‘Kazungula’ which originated in Zambia is better adapted to higher temperature and drought (Hacker and Jank 1998). Increased nitrogen application has proved to increase in seed yields in this grass (Dwivedi et al. 1999).

In the urban and peri-urban parts of most of the
developing countries, industrial and municipal wastes of organic or inorganic origins are added to rivers or streams flowing through the cities. Farmers utilize the banks of such rivers for growing different crops. Various species of grasses are also found in vegetation in such places. More often not than, the soils receiving such waste sources are productive, likely due to constant supply of plant nutrients from the wastes, and usually a good crop harvest is obtained. Cattle in and around cities like Addis Ababa, Ethiopia, graze on grasses growing with water sources from municipal and industrial wastes.

There are reports which indicated the benefits of applying sewage and sludge on agricultural fields to increase crop productivity, as well as the potential hazards (Sommers 1977; Kelling et al. 1977). Sheaffer et al. (1979) stated that the high levels of N, P and micronutrients found in municipal wastes make them good sources of nutrients. The water from liquid industrial and municipal wastes is also useful to irrigate crops. On the other hand, there are also many reviews indicating higher concentration of potentially toxic heavy metals in plant tissues of the crops grown with industrial or municipal wastes (Valdares et al. 1983).

The main objective of this study was to assess the effects of industrial and municipal wastes on forage quality of oat, Rhodes and Setaria grasses in Ethiopia.

MATERIALS AND METHODS

The study sites:
The experiments were undertaken at four vegetable growing farms within and outside Addis Ababa. Addis Ababa is located in the center of the country at 9° 3' N latitude and 38° 43' E longitude (Ethiopian Mapping Authority, 1988). Its elevation is above 2380m above sea level. The first site, Akaki, is located in the southeastern part of Addis Ababa. At Akaki, industrial liquid waste from a textile factory was used for irrigating vegetable farms. The second and third sites, Peacock Park and Kolfe are found in the central and western parts of Addis Ababa, respectively. Vegetable crops at these sites are irrigated with water of Kebena and Akaki Rivers, respectively.

In addition to the Kebena River, the Bulbula River is also a source of irrigation for other farms in the Peacock Park area. These rivers carry both liquid and solid forms of mainly municipal wastes from the city of Addis Ababa.Livestock in the vicinity are normally fed on remnants of vegetable products grown on these sites, or graze the grasses along the banks of the rivers. The fourth site, located at Kerabu Hurbu (15 km north-east of Addis Ababa), was previously fertilized with compost. Its source of moisture was either rainwater, or clean potable tap water from a source different than these rivers.

Effluents and municipal wastes:
The effluent from the preparation room of the Akaki Textile Factory contains BOD (biological oxygen demand), COD (chemical oxygen demand), TDS (total dissolved salts), and TSS (total soluble salts) with concentrations of 2460, 6720, 9300, and 4230 mg/l, respectively; whereas the concentrations of the BOD, COD, and TDS in the effluents from the dyeing room are, 154, 615, and 4615 mg/l, respectively.

The municipal wastes at Kolfe consisted of industrial effluents largely from a tannery, shoe, soap and marble factories. The daily domestic and wastewater discharge from the above industries is 305, 200, 62 and 21 m³, respectively. Other wastes from garages, gas stations, hospitals etc. are also included. The organic deposits include those from direct human sources, and house and town refuses such as garden clippings, vegetable, fruit and crop remnants, etc.

The Peacock Park municipal waste composition includes some industrial wastes and organic wastes like that of the Kolfe area. Wastewater from the above sources is applied once a day during the dry season and twice a day under extremely dry conditions. The quantity of wastewater applied at these sites from the various sources are not recorded but are added as deemed sufficient by the growers.

Climatic Conditions:
The rainfall in Addis Ababa from July 1 to October 31, 1999 was 811mm with mean maximum and minimum temperatures during July 1999 to February 2000 were 22°C and 8°C, respectively. Since Kerabu Hurbu and Akaki are very close to Addis Ababa and do not have meteorological stations, the weather data provided for Addis Ababa is supposed to be relevant.

Field experiments:
Seeds of oats and cuttings of Rhodes grass (cv. Callide) and forage setaria (cv. Kazungula) were provided by the International Livestock Research Institute (ILRI). Planting was done on July 22 at Kolfe, on July 23 at Peacock Park, on July 25 at Akaki and on July 26, 2007 at Kerabu Hurbu according to recommendations by ILRI in order of oats, Setaria and Rhodes grass along the descending gradients, at all the sites. The plot size was kept 2.0 m x 1.0m consisting of four rows spaced at 20 cm apart. Oat was sown directly, whereas the other two grasses were established from cuttings.

Soil sampling and analyses:
A composite soil sample (0-15 cm) formed from twenty sub-samples was collected from each site before planting. These were first air dried and sieved to pass through 10 and 35 mesh sieves, for 2mm and 0.5 mm size particles, respectively. The organic
The carbon content of the soils was determined using the LECO CR-12 carbon determinator; whereas the total nitrogen was determined using the LECO CNS-2000 Carbon, Nitrogen and Sulfur analyzer. The organic carbon (OC) percent was multiplied by 1.72 to give the percent organic matter (% OM). Particle size analysis was made by the pipette method through wet sieving. The plant available micro-nutrients were determined by the DTPA extraction method (Liang and Karmanos 1993).

Plant sampling, sample preparation and analysis: Three samples for each forage species at each site were taken. Twenty-five tillers were collected for each sample from each experimental plot at 50% (December 13 and 14, 1999) and at full flowering (January 12, 2000) stages for the three contaminated sites and at Kerabu Hurbu. All the samples were dried at 60 °C for 48 hours in a Unitherm drying oven and ground to pass through a 1mm mesh sieve.

Neutral-detergent fiber (NDF), acid-detergent fiber (ADF): The neutral-detergent fiber (NDF) and acid-detergent fiber (ADF) of grass samples were determined sequentially with an ANKOM Fiber Analyzer using a slight modification of the method as described by Vogel et al. (1999). This method involves the use of filter bags in which weighed samples (0.5 g) are placed, sealed, and digested in the ANKOM Fiber Analyzer. For NDF, sodium sulfite (20 g) was added to the NDF solution (Sodium lauryl sulfate) and samples digested at 100 °C for 60 minutes. Following digestion, the bags were rinsed with alpha-amylase, dried overnight at 80 °C and weighed to determine NDF (%). The bags were then placed in cetyl trimethyl ammonium bromide (ADF solution) and the above process was repeated (without sodium sulfite and alpha-amylase) to determine ADF (%). Nitrogen was determined by the micro-Kjeldahl digestion method according to Thomas et al. (1967) and the percent crude protein was calculated by multiplying percent N by 6.25.

Statistical analysis: The data were analyzed by the GLM (General Linear Models) procedure of the 1996 SAS Version 6.12. LSDs (Least Significant Differences), and CVs (Coefficients of Variation) were calculated and comparisons of means of fiber and crude protein of grasses at different locations, and different growth stages were made.

The three forage species were not randomized within sites, thus site x species interactions could not be determined. Two analyses were carried out: (1) Each grass species was analyzed individually over sites, and; (2) The three grass species were compared using sites as replications.

RESULTS AND DISCUSSION

Soil Properties: The Kolfe soil had the highest OM and total nitrogen, among the studied sites. The sites treated with municipal wastes had the highest total nitrogen followed by the check, while the site treated with industrial waste had the least (Table 1).

The Akaki soil was strongly alkaline (pH, 8.9) whereas soils of both Kerabu Hurbu (pH 5.8) and Kolfe (pH, 5.8) were moderately acidic, the pH of the Peacock Park soil was neutral (pH, 7.0). Availability of micro-nutrients was reduced with high pH, but it was increased under neutral or moderately acidic conditions. As such, Akaki had lower DTPA Fe, Mn and Zn than the other three sites.

NDF and ADF: Although the NDF of the three forage species was not significant (Table 2) however, oat had significantly higher ADF over both Setaria and Rhodesgrass (Table 3). These fiber values are lower than those reported for the same grasses in similar ecosystems (Gebrehiwot et al. 1997; Mero and Uden 1998; Mbwile and Uden 1997).

<table>
<thead>
<tr>
<th>Location</th>
<th>OM***</th>
<th>TN****</th>
<th>pH/H2O</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kerabu H.</td>
<td>4.5</td>
<td>0.02</td>
<td>5.8</td>
<td>3.1</td>
<td>113.2</td>
<td>47.1</td>
<td>3.5</td>
</tr>
<tr>
<td>Akaki</td>
<td>3.4</td>
<td>0.01</td>
<td>8.9</td>
<td>3.5</td>
<td>19.3</td>
<td>11.3</td>
<td>2.8</td>
</tr>
<tr>
<td>Peac. P.</td>
<td>3.4</td>
<td>0.03</td>
<td>7.0</td>
<td>2.5</td>
<td>60.3</td>
<td>96.1</td>
<td>9.9</td>
</tr>
<tr>
<td>Kolfe</td>
<td>5.0</td>
<td>0.06</td>
<td>5.8</td>
<td>3.3</td>
<td>89.1</td>
<td>147</td>
<td>10.4</td>
</tr>
</tbody>
</table>

OM*** Organic matter in soil
TN**** Total nitrogen in soil
Gebrehiwot et al. (1997) reported high fiber content in C4 warm-season grasses due to the anatomical characteristics of the leaves. Compared to the C3 cool season grasses, the warm season grasses have higher proportions of bundle sheaths and vascular tissues and lower proportion of mesophyll cells (Norton 1981). In the present study, warm and cool-season grasses did not differ in NDF. However, the cool season oat had higher ADF than the warm season grasses. The relatively higher ADF content of oats than the indigenous warm season species is not consistent with some reviews that suggest that tropical grasses have higher NDF and ADF concentrations than temperate grasses (Moore and Mott 1973). Although, leaves of warm-season grasses have higher fiber, oats may have a higher stem percentage than Setaria and Rhodesgrass, and stems have higher concentrations of lignin and cellulose as main components of ADF.

Significant increase in NDF and ADF in forage cut at the 50% and full flowering stages was noticed. Significant increase in NDF and ADF with advancing maturity has been reported elsewhere (Edmisten et al. 1998; Mbwile and Uden 1997; Gebrehiwot et al. 1997). Gebrehiwot et al. (1997) recorded an increase in ADF concentration with plant maturity to a decrease in a leaf:stem ratio and an increase in cell wall lignification.

Significant differences in NDF in oat at different locations were not analyzed (Table 2). For ADF, oat at Peacock Park had higher concentrations than at Akaki. For Setaria, the highest NDF concentrations were found at Akaki and the lowest at Peacock Park and Kolfe. This trend was also similar for ADF. In Rhodes grass, both ADF and NDF were the lowest at Peacock Park and Kolfe and the highest at Akaki and Kerabu Hurbu. For the warm-season species, it appeared that the municipal waste fertilization led to lower fiber forage. The rivers carrying the municipal wastes carry organic materials from house or town refusors, or from direct human activities. The organic substances have high N, P and micro-nutrient levels, which might have increased the succulence of the grasses and reduced the fiber content. Lower micronutrient concentrations at Akaki, and the poor growth at Kerabu Hurbu, might have affected growth, leading to higher fiber contents due to leaf senescence.

<table>
<thead>
<tr>
<th>Location</th>
<th>Species</th>
<th>Kerabu H.</th>
<th>Akaki</th>
<th>Peac. P.</th>
<th>Kolfe</th>
<th>Mean</th>
<th>1LSD05</th>
<th>1CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat</td>
<td>56.8</td>
<td>53.2</td>
<td>55.6</td>
<td>55.3</td>
<td>55.2</td>
<td>4.3</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>Setaria</td>
<td>57.0</td>
<td>60.9</td>
<td>53.5</td>
<td>55.6</td>
<td>56.7</td>
<td>2.1</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Rhodes</td>
<td>61.1</td>
<td>61.8</td>
<td>53.2</td>
<td>56.1</td>
<td>58.0</td>
<td>1.9</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>56.6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Mean NDF (%) of three forage species at four sites

<table>
<thead>
<tr>
<th>Location</th>
<th>Species</th>
<th>Kerabu H.</th>
<th>Akaki</th>
<th>Peac. P.</th>
<th>Kolfe</th>
<th>Mean</th>
<th>1LSD05</th>
<th>2LSD05</th>
<th>1CV</th>
<th>2CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat</td>
<td>33.3</td>
<td>29.8</td>
<td>33.1</td>
<td>31.0</td>
<td>31.8</td>
<td>3.5</td>
<td>5.9</td>
<td>4.7</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>Setaria</td>
<td>27.0</td>
<td>28.9</td>
<td>25.8</td>
<td>27.0</td>
<td>27.0</td>
<td>1.8</td>
<td>4.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhodes</td>
<td>27.6</td>
<td>28.2</td>
<td>25.3</td>
<td>26.6</td>
<td>26.6</td>
<td>1.5</td>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 Mean ADF (%) of three grass species sampled at four sites

1LSD05 Compares location means for each grass species.
2LSD05 Compares grass species across all locations.
1CV(%) CV for locations for each grass species.
2CV(%) CV for all grass species across all locations.
* Kerabu Hurbu
** Peacock Park
Crude Protein:

As there was a significant species growth stage interaction, crude protein percentages are reported individually for the two sampling stages (Tables 4 and 5). CP (%) was consistently twice as high at Peacock Park and Kolfe than at Kerabu Hurbu and Akaki. This is likely due to the higher soil N and the nutrients from organic materials supplied through the municipal wastes, at the former two sites. It appeared that the industrial liquid waste adversely affected the soil reaction by making it strongly alkaline, which might have affected the ability of the plant to extract optimal amounts of soil nitrogen. Highly alkaline soil conditions at Akaki reduced the mobility of nutrients and hence, the availability of some of the micro-nutrients adversely influenced (Table 1), which might have reduced the overall plant growth and N uptake. Hacker and Jank (1998) reported that protein concentration is affected by plant nutrition. It is possible that the industrial waste raised the salinity level of the soil. There is a general trend of yield reduction in forage crops with increasing salt content (Pasternak et al. 1993), which may also cause reduction in CP (%).

Thus, addition of municipal wastes can contribute to better forage quality from the standpoint of higher CP content of the forages. As such, CP contents of all the grasses grown with municipal wastes at both Peacock Park and Kolfe were higher than the (6-8%) considered to be minimal for ruminant requirements (Gebrehiwot et al. 1997). The statement that tropical grasses are inherently low in N and rarely satisfy the minimum CP requirements for ruminants is not always true due to the fact that municipal waste increased the forage CP content well above the required levels. On the other hand, forage grown with industrial waste at Akaki, falls within the 6-8% CP range for oats and Rhodes grass, while forage Setaria, had only a mean of 5.8%.

### Table 4

Mean CP (%) of three forage species sampled at 50% flowering at four sites

<table>
<thead>
<tr>
<th>Location</th>
<th>Species</th>
<th>Kerabu H.</th>
<th>Akaki</th>
<th>Peac. P.</th>
<th>Kolfe</th>
<th>Mean</th>
<th>1LSD₀.₀-five</th>
<th>2CV(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oat</td>
<td>5.2</td>
<td>8.3</td>
<td>12.0</td>
<td>9.8</td>
<td>8.8</td>
<td>2.7</td>
<td>15.5</td>
</tr>
<tr>
<td></td>
<td>Setaria</td>
<td>7.5</td>
<td>5.7</td>
<td>15.3</td>
<td>14.8</td>
<td>10.8</td>
<td>2.0</td>
<td>9.4</td>
</tr>
<tr>
<td></td>
<td>Rhodes</td>
<td>7.5</td>
<td>6.6</td>
<td>14.0</td>
<td>15.1</td>
<td>10.8</td>
<td>2.1</td>
<td>9.5</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1LSD₀.₀-five Compares location means for each grass species.
2LSD₀.₀-five Compares grass species means across all locations.
CV CV for locations for each grass species.

### Table 5

Mean CP (%) of three grass species sampled at full flowering at four sites

<table>
<thead>
<tr>
<th>Location</th>
<th>Species</th>
<th>Kerabu H.</th>
<th>Akaki</th>
<th>Peac. P.</th>
<th>Kolfe</th>
<th>Mean</th>
<th>1LSD₀.₀-five</th>
<th>2CV(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oat</td>
<td>3.1</td>
<td>7.1</td>
<td>12.9</td>
<td>7.6</td>
<td>7.6</td>
<td>2.1</td>
<td>13.5</td>
</tr>
<tr>
<td></td>
<td>Setaria</td>
<td>7.8</td>
<td>5.9</td>
<td>14.4</td>
<td>14.9</td>
<td>10.7</td>
<td>1.5</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>Rhodes</td>
<td>8.4</td>
<td>6.8</td>
<td>17.5</td>
<td>15.9</td>
<td>12.1</td>
<td>1.5</td>
<td>7.1</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1LSD₀.₀-five Compares location means for each grass species.
2LSD₀.₀-five Compares grass species means across all locations.
CV CV for locations for each grass species.

1CV CV for all grass species across all locations.
Crude protein concentration decreased in oat and increased in Rhodesgrass with advancing maturity. Production of new tillers in Rhodesgrass, might have increased the CP at an early stage while a decline in CP concentration of grasses with advancing maturity due to decrease in foliages (Gebrehiwot et al. 1997).

Significant differences in the CP concentrations of the three grasses at 50% flowering were not recorded with exception to Rhodes grass which was analyzed for higher CP than the oat harvested at full flowering stage. Oat, being a temperate crop, might not have improved its quality under tropical conditions in the highlands. Greater than 10% CP in oat has been reported elsewhere (Hussain et al., 1994).

**CONCLUSION**

NDF and ADF concentrations of the warm-season grasses, Setaria and Rhodesgrass, are generally lower with higher CP concentrations on sites in Ethiopia, receiving municipal wastes than those receiving industrial waste or no fertilizer. This advantage in quality is not always found for oat. It appears that the addition of organic matter and nutrients from the municipal wastes promoted succulent, high quality growth in the warm season grasses. As long as toxic substances such as heavy metals are not introduced, municipal wastes appeared to be an excellent nutrient source for the production of high quality forage. Hacker and Jank (1998) suggested that appropriate management practices could increase the milk production in the tropics. Utilization of available municipal wastes to improve forage quality represents one aspect of appropriate management if the concentration of other toxic substances must be within the safe level.

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