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Fresh banana peelings ready to be fed out Photo: Linn Frendberg

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Sammanfattning

Urbaniseringen i Kampala växer snabbare än den ekonomiska tillväxten, vilket skapar en stor grupp människor med så svag köpkraft att de inte kan köpa mat för dagen. En lösning på problemet är att odla sin egen mat, men med de begränsade landarealer som en växande befolkning leder till, finns det inte tillräckligt med mark att odla eller bedriva extensiv boskapsproduktion. Bönderna tvingas därför att utfodra djuren med de biprodukter som genereras från hushållet och från den lokala marknaden.

Uganda är en av världens främsta bananproducenter, där den större delen av produktionen går till landets egna humankonsumtion, vilken i sin tur genererar enorma kvantiteter bananskal varje år. Bananskalen säljs på de lokala marknaderna och utgör en billig foderkälla till framförallt idisslare för Ugandas bönder. Det varma klimatet samt skalens höga vatteninnehåll, gör att bananskalens hållbarhet begränsas till 1-3 dagar, vilket medför att bönderna nästintill dagligen måste åka till marknaden för att köpa mer.

Denna studie syftade till att utreda ensileringsegenskaperna hos bananskal för att undersöka om lagring genom konservering av materialet är möjligt. Studien genomfördes som en minor field study i Kampala och är en del av det pågående projektet ”Feed for livestock in urban/peri-urban areas of Kampala” mellan Sveriges lantbruksuniversitet (SLU) och Makerere University, Kampala. Bananskal köptes in färska för att sedan ensileras på fyra olika gårdar, en silo på varje gård, under 4 veckor. Två prov från varje silo togs för analys av torrsubstans (ts), neutral detergent fibre (NDF) och acid detergent lignin (ADL), både direkt efter fermentationen och efter 6 dagars syreexponering. Temperatur och pH mättes dagligen under de 6 dagarna för att avgöra ensilagets aeroba stabilitet. Slutligen togs 2 prov från varje silo för analys av flyktiga fettsyror (VFA). Resultaten visade låga värden av samtliga VFA samt stigande pH och temperatur under syreexponeringen hos majoriteten av gårdarna, vilket tyder på en otillräcklig fermentation med hygieniskt och näringsmässigt förfall som konsekvens vid syreexponering. ADL och NDF ändrades inte nämnvärt under syreexponeringen. Den otillräckliga fermentationen kan bero på otillräckliga mängder lättsmälta kolhydrater i ensileringsmaterialet, samt en bristande mekanisk bearbetning av materialet innan ensilering. Förslag för vidare studier inom området är att blanda bananskalen med ett fodermedel rikt på socker för att skapa ett mer lättfermenterat ensilagematerial.

Introduction

General facts of Uganda

Uganda is a country located at the equator in East Central Africa and borders to Democratic Republic of Congo, Sudan, Kenya, Tanzania and Rwanda. The country is landlocked and has a total land area of 241, 000 km², out of which approximately 44, 000 km² is water. In July 2012, The World Factbook estimated the population to be 33.6 million people, out of which 35% is living below poverty line. The annual population growth rate in the country is approximately 3.6% and the estimated annual urbanization rate 2010-2015 is 4.8%. The life expectancy is 54 years and today only 2.1% of the population reaches above the age of 65 (CIA, 2012).

Uganda is a former British colony, which claimed its independence in 1962. In the following years Uganda experienced a decade of relative political and economic stability, but in 1971 Idi Amin (dictator and 3rd president of Uganda) took over power through a military coup. The Amin regime (1971-1979) resulted in a trajectory of violence and mismanagement that reduced the country to a failed state, collapsed economy, and widespread corruption

(Banugire, 1985). The political and economic instability continued as the Amin regime was followed by a war between the government and the Lord´s resistance army, beginning in 1986 (FAO, 2012l). In 2006 the economy stabilized but the poverty remains widespread and in the northern parts of Uganda 64% of its population is still unable to meet basic needs (FAO, 2012i).

Furthermore, the high incidence of infectious diseases, limited access to health care and sanitation, food insecurity and undernourishment contribute to a high rate of maternal and child mortality (FAO, 2012h). Another great challenge that the country faces is the struggle against HIV/AIDS, and according to CIA (2012), 1.2 million people are living with HIV/AIDS today. The epidemic is not only a personal tragedy, but also causes a great labor shortage domestically and on farm, resulting in a setback in the agricultural development (FAO, 2012j).

Over 95% of Uganda's population is involved in farming (both crops and livestock) (FAO, 2012a). Furthermore, agriculture contributes to over 40% of the Gross Domestic Product (GDP) and over 90% to the country's foreign exchange earnings (FAO, 2012a). This makes agriculture the backbone of Uganda's economy, employing over 80% of the work force (CIA, 2012). Uganda has substantial natural resources. The tropical climate with regular rainfalls, fertile soils, and a great number of lakes and rivers makes the country suitable for crop growing as well as livestock rearing and more than 75% of the land area is available for both cultivation and pasture (FAO, 2012a).

The livestock species most frequently kept in Uganda include cattle, sheep, goats, pigs, rabbits and poultry. Livestock production is an important sub-sector of agriculture contributing about 7.5% to total GDP. The most common production systems are mixed farming small holders and pastoralists, which owns over 90% of the cattle herd and all of the small ruminants and non-ruminant livestock. From an economic point of view, cattle are the most important livestock with significant contributions of milk and meat products and the national average is 1.37 cattle per household (FAO, 2012a).

General facts about Kampala

Kampala, the capital of the Republic of Uganda, is the only district in Uganda with a city status and is located on the northern shores of Lake Victoria. The city resides of five different divisions (Central, Kawempe, Rubaga, Makindye and Nakawa). Each division is further divided into parishes and subsequently into villages (Atukunda *et al*., 2012). The area that constitutes Kampala has rapidly grown from 8 km^2 to approximately 195 km^2 and the population has increased from 450,000 in 1980, to 1.7 million people in 2011. At this growth rate the population is projected to reach 3.03 million people by the year of 2020 (UBOS, 2012).

Urban and peri-urban farming

Urban and peri-urban farming have been practiced in Uganda for many years. However, the increase in urban agriculture can be traced back to the Idi Amin regime (1971-1979) when the value of wage labor drastically declined and as a result many urban households were forced to resort to whatever income-generating activity in order to make a living, farming being one of them (Maxwell, 1995; Bigsten & Kayizzi-Mugerwa, 1992).

Today urban farming and livestock production still plays a significant role in developing countries as it contributes to poverty alleviation. The persistent rural poverty causes people to migrate to urban areas with the hope of improving their livelihood. However, the urbanization rate in many cities is outpacing the economic growth, leading to lack of employment opportunities. Consequently, many low income households with weak purchasing power are experiencing daily food scarcity. One of the major coping mechanisms to urban poverty and hunger is urban farming (Gonzalez Novo and Murphy, 2000; Armar-Klemesu, 2012) and according to Cofie *et al.* (2003), up to 60% of the food consumed by low income groups is self-produced.

Furthermore, Lee-Smith (2008) categorized the farming households of Kampala into four groups: commercial farmers, food self-sufficiency farmers, food security farmers and survival farmers. The largest group is the "survival farmers" and includes a big number of women-headed households, often found in urban and peri-urban areas, which are either widowed or abandoned by their husband. These women have limited access to other forms of urban employment and have no other choice than to practice agriculture in order to meet the daily food requirements. However, according to results from an on-going collaborative research project between the Swedish University of Agricultural Science (SLU) and Makerere University on "Feed for livestock in urban/peri-urban areas of Kampala", livestock production in Kampala is being limited by the scarcity of animal feed. Due to the rapid urbanization and the high population density that follows, land area available for the cultivation of forage and grazing is restricted. Additionally, commercial feeds or agro-industrial by-products are often too expensive for the low-income urban and peri-urban farmers, compelling the farmers to rely on unconventional fodder resources, such as banana peelings (obtained from food markets, restaurants/hotels, households etc.) (Katongole, personal communication, 2012).

Banana peelings

Bananas constitute one of the most important staple food crops for human consumption in Uganda. The country produces about 8.5 million tons of bananas a year, which is approximately 15% of the world's production, most of it for domestic use (FAO, 2012k). This means that bananas are a key part of many families' every day diet, which in return generates considerable quantities of banana peelings each day all year round. Banana peelings are therefore one of the most frequently used feed resource in livestock production in Uganda (Nambi-Kasozi, 2008).

Banana peelings have a number of positive attributes, which make them suitable as animal feed and as an alternative complementary feed during periods of forage shortage. They have high moisture content, around 15% DM (FAO, 2012f), which helps animals to stay hydrated. Banana peelings are also a good source of minerals, especially in potassium (Anhwange, 2008) and have a fiber content around 30% NDF of DM (Happi Emaga *et al*, 2011). In comparison to many grass species, that has NDF fractions around 45% of DM (NRC, 2001), banana peelings have a lower fiber content, which gives an improved digestibility and subsequently an elevated intake compared those of grasses (Nambi-Kasozi, 2008). According to a study by Kimambo and Muya (1991), banana peelings showed a 60.6% digestibility of DM and a 58.6% digestibility of organic matter (OM). However, due to low levels of crude protein (CP) (around 8% of DM) the banana peelings should be offered with supplementation in order to reach optimum performance of the animal (Happi Emaga *et al*, 2011; Nambi-Kasozi, 2008).

The availability and the characteristics of banana peelings, makes it a food waste suitable for ruminant feeding. Nevertheless, there are some concerns about the utilization, including poor storage ability and heavy contamination due to indiscriminate dumping. According to Katongole *et al.* (2011), the average storage length of market crop wastes, like banana peelings is 1 to 3 days. Because of the poor storage ability the farmers have to collect the banana peelings from markets on a daily basis, yet transportation is time consuming, and expensive and as the farmers themselves often lack the appropriate vehicles for transportation, they cannot be guaranteed a constant access of feed. Also, the demand for banana peelings is high and most of the time not free of charge for the farmers (Katongole *et al*, 2011).

The potential use of silage

In order to increase the durability of feed there are several conservation techniques today being used in a modern farming systems. Sun drying, artificial drying, and addition of acids are the most common ones and are effective storage methods when it comes to avoiding feed scarcity during periods when feed resources are being limited. However, hay making in the tropics can be difficult because at the time when the forage is of good quality for conservation (early in the wet season), the weather is likely to be too unpredictable for sun drying. Artificial drying is too expensive and the facilities are not available. Fermentation with the addition of acids is beyond the resources of smallholders and can be dangerous to handle (FAO, 2012c).

Fermentation only using naturally produced acids is however a convenient and economical alternative for ensuring constant availability of feed resources for the smallholders. Yet, fermentation without additives places greater demand on the moisture content, the chemical composition and the management of the silage material. The strong correlation between the fermentation process and the nutritional values of the fermented feed make factors like silo packing speed, chop length, silage pack density and silo management during storage and feed-out, of great importance in order succeed (Kung and Shavers, 2001). Secondly, the quality of the ensiled product also depends on the properties of the fresh material. Silage making using only naturally present bacteria is preferably practiced with materials having a low buffering capacity, a DM content higher than 20%, and with naturally occurring lactic acid fermentative microorganisms present (FAO, 2012d). Additionally, in order to achieve a rapid lowering of the pH and restrict the activities of undesirable bacteria without losing nutrients, the concentration of easily fermentable carbohydrates is another factor of great importance (FAO, 2012f).

Also, in order for the ensiling system to be worthwhile to the low income, small-scale farmer it must have a low investment cost, uncomplicated technology, give rapid and significant returns on investment and be reliable and repeatable (FAO, 2012d).

The ensiling process

Ensiling is a preservation method based on spontaneous lactic acid fermentation under anaerobic conditions. The lactic acid bacteria (LAB) convert the free sugars in the forage to lactic acid, which lowers the pH and inhibits pH-sensitive microorganisms to spoil the silage (Danner *et al*, 2003). A lactic acid concentration around 7% of the DM in grass silage indicates a good fermentation process (Kung and Shavers, 2001). A low pH in a well ensiled product preserves the material for as long as it remains in airtight storage (FAO, 2012e). The optimal pH varies to some extent with the DM content, but the desired pH in a grass silage with a 30-35% DM ranges from 4.3 to 4.7. A rise in pH above 4.7 may be a consequence of undesirable microbial activity, such as the growth of Clostridia (Lemus, 2010). Clostridia are anaerobic bacteria that degrade the nutritionally value of the silage at the same time as it produces high levels of butyric and acetic acids and of ammonia. Normal concentration (% of DM) of acetic acid in the ensiled material would be 2-3% and for butyric acid <0.5% (Kung and Shavers, 2001).

Ammonia is another end product of importance since the amount of ammonia tells us about the extent of the proteolysis in the silage. The ammonia fraction of the crude protein (CP) in grass silage should be between 8 and 12%. A concentration above 12% does not by itself affect the animal but as a high level of ammonia often is coupled to Clostridia, which reduces the performance of the animal, the ammonia fraction have to be restricted (Kung and Shavers, 2001).

The basic principles of silage making from by-products, such as banana peelings, are the same as silage making from forage. The process of fermentation can be divided into four phases; aerobic phase, fermentation phase, stable phase and the aerobic spoilage phase. In the first phase the respiration from the plant material and the micro-organisms causes the atmospheric oxygen to reduce in the space between the forage. It's important to make the material as compact as possible so that the first phase can occur as quickly as possible, minimizing the growth of unwanted microorganisms. The next phase starts as soon as the environment becomes anaerobic. This is when the LAB becomes the predominant population, resulting in a low pH. During the third phase relatively little happens. As long as an anaerobic environment is provided, the conservation stays unchanged. The last phase starts when the material is exposed to air, usually during time of feed-out. The oxygen makes it possible for the yeast to degrade the preservative acids, causing the pH to ascend, temperature to increase and spoilage microorganisms to ruin the silage (FAO, 2012e).

Objectives

This study is connected to an on-going collaborative research project between the Department of Animal Nutrition and Management at the Swedish University of Agricultural Sciences (SLU) and the Department of Agriculture at Makerere University, Kampala. The major project "Feed for livestock in urban/peri-urban areas of Kampala" aims to identify, quantify and nutritionally classify the feed resources available for smallholders in urban and peri-urban areas of Kampala City. Results from the study indicate that livestock production in Kampala is characterized by low-input systems, particularly in terms of feeding. The participating farmers cited the lack of knowledge as the major limiting factor to why the use of conservation methods, such as silage making, is not practiced. Good ensiling characteristics offer the possibility of storing the feed for long periods of time without losing the nutritional values. Practicing silage making could both save the farmers time and money, since they wouldn't have to go to the market and buy fresh feed on a daily basis. Hence, the aim of this study was to investigating the ensiling characteristics of banana peelings.

Method

Description of study area

In this study Busega, one of the parishes that constitute Lubaga division, was chosen to represent the peri-urban farmers in Kampala district. Busega is located approximately 7.5 kilometers, southwest of Kampala's central business district.

The farmers

Four farmers (Rose, Betty, Godfrey and Mrs. Kiweddemu), all participants from the major collaborative research project between SLU and Makerere University, were chosen for this study. These farmers each answered a questionnaire regarding their background, productions system and major challenges faced as livestock keepers. All of them keep dairy cattle and applies a non-grazing system, but their conditions differ to some extent. The background and conditions of the four participating farmers will be presented in Table 1, in the result section of this paper. In the following sections of the report the farmers will be named Farm A (Rose), Farm B (Godfrey), Farm C (Betty) and Farm D (Mrs. Kiweddemu).

Ensiling technique used in this study

The ensiling technique used in this study was silage making using naturally present bacteria. The acids conserving the fodder are produced by the fermentation of carbohydrates present within the material, by naturally occurring bacteria.

Experimental design

The field study was carried out at four farms (A, B, C, and D). Four trenches, one trench for each farm, were dug on locations on the properties that the farmers found suitable. The trenches each measuring 0.5m (depth) x 1m (width) x 2m (length), giving a total volume of 1 cubic meter, were coated with a total amount of 12 square meters of polythene sheets. The sheets protected the banana peelings from contamination and helped create an anaerobe environment. On the polythene in every trench, approximately 500 kg of banana peels were placed. The peelings used were all in an immature stage with a predominant green color and were bought fresh from the local marketplace the same morning. In order to create a compact silage material in the pits, we walked on the peelings using our own body weight to pack the material. Thereafter, the banana peelings were covered with two sheets of polythene and a 20-30 cm top layer of soil. The soil aims to prevent animals from damaging the polythene sheets and ensures an airtight environment. The material was thereafter ensiled for a period of 28 days.

Collection of samples

After 28 days the pits were uncovered and 5 samples from each pit were collected, giving a total of 20 samples. The samples were collected at a depth of 15-20 cm on the sides and in the middle of the pits in order to minimize the risk of aerobic exposure and to avoid local variations. Out of the total of five, two samples of 500 ml each were gathered for a chemical analyze on the concentration of volatile fatty acids (VFA), being butyric acid, lactic acid and acetic acid. Also the levels of ammonium in the silage material were analyzed from these samples. The VFA samples were immediately put in a portable ice-box after removal from the trenches in order to preserve the acids in the silage until the analysis began. Furthermore, another two samples of 500 ml were taken for analyzing the amount of neutral detergent fiber (NDF) and acid detergent lignin (ADL). In addition, one sample of approximately 3000 ml was taken from each trench and put in a plastic basin. These samples were exposed to air for 6 days and were during this period monitored, on daily basis, for temperature and pH in order to study the storage ability and the stability during aerobic exposure. The pH values were measured with pH-indicator strips (Merck, Germany) with an accuracy of 0.1 units. The thermometer being used had accuracy of 0.1°C. The pH-indicator strips were before use tested by applying solutions of known pH (4 and 7) and the changes in color were observed. After 6 days of aerobic exposure additional samples were taken for NDF and ADL analysis.

All the chemical analysis was performed in the animal nutrition laboratory at Makerere University. Before analyzes, the DM were determined by oven-drying at a temperature of 60°C for 48 hours, thereafter the samples were ground. The concentrations of NDF and ADL were determined according to Van Soest and Robertson (1985).

The VFA and ammonia were analyzed according to Gloppe and Hvidsten (1995).

Results

Questionnaire study

Table 1. Questionnaire results regarding the background and conditions of the four participating farmers (Rose, Godfrey, Mrs. Kiweddemu and Betty).

Farmer	Rose (A)	Godfrey (B)	Betty (C)	Mrs. Kiweddemu (D)
Sex	Female	Male	Female	Female
Age	49	58	62	52
Marital status	Widowed	Married	Widowed	Married
Highest level of education	Lower secondary	Lower secondary	Lower secondary	Lower secondary
Livestock training	Yes, NGO*/short-course/Institution	Yes, NGO*/ short-course at university/Institution	No, Neighbors	Yes, radio programs
Households total land size	≥30x30m	≥30x30m	≥30x30m	≥30x30m
% to plant fodder of the total land size	50	30	10	40
Number of cattle	3	4	4	8
Cattle breeds	Friesian cross	Friesian cross, Jersey cross	Friesian cross	Boran, Ankole, Cross
Main farming system	Stall feeding	Stall feeding	Stall feeding	Stall feeding
Feed resources most commonly used	1. Elephant grass 2. Banana peelings 3. Brewers grain	1. Elephant grass 2. Banana peelings 3. Brewers grain	1. Banana peelings 2. Elephant grass 3. Local brew wastes	1. Elephant grass 2. Banana peelings 3. Bidens Pilosa
Storage period of banana peels	2 days	.	1 day	1 day
Storage method	Spread	None	None	Spread

* Non-Governmental Organisation (NGO): private organisations operating nationally or trans- nationally, independent from governmental control (UNESCO, 2012)

The answers of the questionnaire (Table 1) showed that all of the farmers had the same level of education and all of them, except for Betty, had undergone some livestock training. Friesian cross was the most common breed kept and Farm D was the only one managing indigenous breeds (Boran, Ankole). At all four farms banana peels was the second most common feed given to the cattle and the system used was exclusively stall feeding (zero grazing).The treatment of the banana peels before feeding is sorting and in some cases sun drying. The storage period ranged from 1 to 2 days and the storage method used was spreading the peels.

pH and temperature

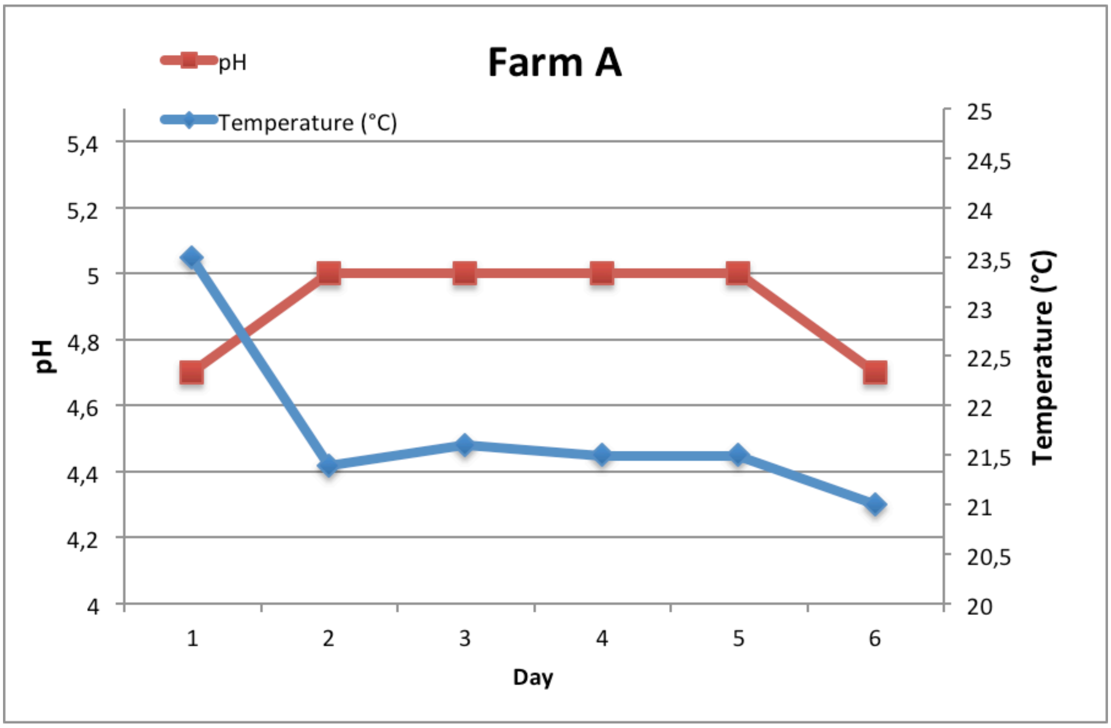

Figure 1. pH and temperature fluctation during 6 days of aerobic exposure on Farm A.

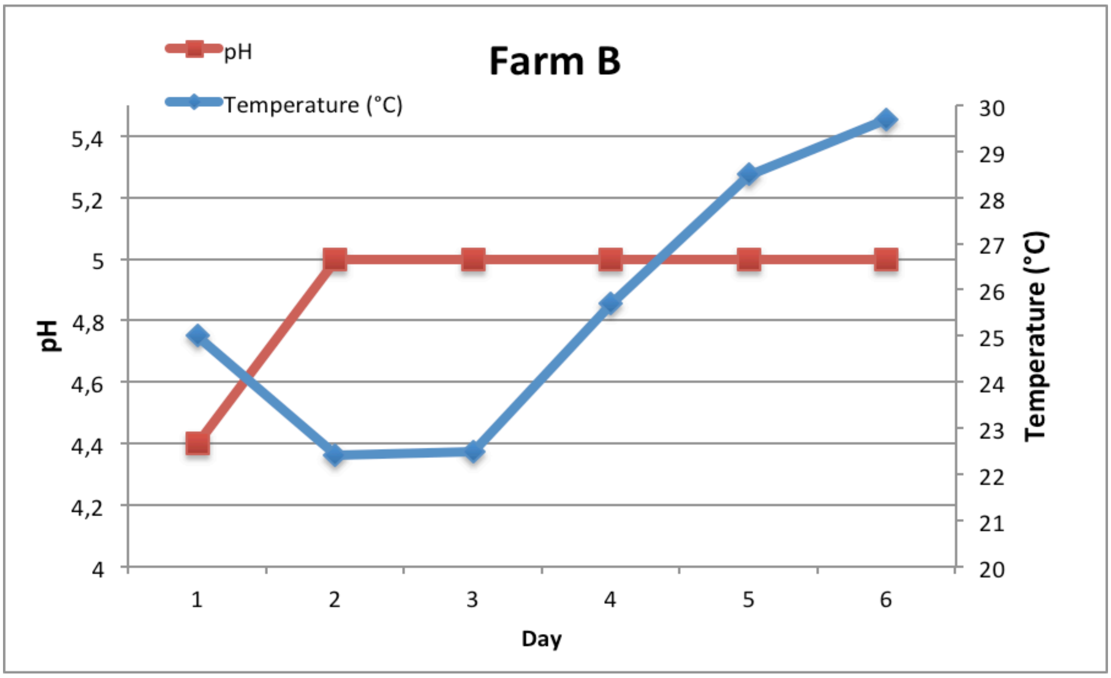

Figure 2. pH and temperature fluctation during 6 days of aerobic exposure on Farm B.

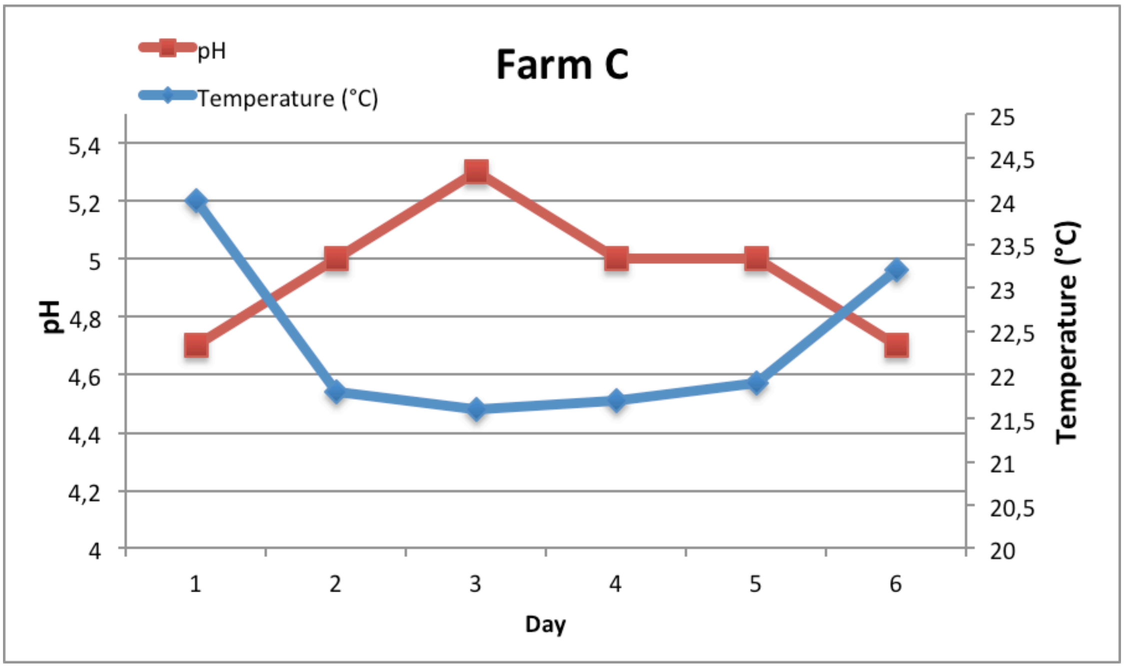

Figure 3. pH and temperature fluctation during 6 days of aerobic exposure on Farm C.

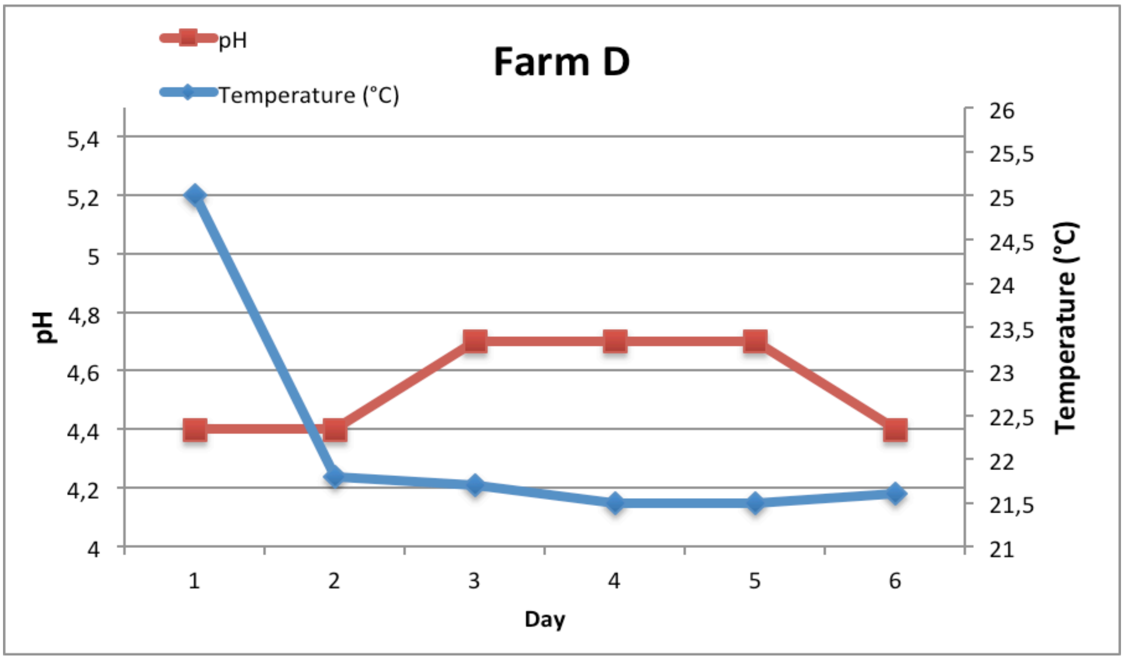

Figure 4. pH and temperature fluctation during 6 days of aerobic exposure on Farm D.

Figure 1-4 shows pH and temperature monitored daily during 6 days. The results show the quality and the stability of the conservation process after the material had been subjected to air. Immediately after opening the trenches, sensory and visual evaluation of the ensiled material indicated a good fermentation process in the middle section of all four trenches. However, some of the material around the side sections had undergone deterioration, showing a brown colour with a rotten smell. No samples were taken from these parts of the trenches. After the air exposure the smell from the samples was still of good character but the colour of the peelings had gone browner then they were immediately after the uncovering of the trenches. On the first day of registration, Farm A and C showed a pH of 4.7, while pH at Farm B and D measured 4.4. At Farm A, B and C the pH reached 5.0 on the following day and stabilized there for the next 4 days. The exception was Farm C who presented a pH at 5.3 on the third day and then, on day 4, went back to 5.0. Farm D kept a lower pH than the rest of the farms throughout the 6 days of measuring, with a highest pH at 4.7. Farm B had a higher average temperature during the week of aerobic exposure than the rest of the farms, with an average temperature of 25.6° C. Farm A, C and D had average temperatures around 22°C. Farm B was also the only sample that had a drastically increase in temperature over the last 3 days.

DM, NDF and ADL

The chemical analysis of the proportions of DM, NDF and ADL of the banana peelings before aerobic exposure showed DM content around 20% on all four farms (Table 2). The difference between the highest percentage and the lowest was 2.15 units. In comparison with the DM values from the analysis done after the aerobic exposure (Table 2), the DM somewhat increased on Farm A and D but was unchanged on Farm B and C. The NDF values before aerobic exposure ranged from 41.84% to 58.66%. After the 6 days of aerobic exposure the values had increased to some extent on Farm B and C but had decreased on Farm A and D, similar patterns before and after aerobic exposure were shown for ADL.

Table 2. Fermentation quality. Mean value and standard deviation (±) of DM, NDF and ADL before and after 6 days of aerobic exposure.

Farm	DM%	NDF%	ADL%
Before			
A	21.19	50.23±10.35	6. 76±1.32
B	21.43	58.66±2.72	6.86±1.51
C	19.28	41.84±1.22	5.84±2.76
D	20.51	50. 25 ±1.73	10.68±1.37
After			
A	24.87	47.06±2.77	5.74±0.03
B	21.43	60.19±4.11	7.11±1.73
C	19.29	51.24±5.18	7.40±0.61
D	22.24	49.52±0.68	5.83±2.04

VFA and Ammonia

Table 3 shows the mean values and standard deviation of VFA and ammonia before aerobic exposure. The values for acetic acid ranged from 0.19 to 0.92, with Farm C representing the lowest percentage and Farm D the highest. Butyric acid did not show the same broad variation in values as the acetic acid. The difference between the highest (Farm C) and the lowest (Farm B) percentage was no more than 0.10 units. The same was shown for the values of ammonia with very little variation among the different farms. The proportions of the lactic acid values range from a percentage of 0.14 (Farm A) to 0.71 (Farm B).

Table 3. Mean value (% of DM) and standard deviation (±) of VFA and ammonia before aerobic exposure

Farm	Acetic acid (%)	Butyric acid (%)	Lactic acid (%)	Ammonia (%)
A	0. 72±0.17	0.31±0.25	0.14±0.04	0.0086±0.0023
B	0.36±0.06	0.22±0.00	0.71±0.05	0.0076±0.0014
C	0.19±0.03	0.32±0.03	0.15±0.07	0.0084±0.0013
D	0.92±0.06	0.24±0.078	0.53±0.21	0.0084±0.00014

Discussion

Nutritional properties

DM, NDF, ADL

The DM content establishes the moisture content in the feed. In comparison to fresh banana peelings the silage samples had a higher DM content, with a mean value of 20.6%, than fresh banana peelings which has a DM content around 15%. As a higher DM is preferred, because of the nutrients being less diluted, the result indicates that a well preserved silage contribute to a diet with a greater nutritional value than the fresh material.

Further fractions that contribute to the nutritional value of the feed are the NDF and ADL. Happi Emaga *et al*. (2011) reported that the NDF and the ADL fractions in fresh banana peelings ranges from 27.8% to 31.3% and from 7.3% to 15.0%, respectively, when analysed according to Van Soest et al. (1991). In the banana peel silage in our study the mean percentage from the NDF and ADL samples taken prior to aerobic exposure were approximately 50% and 8%, respectively. This indicates that the silage process results in twice as high NDF fraction but a similar value of ADL. This is most likely because easily fermentable carbohydrates have been used during the fermentation which results in a more fibre rich feedstuff. Banana peelings are today used as a supplement to roughage and the ensiled peelings NDF and ADF values are comparable to grass silage that has a NDF fraction (% of DM) around 60% and an ADL fraction around 7%, depending on the maturity of the grass and the species (NRC, 2001).

The fiber fraction affects the utilization of the diet and thereby also the health and the performance of the animal. Too high fiber content is synonymous with a low energy, rumen filling diet, which results in a decreased productivity. A diet that contains a too small fiber fraction reduces the chewing activity and a decreased saliva production leading to a lowering of pH in the rumen, which may induce acidosis. According to NRC (2001), the minimum concentration of NDF for diets of lactating cows is 25% of DM. The elevated NDF faction in the banana peeling silage compared to the fresh peelings, can be both desired and undesired depending of the composition of the whole diet. Since this study only focuses on the composition of banana peelings, it doesn't say anything about the rest of the diet that the dairy cattle are being fed. Hence, it's impossible to determine if the values are according to the requirements of the cattle included in this study.

Silage quality and aerobic stability

pH, temperature, VFA and ammonia

Since the goal of a fermentation process is to quickly convert the carbohydrates into desirable organic acids, the pH in the silage is of considerable importance and one of the main indicators on the quality of the fermentation process (Lemus, 2010). The recommended pH of grass silage is 4.3-4.7 (Kung and Shavers, 2001). Since banana peelings are not ensiled on regular basis, I compare our values to grass silage. On the first day the pH of the banana peelings were within this range on all four farms, indicating an accurate fermentation. However, as the samples continued to be exposed to oxygen the pH rose to values above the critical limit, suggesting nutritional value losses, and an insufficient hygienic quality due to undesired microbial activity (Borreani and Tabacco, 2010) Secondly, as high temperatures often is due to growth of bacteria (Borreani and Tabacco, 2010), or yeast and mould (FAO, 2012g), the rise in temperature on two of the farms further implies a deterioration of the material. The exception would be Farm D who, according to the values of pH and temperature, presents an accurate conservation process and an aerobically stabile sample.

Furthermore, all of the VFA showed lower levels of acid than the recommended. The lactic acid is responsible for the major lowering of pH and should be the primary acid in silage, but on Farm A, B and C the lactic acid even showed concentrations lower the acetic acid. The low concentrations of VFA on all four farms imply a limited fermentation process which may be caused by insufficient amounts of easy fermentable carbohydrates. The concentration of free sugars in banana peelings varies to a great extent, from 1.4% to 33.2% of DM, depending on the maturity stage of the crop. The more immature the peeling is, the lower concentrations of free sugars it has (Happi Emaga *et al*, 2011). Since most of the peelings used in this study were at an immature stage with a predominant green colour, this supports the conclusion. Additionally, another reason for the low storage ability can be growth of unwanted bacteria like clostridia. High levels of acetic and butyric acids as well as ammonia may be a result of clostridial fermentation (Kung and Shavers, 2001). The low concentrations of acetic acid, butyric acid and ammonia however, indicate no signs of clostridial fermentation in our study. Instead it seems like an air tight environment has been obtained rather than a fermentation process. A feed stored under air tight conditions doesn't reach the same level of conservation as a fermented feed which results in a poor aerobic stability during exposure to oxygen, with deterioration as a consequence. However, for further research it would be of interest to analyse the samples for VFA and ammonia again after a couple of days of aerobic exposure. This so that one can determine the kind of microbial activity that might have occurred. Additionally, a microbial analysis would be of interest since it tells us exactly which microbes that are being active in the silage.

Improvements

The visual evaluation immediately after opening the trenches showed that some banana peelings in the side sections had undergone deterioration during fermentation. This could partly be a result of inadequate wrapping of the material, but also an effect of an insufficient silage pack density. However, the peelings in the middle had the smell and colour of accurate fermented silage. No chopping of the banana peelings were done before putting them in the trench, doing that can contribute to improve an airtight environment since a more compact material exclude air more effectively. Secondly, chopping would favour the fermentation process, since a shorter chopping length enhances the availability of the energy for the microorganisms (FAO, 2012f). However, as banana peelings are poor in free sugars and as easily fermentable carbohydrates is of highest concern in order to achieve a rapid lowering of pH, they should be mixed with energy- rich materials, e.g. molasses or root crops (FAO, 2012f). Banana peelings could also advantageously be mixed with dry feeds since extremely wet silage (DM <25%) can lead to undesirable fermentation with sour silage as a result (FAO, 2012f).

Furthermore, in tropical conditions where high temperatures are common the spoilage during feed-out is of great concern (FAO, 2010c). The farmers should therefore consider constructing smaller trenches so that the feed can be fed out in a short period of time, minimizing the aerobic spoilage.

Conclusion

Crop residues and by-products play a key role in animal feeding in urban and peri-urban areas of Kampala. The high availability and the chemical composition make banana peelings a valuable component in a low-cost farming system. However, the poor storage ability of the fresh feed is a major constraint limiting the feed resources and more over the development of livestock production.

The result of this study suggests that banana peels can be ensiled. However, in order for the silage to achieve a high enough quality and aerobic stability using only naturally present bacteria, some improvements must be done during the process of silage making. First, since banana peelings lack the appropriate amounts of easily fermentable carbohydrates that are needed for good quality preservation, they should be ensiled together with a feed rich in this. Secondly, the structure of the peelings makes them difficult to compress tightly enough only using simple means, hence chopping of the material before ensiling is preferable. Thirdly, in order to minimize the aerobic spoilage, the trenches should be of a relatively small size. Finally, if the system should be suitable for low-income, small scale farmers simplicity of the technology, low investment costs as well as the required labour must be of highest concern.

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