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Effects of Different Mechanical Preparation Methods on Drying Rate and Nutrient Composition of Forage Sweet Potatoes Hay

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Abstract
Many forage sweet potatoes (*Ipomoea batatas* (L) Lam) cultivars have not been adequately evaluated for their hay making potential in Eastern Africa. The objective of the study was to evaluate three nutritionally superior cultivars to determine the effects of forage mechanical preparation on their drying rate and nutrient composition. The experiment was a split-plot design where the three cultivars (K158, Marooko and Wagabolige) and the three mechanical treatments (un-chopped, chopped and shredded forage) were the main plots and the five sampling times during drying (0, 24, 48, 72 and 96 hr) formed the sub-plots. The DM increase during drying was used to indicate the drying rate as high DM reflected faster moisture loss. The hay had similar DM at 0 and 24 hr but the DM significantly increased at 48, 72 and 92 hr. Mechanical treatments and drying time caused shredded cultivars to increase in DM at all the five drying durations. Chopped cultivars maintained their DM between 0 and 24 hr and again between 48 and 72 hr. The cultivars, however, recorded increased DM at 96 hr that was significantly higher than at all other times. Cultivars left whole recorded similar DM at 0 and 24 hr although they had higher DM at 48, 72 and 96 hr respectively. At 0 hr chopped and shredded cultivars; whole and chopped cultivars respectively recorded similar DM although shredded cultivars had lower DM compared to the whole cultivar treatment. However, the three mechanical treatments maintained similar DM in cultivars at 24, 48 and 72 hr of drying. Chopped cultivars and those left whole had similar DM at 96 hr although the DM was lower than that of shredded cultivars. Shredded cultivars tended to dry faster although this difference did not reach significance until the cultivars were dried for 96 hours. The three mechanical treatments did not influence the nutrient composition in the three cultivars. However, cultivars differed in nutrient composition as, although, K158 and Wagabolige recorded similar DM, OM and ADF but they differed in CP, NDF and ADL. Marooko contained the highest CP and the lowest DM and fibre. The three cultivars contained similar gross energy and mechanical treatments and drying durations did not affect their gross energy.
Keywords: Sweet potato, hay, drying rate, mechanical treatment, nutrient composition.

1.1 Introduction

The need to provide livestock with feeds all year necessitates conservation of forage sweet potato into hay. Hay enables livestock farmers to avail highly nutritious diets to their livestock throughout the year hence improving animal production performance. However, many forage sweet potato cultivars have not been adequately evaluated for their hay making potential in Eastern Africa (Ondabu et al., 2007; Peters, 2008; Wheatley and Loechl, 2008).

While the biological processes that occur in hay making are well documented, this has not been done for forage sweet potato cultivars utilized in Kenya. For example, the effect of the relatively low DM in forage sweet potato cultivars on hay drying rate and the duration to attain safe storage moisture content (i.e. most suitable DM) in hay material has not been documented. Safe hay storage DM is known to range above 80 % DM (Seo et al., 2000; Savoie, 2001, Gupter et al., 2002). In addition, low DM in forage sweet potato cultivars can cause loss of valuable nutrients through hay respiration, effluent and leaching (Savoie, 1986; Pattey et al., 1988; Savoie and Mailhot, 1988), that affect the nutritive value of the resultant hay to livestock.

These knowledge gaps not withstanding, some of these forage sweet potato cultivars are already being used by some livestock farmers in Kenya with some farmers trying all types of forage conservation including hay making. In a survey conducted in Trans Nzoia County, Kenya, Rono et al. (2006) found that over 78 percent of sampled farmers fed sweet potato forage to their livestock. There is, therefore, need to provide objective data on hay characteristics and nutritive values of these cultivars that enable efficient utilization of forage sweet potato cultivars as conserved livestock feed.

The objective of the current study was to determine the effects of different mechanical preparation methods on drying rate and nutrient composition of three most promising forage sweet potatoes cultivars.

1.2 Materials and Methods

1.2.1 Study site

The study was conducted at the Kenya Agricultural Research Institute (KARI) in Lanet located in the outskirts of Nakuru town, within Nakuru County, Kenya. The site is 0^0 18'S, 36^0 09'E and 1920 m above sea level. The area receives bimodal rainfall; with the highest amount of 134 and 100 mm received during the long rains of April and August, respectively. The short rains of about 52 and 51 mm are received in October and November respectively (Jaetzold, 2006). The area, therefore, receives on average 800 mm rainfall annually with a relative humidity of 83 %. The mean maximum and minimum temperatures are 26^0C and 10^0C, respectively. The soils are classified as humic nitosols and the study site falls within agro-ecological zone (AEZ) IV (Jaetzold, 2006).

1.2.2 Experimental design

The three sweet potato cultivars (K158, Marooko and Wagabolige) were grown using standard recommendations and harvested at 120 days. The experiment was a split-plot design where the three sweet potato cultivars and the three mechanical treatments (un-chopped, chopped and shredded forage) were the main plots and the five sampling times during drying (0, 24, 48, 72 and 96 hr) formed the sub-plots.

These three cultivars were chopped or shredded using a motorized chopper or shredder, respectively. Twenty kilogrammes (20 kg) each of these cultivars, un-chopped, chopped and shredded respectively were thinly spread (0.5 cm thick) on separate pieces of black polythene sheets (2 metres width and 4 metres length) and exposed to sunshine for nine hours daily. Triplicate samples (forming replicates) were taken at intervals of 0, 24, 48, 72 and 96 hr from each cultivar and three mechanical treatments. The DM increase during drying was used to indicate the drying rate as high DM reflected faster moisture loss.

1.2.3 Chemical analyses

The proximate composition of forage sweet potato hay was determined using AOAC (1998) procedures. The fibre in form of NDF, ADF and ADL was analysed according to Van Soest et al. (1991). The gross energy of the hay was determined using an adiabatic bomb calorimeter. The hay mean samples' DM, proximate composition and gross energy were determined for each mechanical treatment, drying time and. cultivar.

1.2.4 Statistical analyses

The general linear model (GLM) was used to compute analysis of variance (SAS, 2003) for hay DM, nutrient composition and gross energy for a split-plot design. The three cultivars and the three mechanical treatments (un-chopped, chopped and shredded forage) were analyzed as main plots and the five sampling times (0, 24, 48, 72 and 96 hr) as sub-plots. To separate the mean hay DM, nutrient composition and gross energy for the three cultivars, the three mechanical treatments and at the five sampling times, LSD procedures were applied.

The following statistical model was used:

$$Y_{ijk} = \mu + V_i + M_j + \beta(VM_{ij}) + T_K + V_iT_K + M_jT_K + V_iM_jT_K + \acute{\varepsilon}_{ijk}$$

Where: Y_{ijk} = Estimated nutrient composition, μ = Overall mean nutrient composition, V_i = Effects of cultivar on nutrient composition, M_j = Effects of mechanical treatment on nutrient composition, T_K = Effects of sampling time on nutrient composition, $\beta(VM_{ij})$ = Residual effects of treatments on nutrient composition (Error A), $\acute{\varepsilon}_{ijk}$ = Residual effects of treatments on nutrient composition (Error B).

1.3 Results

The results of the effects of mechanical treatments, cultivars and sampling time on hay DM and the hay nutrient composition of selected forage sweet potato cultivars are presented in Tables 1, 2 and 3. The DM increase during drying was used to indicate the drying rate as high DM reflected faster moisture loss.

1.3.1 Moisture loss and dry matter in hay

The three mechanical treatments did not influence ($P>0.05$) the hay DM but the cultivars and drying time affected ($P<0.05$) the DM in hay (Table: 1). Cultivars K158 and Wagabolige recorded similar ($P>0.05$) DM that was higher than ($P<0.05$) in Marooko. Forage sweet potato hay had similar ($P>0.05$) DM at 0 and 24 hr but the DM significantly increased ($P<0.05$) at 48, 72 and 96 hr.

Mechanical treatments and drying time caused shredded cultivars to increase ($P<0.05$) in DM at all the five drying durations (Table: 2). Chopped cultivars maintained ($P>0.05$) their DM between 0 and 24 hr and again between 48 and 72 hr. The cultivars, however, recorded increased ($P<0.05$) DM at 96 hr that was significantly ($P<0.05$) higher than at all other times. Cultivars left whole recorded similar ($P>0.05$) DM at 0 and 24 hr although they had higher ($P<0.05$) DM at 48, 72 and 96 hr respectively. At 0 hr chopped and shredded cultivars; whole and chopped cultivars respectively recorded similar ($P>0.05$) DM although shredded cultivars had lower DM ($P<0.05$) compared to the whole cultivar treatment. However, the three mechanical treatments maintained similar ($P>0.05$) DM in cultivars at 24, 48 and 72 hr of drying. Chopped cultivars and those left whole had similar ($P>0.05$) DM at 96 hr although the DM was lower than ($P<0.05$) that of shredded cultivars. Shredded cultivars tended to dry faster (P<0.05) although this difference did not reach significance until the cultivars were dried for 96 hours.

The cultivar and drying time caused Marooko and Wagabolige to maintain similar (P>0.05) DM at 0 and 24 hr of drying (Table: 2). However, Wagabolige increased (P<0.05) in DM at 48, 72 and 96 hr while Marooko maintained similar (P>0.05) DM at 48 and 72 hr which was lower than (P<0.05) at 96 hr. Cultivar K158 maintained a similar (P>0.05) DM at 48, 72 and 96 hr which was higher than at 0 and 24 hr. All the three cultivars recorded similar (P>0.05) DM at the start of the experiment (Table 2). However, Marooko and Wagabolige; K158 and Marooko had similar DM (P>0.05) at 48 and 96 hr respectively. The DM in all the three cultivars was different (P<0.05) at 24 and 72 hr (Table 2). Drying for 72 and 96 hours, Wagabolige recorded higher (P<0.05) DM than the other two cultivars. Although K158 recorded higher (P<0.05) DM than Marooko at 72 hr, they had similar (P>0.05) DM at 96 hr. At 24 and 48 hr, K158 maintained the highest DM (P<0.05) compared to Marooko and Wagabolige.

The cultivars and mechanical treatment caused K158 and Marooko to maintain similar (P>0.05) DM whether whole, chopped or shredded (Table: 3). However, shredding tended to increase (P<0.05) DM in Wagabolige compared to drying it whole or chopped. Within each mechanical treatment the cultivars were affected differently (P<0.05). When chopped, K158 and Wagabolige recorded similar (P>0.05) DM which was higher than (P<0.05) that observed in Marooko. When left whole or shredded, Wagabolige recorded the highest (P<0.05) DM while Marooko recorded the lowest DM (P<0.05).

1.3.2 Nutrient composition

The three mechanical treatments did not influence (P>0.05) the nutrient composition in the three cultivars (Table: 1). Cultivars K158 and Wagabolige recorded similar (P>0.05) DM, OM and ADF but differed (P<0.05) in CP, NDF and ADL. Drying time only affected (P<0.05) the DM without affecting (P>0.05) other nutrients. The mechanical treatments and drying times did not affect (P>0.05) the cultivars' GE and the three cultivars did not differ (P>0.05) in their GE.

1.4 Discussion

1.4.1 Moisture loss in hay

Rapid moisture loss in hay making is essential to reduce losses due to spoilage and minimize respiration (Savoie, 2001; Gupta et al., 2002; Enoh et al., 2005). However, care is essential to reduce shattering of leaves and loss of nutrients. Mechanical treatments increase the DM by exposing a larger surface for moisture to evaporate rapidly (Pattey et al., 1988; Seo et al., 2000; Suttie, 2000) compared to leaving the cultivars whole. The fact that there was no major advantage in chopping or leaving the cultivars whole in the present study, may suggest that the cultivars were either insufficiently thinly spread or the study was not long enough for these benefits to be recorded (Table 1) (Pattey et al., 1988; Savoie and Mailhot 1988; Enoh et al., 2005). An extended duration may be essential as shown by the fact that although shredded cultivars tended to dry faster, the difference did not reach significance. Unfortunately, the three mechanical treatments and the drying duration did not achieve the 800g per kg DM recommended as the safe storage moisture (Seo et al., 2000; Wanapat et al, 2000; Enoh et al., 2005).

Cultivars with similar morphology and physiological activities have been shown to loose moisture at similar rates (Pattey et al., 1988; Savoie and Mailhot, 1988; Suttie, 2000). Hence K158 and Wagabolige had probably similar rate of moisture loss as they had similar DM and they differed from Marooko which recorded a lower DM (Tables 1 and 3). Wagabolige may be coarser than K158 and Marooko as shredding increased its DM more than in K158 and Marooko. Wagabolige tended to increase in DM most rapidly when dried whole or shredded compared to K158 and Marooko (Table 3). This may indicate that Wagabolige was leafier than K158 and Marooko as it has been shown that leaves dried faster than fleshy stems (Pattey et al., 1988; Suttie, 2000; Enoh et al., 2005). However, Wagabolige had the highest DM when shredded an indication that this may be the best mechanical treatment to ensure rapid drying in it.

Although the cultivars maintained their DM at 0 and 24 hr, it significantly increased at 48, 72 and 96 hr when the cultivars were dried at the same ambient temperature (Table 2). The similarity in DM before 24 hr may suggest an initial slow evaporation which predominantly involved leaves and free moisture on the plat surface (Pattey et al., 1988; Savoie and Mailhot 1988; Gupta et al., 2002). More than 48 hr of sun-drying may be essential for moisture loss from plant stems to influence DM in these cultivars as shown by the increased moisture loss beyond 48 hr. Also according to Suttie (2000) the initial moisture loss is rapid through the open stomata but following wilting the stomata close and moisture loss decreases through the waxy epidermis of plant leaves and stems.

1.4.2 Nutrient composition

The cultivars in the current study were shown to contain similar OM hence it was consistent that neither the mechanical treatments nor the drying time could affect the vine OM (Pattey et al., 1988). The OM in the cultivars reported in this study under different treatments are within those reported in the literature (Farrell et al., 2000; Iyeghe-Erakpotobor et al., 2006; Chhay et al., 2007).

The difference in CP and NDF in K158, Marooko and Wagabolige indicated their inherent characteristic (Table 1). The CP reported in this study under different treatments is within those reported in the literature (Olorunnisomo 2007; Ondabu et al., 2007; Kebede et al., 2008). Also, the NDF, ADF and ADL values were within the reported range (Giang et al., 2004; Lam and Ledin, 2004; Ouda et al., 2004). The three mechanical treatments and the five sampling times did not affect the CP, OM, NDF, ADF and ADL (Pattey et al., 1988) (Tables 1). These facts may show that there were minimal losses due to spoilage and crop respiration during the studied drying periods which is in agreement with reports in the literature (Pattey et al., 1988; Suttie, 2000; Savoie, 2001).

1.4.3 Gross Energy

The three cultivars have been shown to contain similar OM in the current study. Organic matter is the primary source of energy and Olorunnisomo (2007) reported that GE did not differ among the cutting ages in sweet potato. Oduro et al. (2008) and Diaz et al. (2013) showed that there was little difference in GE among various sweet potato cultivars. The climatic factors at the study area may be optimal for these cultivars and the harvesting age allowed adequate time for the plants to accumulate optimal GE (Larbi et al., 2007; Olorunnisomo, 2007). Hence the similarity in GE among the test cultivars showed that they expressed their full potential in GE accumulation. As the three mechanical treatments did not affect the sweet potato GE, the test treatments had similar effects among the three cultivars. This also applied in the effects of the five sampling times. The GE values were within the range reported by Ojeda et al. (2010), Muoi, (2012) and Diaz el al. (2013) but were higher than those reported by Aregheore and Tofinga (2004), Antia et al. (2006) and Oduro et al. (2008). This difference may have arisen due to cultivars differences as Karachi (1982a, b) and Irungu et al. (2000) showed variation among cultivars and between experimental sites.

1.5 Conclusions and Recommendations

The cultivars maintained similar DM whether whole, chopped or shredded. However, shredding was considered the best treatment to encourage rapid drying. The observations recorded in this study showed that there were minimal losses due to spoilage and crop respiration under the experimental treatments. Mechanical treatment was essential to increase the drying rate in forage cultivars of sweet potato. Shredding was recommended as the best treatment to rapidly increase the DM in these cultivars.

Cultivars K158 and Wagabolige recorded similar DM, OM and ADF but differed in CP, NDF and ADL. Marooko contained the highest CP and the lowest DM and fibre. All the three cultivars contained similar OM and GE. Cultivars K158 and Wagabolige overall dried at similar rate which was higher than in Marooko. Wagabolige increased in DM most rapidly when dried whole or shredded compared to K158 and Marooko. Drying time only affected the DM without affecting other nutrients. The forage sweet potato hay had similar DM at 0 and 24 hr but the DM significantly increased at 48, 72 and 92 hr. However hay making is a poor conservation method as it did not attain 800 g/kg DM after 96 h of drying. Future studies should ensure that the cultivars are sufficiently thinly spread and extend long enough for the full benefits in chopping and shredding compared to leaving the cultivars whole to be recorded.

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Table 1: Effects of mechanical treatments, cultivars and drying time on the nutrient composition of selected forage sweet potato cultivars (g/kg DM)

Nutrient	DM	OM	CP	NDF	ADF	ADL	GE*
Mechanical treatment							
Whole	298.8	869.7	164.5	385.0	282.1	96.4	16.8
Chopped	298.1	870.3	164.7	383.6	281.6	93.8	16.8
Shredded	306.2	870.3	164.6	383.8	281.7	96.9	16.8
LSD	22.6	4.1	1.5	2.8	2.0	5.2	0.2
Cultivar							
K158	310.0_{2}	870.4	156.8_{1}	382.3_{2}	281.7_{12}	85.0_{1}	16.8
Marooko	263.0_{1}	869.8	170.4_{3}	373.0_{1}	280.3_{1}	85.1_{1}	16.9
Wagabolige	330.2_{2}	870.1	166.5_{2}	397.1_{3}	283.4_{2}	117.1_{2}	16.8
LSD	22.6	4.1	1.5	2.8	2.0	5.2	0.2
Drying time (hrs)							
0	212.6_{1}	869.9	164.3	385.2	282.1	96.1	16.8
24	233.0_{1}	870.5	164.8	383.6	282.3	97.6	16.8
48	307.6_{2}	869.8	164.4	383.9	280.5	92.3	16.8
72	347.2_{3}	870.4	164.7	385.1	282.3	98.2	16.8
96	404.1_{4}	869.8	164.7	382.9	281.5	94.2	16.9
LSD	22.4	5.3	3.1	3.6	2.6	6.7	0.2

Selected forage sweet potato cultivas are K158, Marooko and Wagabolige found in Kenya's Central Highlands
$_{1234}$ Means within a column bearing different subscripts are different (P<0.05)
*MJ/kg DM

Table 2: Effects of mechanical treatment, cultivar and drying time on dry matter in selected forage sweet potato cultivars (g/kg DM)

Time in Hrs	0	24	48	72	96	LSD
Mechanical Treatment,						
Chopping	211.9_{12}^{a}	228.0^{a}	311.1^{b}	344.1^{b}	395.4_{1}^{c}	23.1
Shredding	197.6_{1}^{a}	241.4^{b}	313.1^{c}	355.1^{d}	423.2_{2}^{e}	
Whole	228.3_{2}^{a}	231.8^{a}	298.0^{b}	342.2^{c}	393.8_{1}^{d}	
Cultivar,						
K158	215.6_{1}^{a}	275.2_{3}^{b}	347.6_{2}^{c}	345.8_{2}^{c}	365.7_{1}^{c}	21.7
Marooko	210.3_{1}^{a}	193.5_{1}^{a}	288.9_{1}^{b}	277.8_{1}^{b}	344.2_{1}^{c}	
Wagabolige	211.9_{1}^{a}	232.5_{2}^{a}	286.2_{1}^{b}	418.0_{3}^{c}	502.4_{2}^{d}	

Selected forage sweet potato cultivas are K158, Marooko and Wagabolige found in Kenya's Central Highlands
^{abcde} Means within a row bearing different superscripts are different (P<0.05)
$_{123}$ Means within a column bearing different subscripts are different (P<0.05)

Table 3: Effects of cultivar and mechanical treatment on dry matter in selected forage sweet potato cultivars

	Mechanical Treatment			
Cultivar	Chopping	Shredding	Whole	LSD
DM (g/kg DM)				
K158	317.2_2	312.4_2	300.4_2	21.7
Marooko	259.4_1	256.3_1	273.2_1	
Wagabolige	317.8_2^a	349.9_3^b	322.9_3^a	

Selected forage sweet potato cultivas are K158, Marooko and Wagabolige found in Kenya's Central Highlands
[ab] Means within a row bearing different superscripts are different (P<0.05)
$_{123}$ Means within a column bearing different subscripts are different (P<0.05)

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