# DETERMINATION OF SUITABLE HARVESTING AGE OF SELECTED FORAGE SWEET POTATO CULTIVARS TO ACHIEVE HIGH NUTRITIVE VALUE IN RUMINANTS

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**Abstract**

Protein is a major limiting nutrient in livestock production in Kenya especially during the dry season. Sweet potato (*Ipomoea batatas* (L) Lam) is a protein rich forage and grows well under many farming conditions. The study objective was to determine the suitable harvesting age of forage sweet potato cultivars that will result in high nutritive value in ruminants. Nutritive value was measured through *in vitro* organic matter digestibility (IVOMD), metabolizable energy (ME), volatile fatty acids (VFA) and microbial crude protein (MCP) yield. Cultivars 99/1, K049, K158, Marooko, Mugande and Wagabolige were planted in randomized complete block design (RCBD) with three replications. These cultivars were sampled at 90, 120, 150 and 180 days growth and subjected to *in vitro* gas production technique according to Makkar (2004). Gas volume produced during 24 hr sample incubation was used to calculate IVOMD, ME, VFA and MCP using recommended equations. The data was subjected to analysis of variance and means separated using least significant difference. Harvesting age affected the studied parameters. Most cultivars recorded their optimum IVOMD (711-851 g/kg DM), ME (7.43-8.13 MJ/kg DM), VFA (0.71-0.84 mg/L) and MCP (85.4-103 g/kg DM) at 120 days. Wagabolige maintained similar ME (8.18-8.24 MJ/kg DM), VFA (0.82-0.84 mg/L) and MCP (102-102 g/kg DM) across the harvesting ages which were, also, the highest among the cultivars. Lowest IVOMD (684-711 g/kg DM) and MCP (7.43-7.83 g/kg DM) was recorded in K158 at all four harvesting ages and lowest ME (7.25-7.43 MJ/kg DM) and VFA (0.68-0.71 mg/L) were in 99/1. It was concluded that as nutritive value significantly decreased with increased age, then 120 days was recommended as suitable harvesting age for these cultivars. Wagabolige recorded the highest nutritive value hence it is recommended as the most suitable cultivar in ruminant nutrition.

**Key words:** Harvest age, forage sweet potato, nutritive value, digestibility, energy, protein

## 1.0 Introduction

The quality of roughages deteriorates during the dry season hence cannot sustain high livestock production performance. Protein in particular, is a major limiting nutrient in all livestock production systems during the dry season and its supplementation is expensive in Kenya. Sweet potato (*Ipomoea batatas* (L) Lam) forage is rich in crude protein (CP) and is well adapted to small scale production and grows well under many farming conditions (Olorunnisomo, 2007; Kebede et al., 2008; Claessens et al., 2009).
Sweet potato harvesting age and plant part (leaf, petiole or stem) influence their nutrient composition (An et al., 2003; Larbi et al., 2007; Zereu et al., 2014). Studies on forage sweet potato done in Kenya (Snijders et al., 1992; Kinyua, 2013) reported increased organic matter (OM) content with age. The OM component of forages is the main source of energy (ME) (Olorunnisomo, 2007; Oduro et al., 2008). During young growth stage, plant nutrient apportioning in favour of protein accumulation leading to high CP which declines with extended harvesting interval (Snijders et al., 1992; An et al., 2003; Larbi et al., 2007).

Measurement of *in vitro* gas production can provide valuable quantitative information that simulates the kinetics of rumen digestion (Menke et al., 1979; Menke and Steingass, 1988; Makkar, 2004). Increased supply of fermentable carbohydrates and rumen degradable nitrogen increases fermentation, microbial growth and microbial protein synthesis (Sommat et al., 2000; Akinfemi, 2010; Mirzaei-Aghsaghali et al., 2011).
In a previous study on sweet potato, 10 improved cultivars ranked on the basis of dry matter (DM) yield, CP content and draught tolerance were recommended for release (Ondabu et al., 2007). However, there is little documentation on nutrient digestibility and nutrient utilization by ruminants fed on the improved forage sweet potato cultivars available in Kenya. Consequently, it is not easy to make reliable recommendations on forage harvesting regime and feeding methods to livestock farmers. Therefore, it is essential to generate information on suitable harvesting regime to enable high digestibility and nutrient utilization by ruminants.
The objective of the current study was to determine the most appropriate harvesting age to achieve high *in vitro* organic matter digestibility (IVOMD), metabolizable energy (ME), volatile fatty acids (VFA) and microbial protein yield (MCP) of improved forage sweet potato cultivars when fed to ruminants.

## 2.0 Materials and Methods

### 2.1 Study Site

The study was conducted at the Kenya Agricultural and Livestock Research Organization (KALRO) 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 on average 800 mm rainfall annually with a relative humidity of 83 %. It also has a bimodal rainfall distribution; with the long rains occurring late March to May and the short rains received in October and November (Jaetzold et al., 2006). The mean maximum and minimum temperatures are $26^0$C and $10^0$C, respectively. The site falls within agro-ecological zone (AEZ) IV with soils classified as humic nitosols (Jaetzold et al., 2006).

### 2.2 Field Layout and Experimental Design

A fine seed bed was prepared by levelling uniformly using a tractor attached with tine harrow followed by a roller. Three parallel experimental blocks were laid out along less than 0.5 % field gradient. Each block was divided into six plots measuring 3 metres in width and 5 metres in length. Five improved forage sweet potato cultivars (Ondabu et al., 2007; 99/1, K049, K158, Marooko and Wagabolige) and a control cultivar (Mugande) were each assigned to a plot within each of the blocks in a randomized complete block design (RCBD). Mugande was chosen as the control cultivar because it is commonly cultivated by most farmers within the study area. This procedure was replicated four times producing twelve experimental blocks. The five improved forage sweet potato cultivars and control cultivar were harvested at 90, 120, 150 and 180 days.

The cultivars were planted in their respective field plots using 50 cm long cuttings, in holes dug on the flat ground in rows 60 cm apart with the plants spaced 30 cm apart within rows. A base fertilizer dressing with Di-ammonium phosphate was done at planting and top dressing at 45 days after planting with calcium ammonium nitrate (CAN). The fertilizer was applied according to Wielemaker and Boxem (1982) during planting at the rate of 54 and 20 kg/ha of nitrogen (N) and phosphorus (P), respectively. After establishment (45 days after planting), the plots were cut back and top dressed with 52 kg/ha N. Potassium was not applied as soils in study area were known to contain adequate potash to meet the requirements for normal growth of forage sweet potato cultivars (Wielemaker and Boxem 1982). Subsequent re-growth was harvested at approved experimental harvest age of 90, 120, 150 and 180 days. The blocks and field plots were separated by 1 metre wide paths and the experimental plots were kept clean through regular hand weeding.

### 2.3 Obtaining the Samples

The re-growth of each forage sweet potato cultivar was harvested by hand clipping at the pre-determined harvesting age of 90, 120, 150 and 180 days. The forage from each plot was individually weighed, chopped, thoroughly mixed and sub-samples taken for the determination of *in vitro* digestibility according to Menke et al., (1979) and Menke and Steingass (1988). Dry matter (DM), OM, CP and total ash (XA) were determined according to AOAC (1998) procedures.

### 2.4Preparation of Media

Buffer and mineral solutions were prepared and placed in a water bath at $39^0$C under continuous flushing with $CO_2$ (Menke et al., 1979; Menke and Steingass, 1988). Dry matter (DM), OM, CP and total ash (XA) were determined according to AOAC (1998). Rumen fluid was collected before the morning feeding from three rumen cannulated sheep fed on hay. The rumen fluid was collected from sheep into pre-warmed insulated bottles, filtered through three layers of cheese-cloth and flushed with $CO_2$. The well mixed and $CO_2$ flushed rumen fluid was added to the buffered rumen solution (1:2 v/v), which was maintained in a water bath at $39^0$C, and mixed.

Milled samples (200 mg) of air dried forage sweet potato cultivars were accurately weighed into 100 ml calibrated glass syringes fitted with plungers. Buffered rumen fluid (30 ml) was pipetted into each syringe, containing the feed sample and immediately placed into water bath at $39^0$C. Three syringes with only buffered rumen fluid were incubated and considered as blanks. The syringes were gently shaken every 2 hr and the incubation terminated after recording the 24 hr gas volume. Gas production was recorded after 3, 6, 9, 12 and 24 hr of incubation. Total gas production values were corrected for the blank incubation and reported gas values expressed in ml per 200 mg of DM. The following equations were used to calculate organic matter digestibility (OMD) and metabolizable energy (ME), respectively, according to Makkar (2004):

OMD (%) = 14.88 + 0.889GP+ 0.45CP +0.0651XA (Equation 1)

ME (MJ/kg DM) = 2.2 +0.136GP +0.057CP (Equation 2)

Where: OMD is organic matter digestibility
ME is metabolizable energy
GP is 24 hr gas production (ml/ 200 mg DM)
CP is crude protein (% of DM)
XA is ash (% of DM)

Partition factor, Short chain fatty acids and Microbial protein yield

Partition factor (PF) is defined as the ratio of substrate truly degraded *in vitro* to volume of gas produced (Makkar, 2004). The PF values were calculated according to Makkar (2004). Volatile fatty acids content in milligrammes (mg) per litre was calculated as VFA = 0.0239GP – 0.0601 according to Akinfemi et al. (2009). Microbial protein production in g per kg DM was calculated as 19.3 g microbial nitrogen per kg OMD multiplied by the factor 6.25 according to Czerkawski (2006).

### 2.5 Statistical Analyses

The general linear model (GLM) of SAS (2003) was used to compute analysis of variance for RCBD for *in vitro* OM digestibility, ME, VFA, MCP and PF of the control cultivar and the five forage sweet potato cultivars at their respective harvesting ages. The means were separated using least significant difference (LSD) procedures.
The following statistical model was used:-

$Y_{ijk} = \mu + p_i + \alpha_j + (p\alpha_{ij}) + \beta_k + \acute{\varepsilon}_{ijk}$

Where $Y_{ijk}$ = Estimated cultivar *in vitro* OM digestibility, ME, VFA, MP and PF
$\mu$ = Overall cultivar mean
$p_i$ = Cultivar effect
$\alpha_j$ = Effect of harvesting age
$(p\alpha_{ij})$ = Interaction of cultivar and harvesting age
$\beta_k$ = Block effect
$\acute{\varepsilon}_{ijk}$ = Residual effects of treatments

### 3.0 Results

*In vitro* organic matter digestibility

Harvesting age significantly influenced (P<0.001) *in vitro* organic matter digestibility (IVOMD) (Table 1). Most of the cultivars recorded their highest (P<0.05) IVOMD at 120 days except 99/1 and Mugande that recorded their highest value (P<0.05) at 180 days. Cultivars 99/1, K049 and Mugande recorded their lowest (P<0.05) IVOMD at 90 days while Marooko and Wagabolige; K158 recorded their lowest value (P<0.05) at 150 and 180 days, respectively. Unlike the other cultivars, Mugande recorded similar (P>0.05) IVOMD between 90 and 150 days. The lowest (P<0.05) IVOMD was in K158 at all the four harvesting ages.

### 3.1 Metabolizable Energy

The harvesting age influenced (P<0.001) the metabolizable energy (ME) in the cultivars (Table 2). Most of the cultivars recorded their lowest ME at 90 days and their highest at 120 days. However, Marooko recorded the highest (P<0.05) ME at 180 days and Wagabolige maintained similar (P>0.05) ME across the harvesting ages. Among all the cultivars Wagabolige had the highest (P<0.05) ME in all four harvesting ages. The lowest (P<0.05) ME was in Mugande at 90 days and in 99/1 at 120, 150 and 180 days.

### 3.2 Volatile Fatty Acids

Harvesting age affected (P<0.001) production of volatile fatty acid (VFA) in all cultivars (Table 3). Cultivars 99/1, Wagabolige and Mugande produced similar (P>0.05) quantities of VFA at all four ages while K049, K158 and Marooko recorded similar (P>0.05) VFA at 90 and 150 days; 120 and 180 days, respectively. The age at 120 days seemed the optimum harvesting age for VFA production. The highest (P<0.05) VFA was recorded in Wagabolige at all four harvesting ages. The lowest (P<0.05) VFA was in K049 at 90 days and in 99/1 at 120, 150 and 180 days.

### 3.3 Microbial Protein Synthesis

The harvesting age influenced (P<0.05) the microbial crude protein (MCP) synthesis in all cultivars (Table 4). Cultivars 99/1 and K049 recorded their lowest (P<0.05) MCP at 90 days; Marooko and Wagabolige at 150 days and K158 at 180 days. Cultivars K158 and Mugande maintained similar (P>0.05) MCP synthesis at 90, 120 and 150 days while Wagabolige recorded similar (P>0.05) MCP synthesis at 90, 120 and 180 days. Cultivar K049 recorded similar (P>0.05) MCP synthesis at 90 and 150 days while Marooko, also, recorded similar (P>0.05) MCP synthesis at 120 and 180 days respectively. The optimum harvesting age appears to be 120 days for MCP synthesis. The highest and the lowest (P<0.05) MCP was recorded in Wagabolige and K158 at all four harvesting ages.

### 3.4 Partition Factor

The harvesting age influenced (P<0.05) the partition factor (PF) in all cultivars (Table 5). Generally, the PF was lowest (P<0.05) at 150 days in 99/1, K158, Mugande and Wagabolige but this value was lowest (P<0.05) at 90 and 180 days in Marooko and K049, respectively. The PF in general did not differ (P>0.05) within most of the cultivar across the remaining harvesting ages. The highest and lowest (P<0.05) PF was recorded in Mugande and Morooko at all four harvesting ages, respectively.

## 4.0 Discussion

*In vitro* organic matter digestibility

The results of effect of harvesting age on the *in vitro* organic matter digestibility (IVOMD) for all cultivars is in agreement with observations by Snijders et al. (1992) and Kiragu and Tamminga (1997) who reported that OM increased with age in sweet potato forage. The OM content has been shown to be positively correlated to IVOMD (Kamalak et al., 2004; Karabulut et al., 2007; Akinfemi, 2010). The lower IVOMD in K158 at 90 and 180 days may indicate that the cultivar was at a more vegetative stage (Snijders et al., 1992; Kiragu and Tamminga 1997). In addition, the lower IVOMD in the cultivars beyond 120 days may be attributed to an increase in mature leaves (Snijders et al., 1992) which are known to contain high NDF. High NDF has been shown to be negatively correlated to IVOMD (Kamalak et al., 2004; Karabulut et al., 2007; Akinfemi, 2010). The lower IVOMD recorded among the cultivars beyond 120 days showed that this age was the optimum age and an accumulation in the proportion of dead leaves occurred beyond this age (Snijders et al., 1992). At the optimal age, plant leaves recorded high IVOMD which decrease thereafter (Sallam, 2005).

The IVOMD in most of the forage sweet potato cultivars at all four ages was higher than that of Lurcene (592-706 g/kg DM), vetch (582-755 g/kg DM) and white clover (678 g/kg DM) (Abas et al., 2005; Kamalak et al., 2005; Karabulut et al., 2007). The IVOMD for forage sweet potato cultivars were higher than values reported for sunflower meal (597 g/kg DM) (Abas et al., 2005) and full fat rapeseed (668-743 g/kg DM) (Kilic and Garipoglu, 2009). The forage sweet potato cultivars recorded their highest digestibility at 120 days which at 711-851 g/kg DM can be considered as quite high for most forages. Lurcene, vetch and white clover are common fodder legumes cultivated in Kenya whereas sunflower and rapeseed cakes are major sources of protein in ruminant compounded feed. Forage sweet potato cultivars as protein sources, therefore, can contribute significantly to ruminant feeding without greatly reducing feed digestibility.

Metabolizable energy

The little variation in ME with the extended harvesting age of cultivars observed in the present study is in agreement with the findings of Olorunnisomo (2007) who showed that energy in sweet potato vines did not vary between 30 and 150 days harvesting intervals. In the present study this was demonstrated in Wagabolige whose ME value was similar across harvesting ages. This occurred as the OM being the main source of energy did not differ among the harvesting ages (Olorunnisomo, 2007). Oduro et al. (2008) also showed that there was little difference in energy among various sweet potato cultivars. However, the wide variation in ME recorded in Marooko may be attributed to difference in OM at different harvesting ages.

The metabolizable energy values in this study were within the range reported by other workers (Kariuki et al., 1998; Aregheore and Tofinga, 2004; Antia et al., 2006; Oduro et al., 2008) but were slightly lower than those reported by Olorunnisomo (2007). This difference may be due to cultivars differences as observed by Karachi (1982a, b), Irungu et al. (2000) and Mirzaei-Aghsaghali et al. (2011) who also reported variation between experimental sites. The climatic factors at the study site may be optimal for these cultivars and their harvesting age allowed adequate time for plants to accumulate optimal energy (Larbi et al., 2007; Olorunnisomo, 2007). These cultivars may have rapidly partitioned energy accumulation in favour of leaf production (Snijders et al., 1992; Olorunnisomo, 2007). Sweet potato leaves have been shown to contain higher metabolazable energy than stems essentially due to their lower fibre content and high OMD (Aregheore and Tofinga, 2004). Snijders et al. (1992) recorded decrease in photosynthetic leaves and increase in dead leaves with extended harvesting age, an indication of decreased photosynthetic efficiency.

The ME in most of the forage sweet potato cultivars at all four ages in the present study was lower than that of Lurcene (8.9-10.5 MJ/kg DM), vetch (11.1 MJ/kg DM), white clover (10.0 MJ/kg DM) (Kamalak et al., 2005;

Karabulut et al., 2007), sunflower meal (9.2 MJ/kg DM) (Abas et al., 2005) and full fat rapeseed (9.8-9.5 MJ/kg DM) (Kilic and Garipoglu, 2009). The forage sweet potato cultivar ME values were, however, higher than values reported for vetch (7.4 MJ/kg DM) (Abas et al., 2005). Majority of the cultivars recorded their highest ME at 120 days (7.63-8.13 MJ/kg DM). Generally, the fodder legumes, sunflower and rapeseed meals contained higher OM (Abas et al., 2005; Kamalak et al., 2005; Karabulut et al., 2007; Kilic and Garipoglu. 2009) compared to forage sweet potato cultivars. The OM is the main source of energy in ruminants. Feeding of these forage sweet potato cultivars to livestock may, therefore, require energy supplementation.

### 4.1 Volatile Fatty Acids

The harvesting age influenced the total volatile fatty acid (VFA) production in all cultivars of sweet potato. This was in agreement with Irungu et al. (2000), Ngyen and Ogle (2005) and Olorunnisomo (2007) who showed that different sweet potato cultivars responded differently to extended harvesting age. The similarity in amount of fermented VFA in 99/1, Wagabolige and Mugande at the four harvesting ages could be attributed to similarity in chemical composition (Kamalak et al., 2004; Karabulut et al., 2007; Akinfemi, 2010). Organic matter (OM) has been shown to be positively correlated to *in vitro* digestibility and that high digestibility enables increased production of VFA (Mirzaei-Aghsaghali et al., 2011; Mohammadadadi and Chaji, 2012; Taher-Maddah et al., 2012). The similarity in VFA in some test cultivars at different harvesting ages in this study was in agreement with observations by Oduro et al. (2008) who reported little difference in energy among various sweet potato cultivars. Again, the lower VFA values recorded in the current study compared to Lucerne may be due lower OM (Blummel et al 2003) in forage sweet potato cultivars.

### 4.2 Microbial Protein Synthesis

In the current study harvesting age affected the microbial protein (MCP) synthesis in all cultivars. These findings are in agreement with Irungu et al. (2000), Ngyen and Ogle (2005) and Olorunnisomo (2007) who showed that different sweet potato cultivars responded differently to extended harvesting age. The similarity in CP, IVOMD and VFA production at respective ages in K049 at 90 and 150 days may have applied although the IVOMD was lower at 90 days than at 150 days (Naskar and Nedunchezhiyan, 2009; Mirzaei-Aghsaghali et al., 2011). This may have been caused by lower protein availability at 90 days compared to 150 days.

Most forage sweet potato cultivars in this study recorded MCP values that were within the range of 90.4-126.4 g/kg DM reported by Karabulut et al. (2007) in legume hays. These values were; however, lower than those for Lurcene, vetch and white clover at 120, 138.1 and 126.4 g/kg DM, respectively (Karabulut et al., 2007). This may have occurred due to the lower ME in forage sweet potato cultivars compared to these fodder legumes. Crude protein (CP) may not have been the cause of lowered MCP as the CP content in the legumes and forage sweet potato cultivars was similar (Karabulut et al., 2007). Forage sweet potato cultivars when fed to livestock, therefore, may require energy supplementation to enhance MCP synthesis.

### 4.3 Partition Factor

Partition factor (PF) was defined as the ratio of substrate truly degraded *in vitro* (mg) to the volume of gas (ml) produced by it (Makkar, 2004). The PF is, therefore, a measure of efficiency of microbial mass production or efficiency of microbial protein production. Feeds with high PF mean that proportionately more degradable matter was incorporated into microbial mass. This was the case in the current study where the changes in PF trends were in tandem with that of MCP. The theoretical range for PF is 2.74 to 4.41 (Blummel and Becker, 1997; Makkar, 2004). Thus the PF values in the current study were within the documented range. According to Blummel and Becker (1997), Arhab et al. (2009) and Arhab et al. (2010) plants with high PF are generally highly digestible and the values correlate well with DM intake in ruminants. The PF trend in the current study was in phase with IVOMD which was in agreement with Blummel and Becker (1997). The age at harvest had little effect on PF as the IVOMD did not greatly vary with age.

## 5.0 Conclusions

Harvest age affected *in vitro* organic matter digestibility (IVOMD), metabolizable energy (ME), volatile fatty acids (VFA), microbial crude protein yield (MCP) and partition factor (PF) in forage sweet potato cultivars. Generally, IVOMD, ME, VFA, MP and PF were at their highest level at 120 days and declined thereafter indicating that this age was the most appropriate for harvesting these forage sweet potato cultivars. Wagabolige was the most suitable and stable cultivar regarding IVOMD, ME, VFA and MCP while K158 and 99/1 were the lowest in IVOMD and MCP; ME and VFA, respectively.

The IVOMD in most of the forage sweet potato cultivars at all four ages was higher than that of Lurcene, vetch, white clover, sunflower meal and full fat rapeseed. However, ME, MCP, VFA were lower due to lower OM in forage sweet potato cultivars. Forage sweet potato cultivars as protein sources can contribute to ruminant feeding without significantly reducing feed digestibility. These cultivars will, however, require energy supplementation to enhance ME, MCP and VFA synthesis.

**Acknowledgement**
We thank the Director, Kenya Agricultural Research Institute (KARI) and Director General, Kenya Agricultural and Livestock Research Organization (KALRO) for financial support. The KALRO Muguga Laboratory staff performed sample analysis.

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*Table: Effects of harvesting age of forage sweet potato cultivars on in vitro organic matter digestibility (g/kg DM)*

| Harvesting age (days) | | | | |
|---|---|---|---|---|
| Cultivar | 90 | 120 | 150 | 180 |
| 99/1 | $696_{1}^{a}$ | $761_{2}^{c}$ | $724_{2}^{b}$ | $769_{2}^{d}$ |
| K049 | $730_{3}^{a}$ | $830_{4}^{d}$ | $740_{3}^{b}$ | $807_{3}^{c}$ |
| K158 | $700_{1}^{b}$ | $711_{1}^{c}$ | $708_{1}^{bc}$ | $684_{1}^{a}$ |
| Marooko | $718_{2}^{b}$ | $851_{5}^{c}$ | $699_{1}^{a}$ | $851_{4}^{c}$ |
| Wagabolige | $842_{5}^{b}$ | $846_{5}^{b}$ | $829_{5}^{a}$ | $844_{4}^{b}$ |
| Mugande | $775_{4}^{a}$ | $781_{3}^{a}$ | $775_{4}^{a}$ | $813_{3}^{b}$ |

LSD ($P<0.05$) for comparing effect of age at harvest (row) on IVOMD means = 8.2, SEM=2.9
LSD ($P<0.05$) for comparing effect of fodder cultivar (column) on IVOMD means = 10.1, SEM=3.5
$^{abcd}$ Means within a row bearing different superscripts are different ($P<0.05$)
$_{12345}$ Means within a column bearing different subscripts are different ($P<0.05$)
SEM: Standard Error of Means

*Table: Effects of harvesting age of forage sweet potato cultivars on metabolizable energy (MJ/ kg DM)*

| Harvesting age (days) | | | | |
|---|---|---|---|---|
| Cultivar | 90 | 120 | 150 | 180 |
| 99/1 | $7.52_{23}^{b}$ | $7.43_{1}^{b}$ | $7.37_{1}^{ab}$ | $7.25_{1}^{a}$ |
| K049 | $7.26_{1}^{a}$ | $7.63_{23}^{c}$ | $7.46_{1}^{b}$ | $7.67_{23}^{c}$ |
| K158 | $7.43_{1}^{a}$ | $7.82_{3}^{b}$ | $7.45_{1}^{a}$ | $7.77_{3}^{b}$ |
| Marooko | $7.58_{3}^{a}$ | $8.10_{4}^{b}$ | $7.54_{1}^{a}$ | $8.28_{4}^{c}$ |
| Wagabolige | $8.18_{4}$ | $8.13_{4}$ | $8.28_{2}$ | $8.24_{4}$ |
| Mugande | $7.38_{12}^{a}$ | $7.59_{12}^{b}$ | $7.44_{1}^{ab}$ | $7.56_{2}^{b}$ |

LSD ($P<0.05$) for comparing mean effect of age at harvest (row) on metabolizable energy = 0.15, SEM=0.05
LSD ($P<0.05$) for comparing mean effect of fodder cultivar (column) on metabolizable energy = 0.19, SEM=0.07
$^{abc}$ Means within a row bearing different superscripts are different ($P<0.05$)
$_{12345}$ Means within a column bearing different subscripts are different ($P<0.05$)
SEM: Standard Error of Means

*Table : Effects of harvesting age of forage sweet potato cultivars on total rumen volatile fatty acids production (mg/L)*

| Harvesting age (days) | | | | |
|---|---|---|---|---|
| Cultivar | 90 | 120 | 150 | 180 |
| 99/1 | $0.71_{2}$ | $0.71_{1}$ | $0.68_{1}$ | $0.71_{1}$ |
| K049 | $0.67_{1}^{a}$ | $0.73_{1}^{b}$ | $0.70_{12}^{a}$ | $0.75_{2}^{b}$ |
| K158 | $0.69_{12}^{a}$ | $0.77_{2}^{b}$ | $0.69_{12}^{a}$ | $0.75_{2}^{b}$ |
| Marooko | $0.72_{2}^{a}$ | $0.82_{3}^{b}$ | $0.71_{12}^{a}$ | $0.84_{3}^{b}$ |
| Wagabolige | $0.82_{3}$ | $0.84_{3}$ | $0.84_{3}$ | $0.83_{3}$ |
| Mugande | $0.72_{2}$ | $0.72_{1}$ | $0.72_{2}$ | $0.74_{12}$ |

LSD (P<0.05) for comparing mean effect of age at harvest (row) on short chain fatty acids = 0.03, SEM=0.01
LSD (P<0.05) for comparing mean effect of fodder cultivar (column) on chain fatty acids = 0.03, SEM=0.01
$^{abc}$ Means within a row bearing different superscripts are different (P<0.05)
$_{12345}$ Means within a column bearing different subscripts are different (P<0.05)
SEM: Standard Error of Means

*Table 4: Effects of harvesting age of forage sweet potato cultivars on microbial protein yield (g/kg DM)*

| Harvesting age (days) | | | | |
|---|---|---|---|---|
| Cultivar | 90 | 120 | 150 | 180 |
| 99/1 | $83.9_{1}^{a}$ | $91.8_{2}^{b}$ | $91.9_{3}^{b}$ | $92.8_{2}^{b}$ |
| K049 | $88.1_{3}^{a}$ | $100.2_{4}^{c}$ | $89.2_{2}^{a}$ | $97.4_{3}^{b}$ |
| K158 | $84.4_{1}^{b}$ | $85.4_{1}^{b}$ | $85.8_{1}^{b}$ | $82.5_{1}^{a}$ |
| Marooko | $86.6_{2}^{b}$ | $102.6_{5}^{c}$ | $84.4_{1}^{a}$ | $102.6_{4}^{c}$ |
| Wagabolige | $101.6_{5}^{b}$ | $102.0_{5}^{b}$ | $100.0_{5}^{a}$ | $101.8_{4}^{b}$ |
| Mugande | $93.5_{4}^{a}$ | $93.5_{3}^{a}$ | $94.3_{4}^{a}$ | $97.9_{3}^{b}$ |

LSD (P<0.05) for comparing mean effect of age at harvest (row) on microbial protein synthesis = 1.15, SEM=0.40
LSD (P<0.05) for comparing mean effect of fodder cultivar (column) on microbial protein synthesis = 1.40, SEM=0.49
$^{abc}$ Means within a row bearing different superscripts are different (P<0.05)
$_{12345}$ Means within a column bearing different subscripts are different (P<0.05)
SEM: Standard Error of Means

*Table 5: Effects of harvesting age of forage sweet potato cultivars on partition factor*

| Harvesting age (days) | | | | |
|---|---|---|---|---|
| Cultivar | 90 | 120 | 150 | 180 |
| 99/1 | $3.07_{12}^{b}$ | $3.10_{23}^{b}$ | $2.87_{1}^{a}$ | $3.00_{2}^{b}$ |
| K049 | $3.13_{2}^{b}$ | $3.20_{34}^{b}$ | $3.17_{2}^{b}$ | $3.00_{2}^{a}$ |
| K158 | $2.93_{1}^{b}$ | $2.93_{1}^{b}$ | $2.77_{1}^{a}$ | $2.70_{1}^{a}$ |
| Marooko | $2.93_{1}^{a}$ | $3.03_{12}^{a}$ | $3.37_{34}^{b}$ | $3.40_{3}^{b}$ |
| Wagabolige | $3.50_{3}^{b}$ | $3.27_{4}^{a}$ | $3.30_{23}^{a}$ | $3.43_{3}^{b}$ |
| Mugande | $3.77_{4}^{c}$ | $3.73_{5}^{bc}$ | $3.50_{4}^{a}$ | $3.63_{4}^{b}$ |

LSD (P<0.05) for comparing mean effect of age at harvest (row) on partition factor = 0.12, SEM=0.04
LSD (P<0.05) for comparing mean effect of fodder cultivar (column) on partition factor = 0.15, SEM=0.05
$^{abc}$ Means within a row bearing different superscripts are different (P<0.05)
$_{12345}$ Means within a column bearing different subscripts are different (P<0.05)
SEM: Standard Error of Means