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Characteristics of *Moringa oleifera* silage with mixtures of *Panicum maximum* and wheat offals

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Abstract

This study was designed to assess some quality characteristics of moringa silage with or without Guinea grass and wheat offals for an optimization of surplus production of moringa and Guinea grass usually produced during the growing season. Moringa (leaves + soft stems + petioles), *Panicum maximum*, and wheat offals were ensiled as follows (w/w); 100*Moringa oleifera* (FMO), 50*Moringa oleifera* + 50Wheat offal (50MW), 50*Moringa oleifera* + 50*Panicum maximum* (50MP), 50*Moringa oleifera* + 40*Panicum maximum* + 10Wheat offal (M40P10W), 50*Moringa oleifera* + 30*Panicum maximum* + 20Wheat offal (M30P20W), 50*Moringa oleifera* + 20*Panicum maximum* + 30Wheat offal (M20P30W) and 50*Moringa oleifera* + 10*Panicum maximum* + 40Wheat offal (M10P40W) in a completely randomized design with three replicates each. The silages were opened after 35 days for assessment. A significantly (P<0.05) highest pH of 6.40 was recorded for FMO, while pH values for moringa silage combinations ranged between 3.61 for M20P30W and 4.04 for M40P10W. The pH of M20P30W and M10P40W were comparable (P>0.05) but both were significantly (P<0.05) lower compared to other silage combinations. Silage colours were light olive green (FMO and 50MW) and olive green (50MP, M10P40W, M20P30W and M40P10W). Silage combinations of the three experimental feed materials had the most pleasant smell, with an observed improving smell with increasing proportion of wheat offals. A similar trend was observed for silage texture, and the aggregates of the three subjective indices. With the exception of 50MP, all the experimental silages met the minimum crude protein requirement for ruminants.

Keywords: Silage, dry season feed supplementation, ruminants, tropical region, *Moringa oleifera*.

1. Introduction

Seasonal shortages in feed supply are major constraints to increasing ruminant productivity in developing countries (Kebreab *et al*., 2005). In most of these countries, which incidentally lie in the tropics, natural pastures, crop residues and indigenous fodder trees are the main feed resources for ruminant livestock, with natural pastures and crop residues providing the bulk of most basal diets. Due to seasonal fluctuations in the availability and quality of these feed resources in these areas, intake of energy, protein and some essential minerals by most ruminants species fall below their maintenance requirements resulting in 'under-nutrition' and low productivity in most animal production systems (Larbi and Olaloku, 2005). The natural pastures, the most predominant basal diets in these areas, are usually unavailable in the dry season and characterized by fibrous and lignified nature with the attendant low nutritive values; resulting in limited intake, digestibility and utilization (Babayemi *et al*., 2009; Olafadehan *et al*., 2009). At this period, the performance of ruminant animals is seriously impaired (Olafadehan *et al*., 2009), with the animals suffering heavy losses (Deaville *et al*., 1994). In order to cope with the identified attendant under-nutrition and improve the productivity of these ruminants, particularly in West Africa, Larbi and Olaloku (2005) recommended a multi-dimensional research approach for the generation of the necessary information on strategies for increasing feed supply such as conservation methods for surplus feed resources during the growing season.

Ensiling is a potent general method for forage preservation and also a form of treatment to occasionally salvage the under-utilized pastures for better acceptability and degradability (Babayemi, 2009). The author opined that silage making in the tropics is paramount if there will be an all year round availability of forage for livestock. He observed that in the wet season, there is abundance of grass while it becomes scarce in the dry season. The major crop for silage-making in some of the leading livestock producing countries in the world, according to Tuah and Okyere (1974), has all along been maize or corn *(Zea mays.),* with whole-maize silage being the basic fodder for cattle in North America, and to a lesser extent in Europe (Wong, 2000). However, as the global demand for maize outpaces its production with the current changes in global energy system with research attention now shifting to maize/corn for the production of biodiesel, coupled with increasing competition between animals and humans for this major food/feed item due to what has been described as "poverty syndrome" as maize/corn is increasingly used for a variety of indigenous dishes (ogi/akamu, tuwo, semovita, etc.) (Bello, 2013), it has become imperative to research into suitable, or even better, alternatives to this conventional crop for silage making, particularly in the tropics. Hence, the notable research attention that forage crops has enjoyed over the years. Silages from forage crops have been widely used in North America, Europe, Israel and some other parts of the world (Weinberg *et al*., 2004). The preservation of forage crops as silage depends on the production of sufficient acid to inhibit activity of undesirable microorganisms under anaerobic conditions (Ogunjobi *et al*., 2012). Babayemi and Igbekoyi (2008) described silage production in the tropics as a sustainable means of supplementing feed for ruminants in the dry season. Hence, the perennial forage surplus obtained when the weather is favorable is recommended for storage as silage in order to meet the animal requirements throughout the year (Bonelli *et al*., 2013). Fortunately, apart from the conventional forage crops, materials that can be ensiled include fodder crops and crop residues or by-products ('t Mannetje, 2000).

The multiple uses and potentials of *Moringa oleifera* have attracted the attention of researchers in recent times (Fadiyimu *et al*., 2010). Its intensive cultivation (dense plantation) with the application of fertilizer and water supply, gives a dry matter yield of up to 120 tonnes per hectare, with seven to eight cuttings in a year (Foidl *et al*. 2001). Leaves of *Moringa oleifera* are high in crude protein and almost all the crude protein is present in the form of true protein (Makkar, 2013). In addition, the amino acid composition and protein digestibility is as good as soybean (over 92 percent). Furthermore the leaves are rich in carotenoids, vitamin C and other antioxidants (Makkar and Becker, 1997; Foidl *et al*., 2001). *Panicum maximum* (guinea grass) is a clump-forming perennial which grows best in warm frost-free areas (Aganga and Tshwenyane, 2004). It is one of the most common grasses in the derived savanna zone of Nigeria (Agishi, 1985). Aganga and Tshwenyane (2004) reported that the grass is abundant in the wet season but scarce in the dry season and where available, they are highly lignified. Preservation, therefore, as opined by Aganga and Tshwenyane (2004), remains the solution to their availability during the dry season. In the 1990s, it became increasingly common to use silage additives to improve the ensiling process (Oude Elferink *et al*., 2000). However, the cost and availability of commercial silage additives are often a limiting factor in most of the tropical and sub-tropical regions, thus making agro – industrial waste /by – products handy alternatives (Odedire and Abegunde, 2014). Wheat offal, a by-product of wheat after obtaining flour for human use (Amaefule *et al*., 2009), is one of the major agro-industrial by-products used in animal feeding (Kent and Evers, 1994). It is made up of wheat germ, bran, coarse middling and fine middling (Alawa and Umunna, 1993). Wheat offal contains 14.80 - 17.60 % CP (Maisamari, 1986; Yin *et al.,* 1993; Olomu, 1995), about 10 % CF (Olomu, 1995) and 3.4 - 6.4 % ash (Maisamari, 1986; Yin *et al*., 1993; Olomu, 1995). Wheat bran represents roughly 50 % of wheat offals and about 10 to 19% of the kernel, depending on the variety and milling process (Hassan *et al.,* 2008; Prikhodko and Rybchynsky, 2009).

Moringa leaves have been successfully used to supplement low-quality forage diets and improve animal performance (Heuze *et al*., 2014). They are typically fed fresh to ruminants (Heuze *et al*., 2014), but the leaf powder has also received some research attention with promising results (Asaolu, 2012; Asaolu *et al*., 2012). There is a death of information on the use of moringa leaves as silage. Reports by Mendieta-Araica *et al*. (2009; 2011) have however shown that they can be ensiled, alone or in mixtures with Napier grass or sugarcane to increase the nutritive value of the silage. Olorunnisomo (2014) reported acceptable pH ranges, physical and chemical characteristics for silage combinations of moringa leaves with cassava peels as well as promising production indices with Sokoto Gudali cows. Du Ponte *et al.* (1998) demonstrated that guinea grass can be successfully ensiled, maintaining quality and minimal spoilage under tropical climatic conditions. Mühlbach (2000) however reported sub-optimal (often poor) initial silage fermentation with tropical grasses such as *D. eriantha* and *P. maximum* due to either a low dry matter (DM) content, high buffer capacities, low level of suitable lactic acid bacteria and a low water-soluble carbohydrate (WSC) content, or a combination of these factors. Coelho (2002) noted that with advances in the agro-industrial sector, by-products, including those from the processing of cereals, are potential alternatives to improve the fermentation pattern, nutritional value, degradability of silages and, ultimately, improvements in animal performance.

This study was therefore conducted to characterize *Moringa oleifera* silages with mixtures of *Panicum maximum* and wheat offals. Quality indices adopted for assessment were silage pH, sensory characteristics (colour, smell and texture) and nutrient compositions.

2. Materials and methods

Experimental site

The study was conducted at the Small Ruminant Unit of the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, in South West Nigeria. Ogbomoso is in the derived savanna zone, and at about 600 m about sea level and located on latitudes 8^o 07' and 8^o 12' N and longitudes 4^o 04' and 4^o 15' E (Oguntoyinbo, 1978). The town has a maximum temperature of 33 ^{o}C and a minimum temperature of 28 ^{o}C. The humidity of the area is high (74 %) all the year round except in January when the dry wind blows from the north and the annual rainfall is over 100 mm (Olaniyi, 2006). Common feed resources in the area, particularly in the dry season, include agro-industrial by-products, crop residues and kitchen wastes; with an abundance of forages in the wet season (Sodeinde *et al*., 2007), with *Panicum maximum* being one of the most common grasses (Ajayi and Babayemi, 2008).

Procurement and processing of experimental feed materials

Moringa leaves with soft stems and petioles were harvested from an established paddock after 60days of re-growth. They were subsequently manually chopped to between 2 and 3 cm lengths. *Panicum maximum* grass was harvested from another established paddock after 56 days of re-growth. They were also thereafter manually chopped to between 2 and 3 cm lengths. Wheat offal was purchased from a reputable feed ingredient store in Ogbomoso.

Experimental treatments and silage preparation

Seven experimental silages were made from the experimental feed materials on a wet basis as follows (w/w):
100 % *Moringa oleifera* (FMO)
50 % *Moringa oleifera* + 50 % Wheat offal (50MW)
50 % *Moringa oleifera* + 50 % *Panicum maximum* (50MP)
50 % *Moringa oleifera* + 40 % *Panicum maximum* + 10 % Wheat offal (M40P10W)
50 % *Moringa oleifer*a + 30 % *Panicum maximum* + 20 % Wheat offal (M30P20W)
50 % *Moringa oleifera* + 20 % *Panicum maximum* + 30 % Wheat offal (M20P30W)
50 % *Moringa oleifera* + 10 % *Panicum maximum* + 40 % Wheat offal (M10P40W)

For each experimental treatment, the chopped guinea grass and moringa leaves were weighed in the desired proportions, thoroughly mixed to achieve uniformity, and filled into 1-m long, 100 mm-diameter PVC pipes in four replicates. The pipes were previously lined at the bottom with straws and on the sides with black polythene sheets. Each layer of the moringa/panicum mixture was compacted manually to displace the air in the pipes until they were filled. Approximately 3 kg of fresh material was packed in each silo. After the silage making process, the remainder of the black polythene sheet was wrapped over the experimental silo. Each experimental silo was further covered with straws, and a 1-kg sand bag was finally placed on the silo in order to ensure adequate compaction as the ensilage process progressed. The silos were opened for assessment after 35 days.

A completely randomized design with seven treatments and four replicates was used in this study.

Silage sampling procedure
For every silage combination, the contents from each experimental silo were transferred into a plastic bag, thoroughly mixed, and then 800g samples were taken from each replicate for analysis (Mendieta-araica *et al*., 2009).

pH measurement and ranking
Measurement of pH was done by a pH meter (model: PHS-25). The obtained values were ranked using a scale of 0 - 5 as developed by Ososanya and Olorunnisomo (2015).

Measurement of sensory characteristics
Five judges with reasonable experiences in silage making were asked to assess and rate the sensory characteristics (colour, smell and texture) of the experimental silages using a slight modification of the 0 - 5 scale of Ososanya and Olorunnisomo (2015) as contained in Table 1. Five was the maximum score for each sensory characteristic, and an average of the sum of scores of all judges was taken as the quality score of each characteristic.

Table 1: Assessment scale for the sensory characteristics of moringa-based silages

	0	1	2	3	4	5
Colour	Very dark	Dark	Olive yellow	Light olive green	Olive green	Deep olive green
Smell	Offensive	Poor	Almost pleasant	Fairly pleasant	Pleasant	Very pleasant
Texture	Slimy	Very soft	Soft	Fairly firm	Firm	Very firm
pH	>6.50	6.10 - 6.50	5.60 - 6.00	4.60 - 5.50	4.00 - 4.50	<4.00

0 = Very bad, 1 = Bad, 2 = Going bad, 3 = Moderate, 4 = Good, 5 = Excellent
*Adapted from Ososanya and Olorunnisomo (2015)

Chemical analyses
Fresh samples of the materials that were used in making the experimental silages were analyzed for proximate composition using the general procedures of AOAC (2000). Dry matter concentrations in the silages were determined using a forced draught oven at 105^{o}C and values obtained were corrected for loss of volatile compounds by multiplying with a correction factor of 1.056 (Fox and Fenderson, 1978). Neutral detergent fibre and acid detergent fibre fractions were determined according to methods of Van Soest *et al*. (1991).

Statistical analysis
All the data collected were subjected to a one way analysis of variance (ANOVA) using SAS (2002) package. Significant treatment means were compared using Duncan's New Multiple Range Test of the same package.

3. Results and discussion
Table 2 shows the proximate compositions of the fresh *Moringa oleifera*, *Panicum maximum* and wheat offals before they were ensiled. The nutritional value of silage depends, in part, on the quality of the original forage (Jianxin and Jun, 2002). The dry matter contents of these materials were 33.00, 27.50 and 90.00 % respectively. The crude protein content of moringa was 25.80 % while the respective values for wheat offals and panicum were 17.40 and 9.40 %. The NFE values were 59.40, 25.00 and 23.00 % for wheat offals, panicum and moringa respectively. It is generally agreed that moisture content is the most important factor in silage making, with a recommendation that silage should be made from materials with suitable moisture content, about 50 to 60 % depending on the means of storage, the degree of compression, and the amount of water that will be lost in storage, but not exceeding 75 %. An upper limit of 80 % was however stated by Jianxin and Jun (2002). According to these researchers however, effluent is produced when moisture is above 75 %, with the amount of effluent increasing with increasing silo height due to increasing pressure. In general, forage with high moisture content makes sour silage (Seiden and Pfander, 2003). Additionally, the critical pH value for clostridial growth varies directly with the moisture content of the plant material, and unless soluble carbohydrate levels are exceptionally high, ensiling wet crops will encourage clostridial fermentation, resulting in high losses and reduced nutritive value. For the tropical regions, the moisture contents of the raw materials should be adjusted to between 65 and 75 % (Chiba *et al*., 2005). The DM contents of moringa and panicum materials used in this study were within this range. Although not measured, the water soluble carbohydrates were likely to be low judging from their NFE values. The addition of wheat offals, with a much higher NFE value (59.40 %) could however be a corrective measure. The crude protein contents of the silage materials were all within the acceptable range for

ruminant performance (NRC, 1981). They were all higher than the critical CP level of 7 % recommended by ARC (1980) and 8 % suggested by Norton (1994) for ruminal function. However, the CP content (9.40 %) of Panicum was however lower than the range of 11.00 to 13.00 % recommended by NRC (1981) to be capable of supplying adequate protein for maintenance and moderate growth performances in goats.

The pH values and the ratings for the various sensory characteristics (colour, smell and texture) of the silages are as shown in Table 3. The pH is the simplest and quickest way of evaluating silage quality (Jianxin and Jun, 2002). These authors however pointed out that silage quality cannot be satisfactorily evaluated on any single one of these subjective indicators, but on methods of integrated evaluation as recommended by BAPH (1996). The observed pH values (3.61 – 4.04), with the exception of fresh *Moringa oleifera* silage (6.40) were even lower than the range of 4.5 to 5.5 considered by Meneses *et al*. (2007) as acceptable for good silage. Kung and Shaver (2002) in their interpretation of silage analysis stated that good quality grass and legume silage pH values in the tropics range between 4.3 and 4.7. Earlier, Weissbach (1996), had presented a critical pH limit for good silages depending on the dry matter content in which pH should be no higher than 0.025xDM (expressed as percentage) + 3.71. The above criteria imply that combinations with guinea grass and wheat offals, particularly M20P30W and M10P40W, enhance the preservation of moringa as silage. Even though the pH of fresh moringa leaves was not measured in this study, Asante *et al*. (2014) reported pH values ranging from 8.35 to 8.71 for fresh moringa leaves, which fall within the slightly alkaline range of the pH scale. Ensiling is a preservation method for moist forage crops. It is based on lactic acid bacteria (LAB) converting water soluble carbohydrates (WSC) into organic acids, mainly lactic acid, under aerobic conditions. As a result, pH decreases and the moist forage is preserved from spoilage microorganisms (McDonald *et al*., 1991; Adesoji *et al*., 2012). pH may be influenced by the moisture content and the buffering capacity of the original materials (Babayemi, 2009). Tropical forages are reportedly (Moran, 2005) difficult to ensile because of their high buffering capacity. This author recommended the addition of a fermentable substrate at ensiling in order to enable a more satisfactory fermentation. The presence of readily fermentable carbohydrates for the metabolism of lactic acid producing bacteria has also been reported (Tuah and Okyere, 1974) to prevent to some extent the activities of clostridia which spoil silages and cause pH to be high. High levels of wheat offal, known for high moisture absorbent capacity and a source of readily fermentable carbohydrate, in M20P30W and M10P40W could have been responsible for the significant ($P<0.05$) lowering of pH observed for M20P30W and M10P40W. Although wheat offal is essentially fibre, it is endowed with reasonable amount of metabolizable energy (Aduku, 1993). Scarr (1987) had reported an approximately 10.0 MJ metabolizable energy for wheat offals. Silage that has been properly fermented will have a much lower pH (be more acidic) than the original forage (Babayemi, 2009). Seglar (2003) reported that the decline in pH promotes increased population of efficient homofermentative lactic acid bacteria and these bacteria reduce silage pH faster and more efficiently by producing predominantly lactic acid.

The mean colour ratings indicate that the experimental silages had shades of light olive green (FMO and 50MW) and olive green (50MP, M10P40W, M20P30W, M30P20W and M40P10W) with the olive green being most ($P<0.05$) intense in 50MP, M10P40W, M20P30W and M30P20W. The smell of the silages were fairly pleasant (FMO, 50MW, 50MP and M40P10W) or pleasant (M30P20W, M20P30W and M10P40W). Statistical ($P<0.05$) differences were however observed to exist among the silage with fairly pleasant smell (50MW and M40P10W > FMO and 50MP). Mean smell ratings were observed to increase with increasing proportion of wheat offals. The best silage texture (firm) was observed for M10P40W while M20P30W, M30P20W, M40P10W and 50MW were fairly firm to varying degrees. The silages from sole fresh moringa (FMO) and its equal mixture with guinea grass (50MP) were observed to be soft. A significant ($P<0.05$) effect of wheat offal inclusion level on silage texture was observed. The mean overall ratings support the observed trends of improvement of silage quality by the addition of wheat offals. Silages without any wheat offal (FMO and 50MP) were observed to be the most disadvantaged. From available reports in the literature (t'Mannetje, 2000; Oduguwa *et al*., 2007; Babayemi, 2009; Adesoji *et al*., 2012), the shades of olive green colour observed for the silages can be regarded as being in order. The olive green colour reflects the original colour of the ensiled moringa and guinea grass forages; an attribute regarded (Oduguwa *et al*., 2007; Babayemi, 2009; Adesoji *et al*., 2012) as an indication of a good quality silage that has been well preserved. t'Mannetje (2000) also reported that good silage usually preserves well the original colour of the pasture or forage. Kung and Shaver (2002) reported that pleasant smell is accepted for good or well-made silage. The results from this study suggest that increasing inclusion levels of wheat offals could have improved the aroma of moringa-based silages. It was probable that the wheat offals offered more readily fermentable carbohydrates for the metabolism of lactic acid bacteria into organic acids, mainly lactic acid, with the attendant preservation of the silage materials from spoilage microorganisms (McDonald *et al*., 1991) and an improved smell. Ososanya and Olorunnisomo (2015) reported an improved aroma of silage from wet brewers' grains with 10 % inclusion level of maize cobs. No further improvements were however observed at higher inclusion levels. The observed trend with silage textures show that inclusion of wheat offals enhanced the texture of the different silage combinations. Wheat offal is made up of wheat germ, bran (greatest proportion of the wheat offal), coarse middling and fine middling (Alawa and Umunna, 1993). Generally, cereal offals have been credited with multiple purposes in livestock nutrition. They are high in phosphorus, trace minerals as well as a wide range of vitamins, and also act as an absorbent for moisture, and have been used to give structure to multinutrient blocks (Sansoucy *et al* 1988; Asaolu, 2012).

Table 4 shows that ensiling an equal mixture of *Moringa oleifera* and wheat offals (50MW) resulted in a significantly (P<0.05) higher dry matter content relative to the sole moringa silage (FMO) (36.20 vs. 31.89 %). The DM contents of all the other silage mixtures were observed to lie within these two values. While the DM content of the silage mixture of equal proportions of *Moringa oleifera* and *Panicum maximum* (50MP) was not significantly (P>0.05) different from that of FMO, increasing proportions of wheat offals in the silage combinations of moringa, panicum and wheat offals resulted in increasing DM contents with the increases becoming significant (P<0.05) at 30 and 40 % inclusion levels. This trend could be reflective of the DM contents of the silage materials. Dry matter was conspicuously much higher in wheat offals. However, the DM range of 31.89 to 36.20 % is within reported (Buxton *et al*., 2003) adequate range for silages. Expectedly, the crude protein content of 50MP was significantly (P<0.05) least (8.25 %) while it was significantly (P<0.05) highest (18.45 %) for FMO. Increasing proportions of wheat offals in the silage mixtures were observed to result in increasing crude protein contents. With the exception of 50MP silage, all the other silage combinations could serve as effective supplements to low protein ruminant diets as a minimum crude protein range of 10 – 12 % is recommended for ruminants by ARC (1980). Olorunnisomo (2014) reported a crude protein range of 11.02 to 18.50 % for moringa based silages while Mendieta-Araica *et al*. (2009; 2011) reported a range of 14.4 to 22.6 %. Differences in the CP contents of pure moringa silages were attributed by Mendieta-Araica *et al*. (2009; 2011) to variations in the proportions of leaves, soft twigs and branches in the silages. The NDF contents of the silages ranged between 10.65 % (M10P40W) and 12.28 % (50MP) while the ADF contents ranged between 8.54 % (M10P40W) and 11.14 % (FMO). The silage NDF and ADF values represent a great reduction from the corresponding respective values of the original silage materials, probably due to the action of cellulolytic microorganism during the ensilage process. The resultant silage ADF and NDF values could be regarded as low to moderate, when compared with low quality roughages which ruminants can readily degrade (Okoli *et al*., 2003), thus promoting dry matter intake and digestibility. It was observed that inclusion of wheat offals and *Panicum maximum* at 50 % levels (50MW and 50MP) significantly (P<0.05) increased the NDF components of moringa silage while the joint inclusion of the two test materials in moringa silages at various inclusion levels had no significant (P>0.05) effects on the NDF contents. While the inclusion of *Panicum maximum* at the 50 % level (50MP) resulted in a non-significant (P>0.05) decrease in ADF content, an equal inclusion level of wheat offal (50MW) was observed to lead to a significant (P<0.05) decrease in the ADF content of the resulting silage. This is reflective of the higher levels of fibre components in panicum and moringa relative to wheat offals (Table 2), and it is generally agreed that fibrous materials are not readily digestible by cellulolytic microorganisms. Graded levels of inclusion of both *Panicum maximum* and wheat offals resulted in further decreases in ADF contents; which were significant (P<0.05) relative to the value for 50MW. Non-significant (P>0.05) differences were observed in the ADF values of various graded inclusion levels of the three test materials.

5. Conclusions

The results of this study show that sole moringa silage (FMO), even with its high crude protein content, and the silage from its combination with fresh *Panicum maximum* in equal proportion (50MP) may not be promising dry season feed conservation strategies for ruminants. However, silage mixtures of 50 % *Moringa oleifera* + 10 – 30 % *Panicum maximum* and 20 – 40 % wheat offals showed great potentials. Using the “Silage Bible” (Rakuno Gakuen Shuppan, 2005), as a guide, it may be possible to feed M10P40W, M20P30W andM30P20W to milking cows in large quantities while some caution should be exercised in offering M40P10W and 50MW to the same set of animals.

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Table 2: Proximate and fibre components of *Moringa oleifera*, *Panicum maximum* and wheat offals

	Moringa oleifera	*Panicum maximum*	Wheat offals
Dry matter	33.00	27.50	90
% of dry matter			
Crude protein	25.80	9.40	17.40
Crude fibre	11.00	35.50	9.30
Ether extract	9.00	7.00	4.30
Ash	13.00	10.40	16.20
Nitrogen free extract	23.00	25.00	59.40
Neutral detergent fibre	21.40	55.00	51.00
Acid detergent fibre	23.50	36.00	30.00

Table 3: Mean ratings of pH and sensory characteristics of moringa/panicum/wheat offal silage combinations after 35 days of ensiling

Treatments	Parameters				
	pH	Colour	Smell	Texture	Overall (colour + smell+ texture)
FMO	6.40^{a}	3.66^{c}	3.32^{c}	2.38^{f}	3.12^{c}
50MW	3.73^{bc}	3.66^{c}	3.56^{b}	3.28^{d}	3.50^{b}
50MP	3.97^{bc}	4.44^{a}	3.18^{c}	2.50^{f}	3.37^{bc}
M40P10W	4.04^{b}	4.48^{a}	3.52^{b}	3.10^{e}	3.70^{b}
M30P20W	3.72^{bc}	4.44^{a}	4.52^{a}	3.44^{c}	4.13^{a}
M20P30W	3.61^{c}	4.46^{a}	4.54^{a}	3.58^{b}	4.19^{a}
M10P40W	3.62^{c}	4.32^{b}	4.58^{a}	4.32^{a}	4.40^{a}
SEM	0.04	0.02	0.02	0.02	0.01

Table 4: Nutrient composition of moringa/panicum/wheat offal silage combinations after 35 days of ensiling

Treatment	Parameters					
	DM (Wet basis)	CP (% of DM)	EE (% of DM)	Ash (% of DM)	NDF (% of DM)	ADF (% of DM)
FMO	31.89^{c}	18.45^{a}	2.21^{b}	2.08^{c}	11.22^{b}	11.14^{a}
50MW	36.20^{a}	14.35^{b}	3.62^{a}	9.11^{a}	12.14^{a}	9.95^{b}
50MP	32.05^{c}	8.25^{e}	1.26^{c}	2.14^{c}	12.28^{a}	11.06^{a}
M40P10W	32.13^{c}	10.48^{d}	1.58^{c}	2.49^{b}	11.18^{b}	9.16^{c}
M30P20W	32.27^{c}	12.27^{d}	1.60^{c}	2.45^{b}	11.00^{b}	9.16^{c}
M20P30W	33.54^{b}	13.13^{c}	1.63^{c}	2.48^{b}	10.89^{b}	8.90^{c}
M10P40W	35.95^{a}	13.40^{c}	1.67^{c}	2.36^{b}	10.65^{b}	8.54^{c}
SEM	0.42	0.20	0.12	0.06	0.19	0.22

^{a,b,c,d,e} Means along the same column without common superscripts are significant at $P<0.05$

FMO = Fresh *Moringa oleifera*, 50MW = 50 % Fresh *Moringa oleifera* + 50 % Wheat offals, 50MP = 50 % Fresh *Moringa oleifera* + 50 % Fresh *Panicum maximum*, M40P10W = 50 % Fresh *Moringa oleifera* + 40 % Fresh *Panicum maximum* + 10 % Wheat offals, M30P20W = 50 % Fresh *Moringa oleifera* + 30 % Fresh *Panicum maximum* + 20 % Wheat offals, M20P30W = 50 % Fresh *Moringa oleifera* + 20 % Fresh *Panicum maximum* + 30 % Wheat offals, M10P40W = 50 % Fresh *Moringa oleifera* + 10 % Fresh *Panicum maximum* + 40 % Wheat offals.