

Forage and tuber yield and nutritional composition of *Manihot esculenta* Crantz meal with organic fertilization

Rendimiento de forraje, tubérculo y composición nutricional de la harina de *Manihot esculenta* Crantz con fertilización orgánica

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ABSTRACT. The objective was to evaluate the production and nutritional composition of cassava (*Manihot esculenta* Crantz) meal under different organic fertilization rates. Twenty 10 × 10 m plots were planted with cassava and fertilized with 0.0, 0.5, 1.0 and 1.5 kg plant⁻¹ of sugarcane filter cake (part of the waste left after processing). The variables measured were fresh and dry forage yield (FFY and DFY), fresh and dry tuber yield (FTY and DTY), meal yield (MY) and their nutritional composition. The results indicate that the organic fertilization significantly increased the FFY, DFY, FTY, DTY and MY compared to the control. Applying 1.5 kg of organic fertilizer significantly improved crude protein content (CP, 3.37%). Organic fertilization with 1.5 kg plant⁻¹ of compost improved forage and tuber yield, and CP content.

Key words: Forage alternative, sugarcane filter cake, compost, nutritional value, local resources

RESUMEN. El objetivo fue evaluar la producción y composición nutricional de la harina de yuca (*Manihot esculenta* Crantz), bajo diferentes niveles de fertilización orgánica. Se establecieron 20 parcelas de 10 × 10 m sembradas con yuca a las que se les aplicó 0.0, 0.5, 1.0 y 1.5 kg planta⁻¹ de composta de residuos de cachaza de caña (*Saccharum officinarum* L.). Se midió el rendimiento de forraje fresco (RFF) y seco (RFS), rendimiento de tubérculo en fresco (RTF) y seco (RTS), harina (RH) y composición nutricional. La fertilización orgánica incrementó de forma significativa el RFF, RFS, RTF, RTS y RH, con relación al testigo. La aplicación de 1.5 kg planta⁻¹ de fertilizante orgánico mejoró de forma significativa el contenido de proteína cruda (3.37%). La fertilización orgánica con 1.5 kg planta⁻¹ de composta mejora el rendimiento de forraje, tubérculo y contenido de PC.

Palabras clave: Alternativa forrajera, cachaza, composta, valor nutricional, recursos locales

INTRODUCTION

In the state of Quintana Roo, livestock production is affected by the lack of local inputs for feeding ruminants (Ku *et al.* 2014). Animal feeding is the fundamental basis of any such production system, because it directly influences its productivity; in this regard, it has been reported that feed is

one of the most important factors in the meat production industry because it represents more than 80% of total production costs (Harun *et al.* 2017). The preparation of supplements for ruminants is based on the use of cereal grains such as corn and sorghum, which constitute 40 to 60% of the inputs used, which causes competition between human and animal food (Tesfaye *et al.* 2014). This

high demand for grains has increased the use of feed supplements in production systems and consequently limits the development of tropical livestock (Piñeiro-Vázquez *et al.* 2013); therefore, it is necessary to obtain and manage new inputs for ruminant feeding, which can be easily produced by producers to reduce production costs (Casanova-Lugo *et al.* 2014, Harun *et al.* 2017).

The cassava (*Manihot esculenta* Crantz) is a tropical plant that has received little attention as a substitute for cereals in ruminant feed (Harun *et al.* 2017). The largest area planted in Mexico is in the states of Tabasco and Michoacán, with a national production average of 14 t ha⁻¹ in rain-fed agriculture and 32 t ha⁻¹ under irrigation (Rivera *et al.* 2012). In this regard, worldwide 196 million t of cassava root are generated every year, of which 28% are used for animal consumption (Hidalgo and Rodríguez 2015), mainly because the cassava meal efficiently replaces the energy contributed by corn in feed production of animal origin, because the tuber is rich in carbohydrates (Tesfaye *et al.* 2014, Hidalgo and Rodríguez 2015, Lezcano *et al.* 2015). Although there is great potential for its use, its cultivation and use in ruminant feeding in southeastern Mexico is non-existent, due to the scarce information on yield and nutritional composition of the meals (Byju *et al.* 2012, Faezah *et al.* 2013). Therefore, the aim of this work was to evaluate the effect of different levels of organic fertilization with sugarcane filter cake on forage and tuber yield, production and nutritional composition of cassava meal.

MATERIALS AND METHODS

Study site

The study was carried out in the cultivation area of the Instituto Tecnológico de la Zona Maya in Quintana Roo, Mexico, located at the geographic coordinates of 21° 51' NL and 89° 41' WL, with an Aw1-type subhumid warm climate. The mean annual temperature ranges between 24.5 and 25.8 °C; the area is located three meters above sea level, with a flat topography. The predominant soil of the

region is Gleysol and the physico-chemical characteristics of the topsoil are shown in Table 1.

Table 1. Physicochemical characteristics of a Gleysol soil in southern Quintana Roo, Mexico.

Parameters	
Ph 7.67	Electrical conductivity (ds/m) 0.23
	Silt (%) 45.92
	Clay (%) 45.90
	Sand (%) 7.86
	Organic matter (%) 3.68
	Total nitrogen (%) 0.18
	Phosphorous (ppm) 43.25
	Potassium (ppm) 1875
	Calcium (ppm) 6100
	Magnesium (ppm) 1611

Experimental plots and design

The area was prepared with a subsoiler pass, followed by a heavy harrowing pass and two cross-wise light harrowing passes. The furrows were made with a cultivator at a distance of 1 m between lines and later the plots were delimited to assign the treatments and repetitions. The sowing of *M. esculenta* took place at the beginning of June 2014, using vegetative material obtained in the Maya Balam Quintana Roo ejido, from a production plot of 150 d of establishment. The stems were cut into 40-cm fragments and left to dry for 24 h; they were later planted vertically at a distance of 1 m between rows and between plants, in 10 x 10 m plots, with a density of 100 plants per plot.

Twenty plots were delimited, to which four treatments were applied with 5 repetitions, under a completely randomized design. At 15 and 45 d after sowing, organic fertilization was provided based on sugarcane filter cake compost (Table 2), which was

Table 2. Chemical composition of sugarcane filter cake from southern Quintana Roo, México.

Parameters	
Ph	7.08
Organic matter (%)	36.90
Organic carbon (%)	17.20
Total nitrogen (%)	2.64
Phosphorous (%)	2.56
Potassium (%)	0.59
Calcium (%)	5.88
Magnesium (%)	0.60

applied manually to the soil surface at 10 cm from the plant stem, under the treatments of 0.0, 0.5, 1.0 and 1.5 kg plant⁻¹.

Variables evaluated

Fresh forage and tuber yields (FFY and FTY) were determined at 180 d after sowing. The samples were bagged and weighed on a 120.0 kg platform scale. From the FFY and FTY, a random sample of 5.0 kg of each treatment and repetition was taken to determine the dry forage and tuber yields (DFY and DTY), for which the sample was dried in a forced-air circulation oven at 60 °C to constant weight. With the FTY per plot, the yield in tons per hectare was estimated.

To prepare the meal, a random sample of 10 kg of fresh tuber was extracted per treatment and repetition, and then washed and cut into 2 cm thick slices and dried in a forced-air oven at 60 °C for 72 h. The material obtained was pulverized in a hammermill with a 3 mm screen. The dry matter (DM), organic matter (OM), ash (Ce) and crude protein (CP) contents of the meal were determined using AOAC (2012) methods. For neutral detergent fiber (NDF), cellular content (CC) and silica (Si), the method described by Van Soest *et al.* (1991) was used.

Statistical analysis

The evaluated variables were subjected to a one-way analysis of variance. When differences were found, Duncan's multiple range test was performed ($p < 0.05$). The analyses were performed with SAS version 9.4 software for Windows (SAS 2013).

RESULTS AND DISCUSSION

The results show that the FFY was greater with the application of 0.5 and 1.0 kg plant⁻¹ of filter cake, with yields of 19.84 and 15.82 t ha⁻¹ respectively. The same happened with the DFY ($p < 0.05$), showing yields of 4.00 and 3.32 t ha⁻¹ with applications of 0.5 and 1.0 kg plant⁻¹. Regarding tuber production, statistical differences ($p < 0.05$) were found with the fertilization of 0.5 and

1.5 kg plant⁻¹ of filter cake, with the FTY values being 11.99 and 13.02 t ha⁻¹ and the DTY ones 4.09 and 4.20 t ha⁻¹. In the same way, the MY showed significant differences ($p < 0.05$) between the fertilized plots and the control plots, since the 0.5 to 1.5 kg plant⁻¹ filter cake applications showed the best yields (Table 3). Several studies show increases in the production and quality of cassava forage with organic fertilization, indicating that organic fertilizers represent a source of nutrients that are quickly assimilated by crops, which improves both the quality and structure of the soil and plant growth (Byju *et al.* 2012, Cucava *et al.* 2015). In addition, it has been pointed out that crops grown in soils rich in organic matter are biologically more active and resistant to adverse factors, which increases their production (Gordillo *et al.* 2011).

The production of cassava forage in fresh (6.8 to 19.84 t ha⁻¹) and dry (1.5 to 4.0 t ha⁻¹) obtained is similar to that reported by Preston *et al.* (1999), who reported yields of 19.5 t ha⁻¹ in fresh and 3.84 t ha⁻¹ in dry, with organic fertilization of cattle excreta, while the fresh tuber production (4.46 to 13.06 t ha⁻¹) is lower than the 7.33-44.16 t ha⁻¹ range reported by Fuenmayor *et al.* (2012) for different cultivars, and the 48.3 t ha⁻¹ reported by Rivera *et al.* (2012). The dry tuber production ranged between 1.42 and 4.21 t ha⁻¹, which is lower than the values of 7.62 to 10.37 t ha⁻¹ reported under irrigation (Félix *et al.* 2014), differences that can be attributed to the age of the cut. However, the volume of production found is within the range of dry matter production reported by Fuenmayor *et al.* 2012 of 2.19 t ha⁻¹ and 13.39 t ha⁻¹.

The tuber yield in meal ranged between 1.34 and 4.11 t ha⁻¹, which gives an estimated conversion value of 4.75 t of fresh tuber per ton of cassava meal. The above data are within the ranges reported by Cucava *et al.* (2015), who observed differences in starch content due to the effect of fertilization. However, they are greater than the meal yields reported by Buitrago and Lucket (1998), under rain-fed conditions. The differences in the conversion values can be attributed to the harvest time of the crops, as it is known that the shorter the harvest

Table 3. Forage, tuber and meal yield and nutritional composition of cassava (*Manihot esculenta* Crantz) meal under different levels of organic fertilization in southern Quintana Roo.

Yield (t ha ⁻¹)	Organic fertilization (kg plant ⁻¹)				SEM	Significance
	0.0	0.5	1.0	1.5		
Fresh forage	6.80 ^b	19.84 ^a	15.72 ^a	14.60 ^a	2.35	*
Dry forage	1.50 ^b	4.00 ^a	3.32 ^a	3.07 ^a	0.46	*
Fresh tuber	4.45 ^b	11.99 ^a	9.73 ^a	13.02 ^a	2.04	*
Dry tuber	1.41 ^b	4.09 ^a	3.21 ^a	4.20 ^a	0.70	*
Meal	1.35 ^b	3.49 ^a	3.21 ^a	4.10 ^a	0.75	*
	Content (%)					
Dry matter	94.02 ^a	94.81 ^a	94.48 ^a	94.58 ^a	0.66	n.s.
Organic matter	90.61 ^a	91.15 ^a	91.14 ^a	91.13 ^a	0.61	n.s.
Ash	3.41 ^a	3.46 ^a	3.35 ^a	3.44 ^a	0.09	n.s.
Crude protein	2.32 ^b	2.14 ^b	1.81 ^b	3.37 ^a	0.29	*
Neutral detergent fiber	12.84 ^a	15.55 ^a	18.43 ^a	16.99 ^a	1.66	n.s.
Cellular content	81.18 ^a	79.26 ^a	76.05 ^a	77.58 ^a	1.38	n.s.
Silica	1.02 ^a	0.32 ^a	0.47 ^a	1.03 ^a	0.21	n.s.

SEM: Standard error of the difference between means; *, indicates significant differences between treatments ($p \leq 0.05$); n.s., there are no significant differences between treatments ($p > 0.05$). Means with different letters between rows indicate significant differences according to Duncan ($p \leq 0.05$).

time the smaller the amount of tuber matter, so more tuber is required to obtain a ton of meal.

When the nutritional composition of the obtained cassava meal was analyzed, no differences were found ($p > 0.05$) for the content of DM, OM, Ce, NDF, CC and Si due to the effect of organic fertilization. However, differences were found ($p < 0.05$) in the crude protein (CP) content, with the 1.5 kg plant⁻¹ fertilization having the highest content (Table 3). The differences found in the CP content in cassava meal due to the effect of organic fertilization may be due to the excess of nitrogen required in the crop, which decreases the starch content and increases the protein substances of the roots, which influences the production of cassava meals (Faazah *et al.* 2013, Tesfaye *et al.* 2014). It has also been reported that sugarcane filter cake has, on average, 2.29% nitrogen, which can influence the yield and quality of the tuber (Byju *et al.* 2012). Although the CP values found are similar to those reported by Ndung'u *et al.* (2012), they are higher than the values reported by Sahoré and Nemlin (2010). The higher CP content found may be due to the lower age of the cut and the use of the tuber and shell, where higher protein content is found.

Regarding the DM content (93.64 to 94.82%), values greater than 90% dry matter were found in cassava meal reported by Cucava *et al.* (2015). The OM found in cassava flour was 90.61 to 91.15%, values that are higher than those reported by Sahoré and Nemlin (2010) in sweet and bitter African cassava varieties. For the mineral matter content, determined by the ash content, values were between 3.35 and 3.44%, which are higher than the values of 2.49 and 2.53% for sweet and bitter varieties (Sahoré and Nemlin 2010), although they can also be due to the harvest time and the processing applied in the preparation of cassava meal. The NDF ranged between 14.43 and 21.02%, values that are lower than those reported for cassava (Sahoré and Nemlin 2010). These differences may be due to the harvest age of the plant, because with the culture age the fiber content increases.

Applying organic fertilization improves fresh and dry forage and tuber yields. The production of dry tuber meal is affected by the amount of fertilization applied. The nutritional composition of cassava tuber meal is not affected by fertilization. The crude protein content is increased with the application of 1.5 kg plant⁻¹ of sugarcane filter cake.

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