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Nutritional evaluation of integral cassava root silages for growing pigs



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ABSTRACT

The experiment aimed at determining the nutritional value of integral cassava root silages with yogurt as inoculant or wastewater (*manipueira*) by liquid addition ensiling process. Eighteen crossbred piglets (Large White × Landrace), castrated males with an initial average weight of 50 kg were allocated in metabolism cages throughout 11-day trial duration (6 days for animal's adaptation to the cages and to the experimental diets, and 5 days of urine and faeces collection). The experimental design was a randomized block arrangement with 3 treatments and 6 replicates: basal diet (100%); mixture composed of 75% basal diet and 25% integral cassava root silage with yogurt as inoculant; a mixture composed of 75% of basal diet and 25% integral cassava root silage with wastewater. The silages with wastewater and yogurt presented the following values of apparent digestibility of dry matter 89.96% and 90.01%, apparent digestibility of crude protein of 60.67% and 66.43%, apparent digestibility of gross energy of 90.43% and 91.48%, gross energy metabolizability coefficients of 87.88% and 88.93%, digestible energy values of 3,705 and 3,783 kcal/kg on a dry matter (DM) basis, and metabolizable energy values of 3,600 and 3,676 kcal/kg DM, respectively. The results have demonstrated that integral cassava root silages with wastewater or yogurt have a high nutritional value and can be used as an alternative energy source in growing pig's diets.

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1. Introduction

In Brazil, maize is the main cereal used in swine diets, due to its large nutritional and energy potential. Worldwide, it is used in food, and especially in countries as the United States for ethanol production, which contributes to enhancement of its price on international market. Thus, the search for alternative feeds that can be used in pig's diets becomes interesting to partially or totally

replace the corn in those diets, since it provides good production rates and competitive prices, enabling its use (Navarro and Bicudo, 2011).

Among ingredients that can be used to replace corn in swine diets, several ingredients have been researched, including cassava (*Manihot esculenta* Crantz), an annual tuber crop grown widely in tropical and sub-tropical area, which its tuberous root is the most important portion of the plant and can be used as raw material in various industrial derivatives (Bastos et al., 2006; Bertol and Lima, 1999; Costa et al., 2005; Fialho et al., 2002; Fireman et al., 2000; Otsubo and Lorenzi, 2002). Cassava is used in food, especially in the form of flour and starch, and for animal feed, it is used as energy source, because it is very rich in starch (Gomez, 1992; Liu et al., 2006; Zardo and Lima, 1999).

According to Silva et al. (2008), some studies have indicated that all livestock could receive cassava roots in their diets because of its energy potential and palatability. However, the limitation point concerns that it easily deteriorates few days after the harvesting,

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complicating its *in natura* conservation (Figueiredo et al., 2000). Thus, this research has been carried out to study storage alternatives to preserve for long-term the nutritional value of cassava root. The ensiling process is characterized by lactic fermentation taking place in anaerobic environment, caused by the removal of air or by liquid addition (which is the case of present study), aiming at development of bacteria which produces lactic acid from substrates such as soluble sugars, organic acids and soluble nitrogen compounds, ensuring feed long-term preservation (Santos et al., 2010).

Cassava roots have favorable characteristics for silage because they have 62%–68% of moisture and easily fermentable carbohydrates (Chung et al., 2010; Lebot, 2009; Yin et al., 2004). As silage, cassava roots have high amount of dry matter, crude protein, crude fiber, ash and less fat compared with fresh roots (Gil and Buitrago, 2002). However, according to each ensiling process, the dry matter content of the final product can be altered, and according to Limon (1992), one of advantages of cassava silage is that their preservation is guaranteed for several months, what releases areas for new crops.

Cereda (2000) reported that wastewater (*manipueira*) is a by-product of flour and tapioca industrial production, resulting from the pressing of cassava grated mass. The processing of one ton of cassava root for starch production approximately generates 1.1 m³ of wastewater. This is an agricultural residue that usually does not present an environmentally correct destination, although alternatives to its use are being studied over the years. Ferreira et al. (2001) reported that use of wastewater as a fertilizer can lead to reducing or even eliminating their uncontrolled dumping into environment, and Pinho (2007) found that its use had fertilizing effect, increasing Mg, K and P concentrations in soil.

Considering the high potential for national production and high nutritional value of cassava, as well as their usage limitations in animal feed, particularly related to the difficulty of conservation, it is important to carry out processing forms to make them usable in swine diets. Therefore, the aim of this study was to determine the coefficients of apparent digestibility of dry matter, crude protein and gross energy, the gross energy metabolizability coefficients as well as the values of digestible protein, digestible energy and metabolizable energy of integral cassava root silages with yogurt as inoculant or wastewater (*manipueira*).

2. Material and methods

The experiment was carried out in the Swine Production Area at Faculty of Animal Sciences and Veterinary Medicine – UNESP, Botucatu Campus, Brazil with the approval by the Animal Ethics Committee from this institution (protocol number 16/2016 – CEUA) and in accordance with the directive 2010/63/EU.

Eighteen crossbred (Landrace × Large White) castrated male pigs with average initial weight of 50 kg were individually housed in metabolism cages similar to those described by Pekas (1968) throughout 11-day trial duration (6 days for adaptation of animals to the cages and to experimental diets, and 5 days for collection of faeces and urine). The period was commonly applied in metabolism studies (Baker et al., 1967; Fialho et al., 2002; Oso et al., 2010). The experimental design was a randomized complete block arrangement to control initial weight differences, with 3 treatments, 6 replicates and one animal per experimental unit.

The experimental diets were as follows: the reference diet (RD) showed in Table 1; a mixture composed of 75% of reference diet and 25% of cassava root silage containing yogurt as inoculant (YS); a mixture composed of 75% of reference diet and 25% cassava root silage containing wastewater (WS). The silage with inoculant replaced the reference diet on a dry matter basis.

Table 1

Percentual and nutritional composition (on a dry matter basis) of reference diet for growing pigs.

Item	Content
Ingredients, %	
Corn, grains	69.654
Soybean meal (45%)	27.000
Dicalcium phosphate (18%)	1.150
Ground limestone	0.610
Soybean oil	0.600
NaCl	0.400
L-Lys HCl (78%)	0.220
DL-Met (99%)	0.056
L-Thr (98.5%)	0.040
Vitamin premix ¹	0.150
Mineral premix ²	0.120
Total	100
Nutritional values ³ , %	
Metabolizable energy, kcal/kg	3,270
Crude protein	18.38
Digestible Lys	0.99
Digestible Met	0.31
Digestible Thr	0.65
Digestible Trp	0.19
Total Ca	0.60
Digestible P	0.31

¹ Vitamin premix supplied per kg of diet: 9,000 IU VA; 2,250 IU VD₃; 22.5 mg VE; 22.5 mg VK₃; 2.3 mg VB₁; 6 mg VB₂; 3 mg VB₆; 0.03 mg VB₁₂; 0.9 mg folic acid; 14.3 mg pantothenic acid; 30 mg niacin; 0.12 mg biotin; 400 mg choline.

² Mineral premix supplied per kg of diet: 100 mg Fe; 10 mg Cu; 40 mg Mn; 100 mg Zn; 1.0 mg Co; 1.5 mg I.

³ Nutritional values are according to Rostagno et al. (2011). These values are calculated.

For ensiling, the integral cassava roots of Campinas Agronomic Institute-13 (IAC-13) variety were utilized, and after harvest the roots were washed to remove soil particles and crop residues, fully chopped with peel and pulp by an electric mill into particles around 3 cm, then transferred to plastic containers of 200 L until two-thirds of its total capacity was filled. In some of the containers, after adding chopped cassava, yogurt was also added at an equivalent volume of 2% of its total volume, and then filled up with water. In the remaining containers with chopped cassava, the volume were completed with wastewater collected from a cassava flour industry in Santa Maria da Serra city, São Paulo State, Brazil. After completing the volume of containers with cassava and liquids (yogurt or wastewater), they were maintained closed and remained that way for a minimum of two weeks before the beginning of this experiment to ensure the entire fermentation process.

Piglets were fed twice a day at 08:00 and 17:00. The amount provided to animals was determined according to their feed intake during adaptation phase (6 days), based on the smallest feed intake within each block and the animal metabolic weight (BW^{0.75}). The diets were moistened before each meal to reduce dustiness, waste and to facilitate the intake. The cages that had been sorted to receive silage as part of diet, so that its liquid fraction was removed and only the solid portion was provided. After each meal, water *ad libitum* was provided to animals.

The total faeces collection method was adopted to define the beginning and the end of the excreta collection period, and 1% of ferric oxide (Fe₂O₃) was added to feed as faecal maker, and faeces samples were collected twice a day at 08:00 and 16:00, packed in plastic bags, weighed, identified and freeze-dried for further analyses.

The volume of excreted urine was collected in plastic buckets placed under the collector funnel of metabolism cage. The buckets contained 20 mL of HCl 6 mol/L to avoid ammonia losses and also bacterial proliferation. Into the collector funnel, a glass wool was

inserted for impurity retention. The urine collection was done at 07:30 and then, a sub-sample of 20% of the total volume was collected and stored in plastic bottles, identified and frozen for chemical analyses.

After homogenization of total excreted faeces from each animal, a representative sample was taken and dried in a forced-circulation air oven (Marconi, model MA035-5, Piracicaba, Brazil) at 55 °C for 72 h. After drying, the samples were weighed to obtain the values of dry matter content and then milled in a knives-type mill through 1 mm sieve.

The urine was analyzed for its gross energy content after drying in a forced-circulation air oven at 55 °C for 72 h. The gross energy quantification was performed in an adiabatic bomb calorimeter (Ika-Werke, model C2000, Staufen, Germany). The analyses of dry matter and total nitrogen contents were followed the methodologies described by [Silva and Queiroz \(2006\)](#). The analyses of hydrocyanic acid and pH in the silages were performed following methodologies described by [Horwitz \(1975\)](#) and [Phillip and Fellner \(1992\)](#), respectively.

The apparent digestibility coefficients of dry matter, crude protein and gross energy, and the gross energy metabolizability coefficients were determined according [Matterson et al. \(1965\)](#) methodology. The estimated values of digestible protein, digestible energy and metabolizable energy of silages were also evaluated.

2.1. Statistical analysis

The data were subjected to analysis of variance (ANOVA) using the PROC GLM (General Linear Model) of [SAS \(2008\)](#), and the means were compared using F test ($P < 0.05$).

3. Results

The results of chemical composition of silages are presented in [Table 2](#). The integral cassava root silage containing wastewater slightly showed lower dry matter content and gross energy consequently, and higher levels of crude protein, hydrocyanic acid as well as higher pH value compared with the integral cassava root silage with yogurt.

[Table 3](#) shows the coefficients of apparent digestibility of dry matter, crude protein, gross energy, the gross energy metabolizability coefficients, the values of digestible protein, digestible energy and values of metabolizable energy of integral cassava root silages with yogurt and wastewater. No statistically significant ($P > 0.05$) effects between integral cassava root silages with wastewater and integral cassava root silages with yogurt were observed, and both values of WS and YS showed high digestibility coefficients and high digestible nutrient contents, demonstrating that they are raw materials with high potential for use as alternative energy source in growing pig diets.

Table 2

Chemical composition of integral cassava root silages with wastewater (WS) and yogurt (YS).

Item	WS	YS
Dry matter, %	30.9	32.3
Crude protein ¹ , %	4.86	4.26
Gross energy ¹ , kcal/kg	3,795	3,832
pH ²	4.9	4.4
Hydrocyanic acid ² , mg/kg	37.61	6.82

¹ Values expressed on a dry matter basis.

² Values expressed as-fed basis.

Table 3

Digestibility coefficients of nutrients, digestible and metabolizable values of integral cassava root silages with wastewater (WS) or yogurt (YS).

Item	WS ¹	YS ¹	CV	P-values ²
DCDM, %	89.96	90.01	0.48	0.8501
DCCP, %	60.67	66.43	13.89	0.3092
DCGE, %	90.43	91.48	2.50	0.4604
GEMC, %	87.88	88.93	2.57	0.4597
DP, %	3.18	3.06	13.99	0.6409
DE, kcal/kg	3,705	3,783	2.72	0.2453
ME, kcal/kg	3,600	3,676	2.92	0.2693

CV = coefficient of variation; DCDM = digestibility coefficients of dry matter; DCCP = digestibility coefficients of crude protein; DCGE = digestibility coefficients of gross energy; GEMC = gross energy metabolizability coefficients; DP = digestible protein values; DE = digestible energy values; ME = metabolizable energy values.

¹ Values expressed on a dry matter basis.

² F test ($P < 0.05$).

4. Discussion

Concerning dry matter results, the content of silages were lower, whereas in relation to crude protein, values were higher than those observed by [Silva et al. \(2008\)](#) for 2 cassava root silages (dry matter of 45.75% and 46.15%, and crude protein of 3.87% and 3.73%, respectively), which probably is related to differences in the silage's production, because the anaerobiosis was achieved in the silo by YS or WS addition in the ensiled mass from this experiment.

The gross energy values of silages were similar to that presented by [EMBRAPA \(1991\)](#) which considered, based on dry matter, the cassava root silage gross energy content as 3,872 kcal/kg. However, results were lower than gross energy values registered by [Silva et al. \(2008\)](#) for cassava root silage with bacterial-enzymatic inoculant and without it (4,058 and 4,033 kcal/kg of DM, respectively) and by [Rostagno et al. \(2011\)](#), when compared with cassava scrapings (4,130 kcal/kg of DM).

The silages pH values were higher compared with those observed by [Silva et al. \(2008\)](#) for all 4 integral cassava root silages analyzed (pH between 3.84 and 3.98), which may be related to differences among ensiling processes.

The hydrocyanic acid values registered in silages indicated that their supply for pigs were safe. According to [Navarro and Bicudo \(2011\)](#), the recommendation is that cassava as feedstuff does not contain more than 100 mg/kg of hydrocyanic acid. [Silva et al. \(2010\)](#) reported maximum concentration of hydrocyanic acid was 12 mg/kg in cassava root silages, which result was similar to the result verified in integral cassava root silage with yogurt.

The highest concentration of hydrocyanic acid verified in cassava root silage with wastewater is related to the fact that wastewater is a by-product of flour and tapioca industrial production as the result of pressing of grated cassava mass. Therefore, it can present higher levels of hydrocyanic acid in its composition ([Cereda, 2000](#)). [Silva et al. \(2008\)](#) conducted an experiment with cassava root silages with or without whole soybeans for piglets, and observed that, after ensiling, hydrocyanic acid content decreased and the presence of silage in diet did not affect performance of animals.

According to [Rostagno et al. \(2011\)](#), integral cassava scrapings on a dry matter basis presents digestible crude protein, digestible energy and metabolizable energy values of 0.99%, 3,477 and 3,445 kcal/kg, respectively. These values were lower than those obtained in this study, suggesting that the ensiling process favored nutrients digestibility. According to [Jongbloed et al. \(2000\)](#), the acidification improves digestibility of dry matter and organic matter, and increases availability of minerals.

[Silva et al. \(2008\)](#) concluded that ensiling process favored the use of protein and energy fractions of cassava. According to authors,

it was attributed to acidification, which in turn had improved animal's intestinal health. Also, acidification of silage reduced gastric emptying rate and favored digestive enzymes action, such as salivary amylase (Holmes et al., 1974), pepsin and pancreatic lipase (Solomon, 1994) that had long-acting. Furthermore, the action of digestive enzymes might be more efficient in wet feed particles (Holmes et al., 1973).

Moreover, researches stated that during ensiling process of high-moisture corn (Lopes et al., 2002) and sorghum grains (Lopes, 2004), structural changes occurred in protein matrix that surrounds starch granules and granules themselves, which probably facilitated the enzymes action involved in digestion processes, especially in pig small intestine.

Silva et al. (2008) carried out an experiment to evaluate the nutritional value of cassava root silage for piglets in initial phase and reported the following results for apparent digestibility coefficients of dry matter and crude protein, digestibility coefficient of gross energy and gross energy metabolizability coefficient of 92.57%, 55.77%, 91.52% and 89.70%, respectively. These values corroborates the values obtained in this study.

According to Gil and Buitrago (2002), the pig's feed at nursery phase may contain up to 40% of cassava flour, and the amount can be higher in growing and finishing phases. Carvalho et al. (1999) found that growing pigs which received integral cassava root scrapings showed weight gain, feed intake and feed:gain ratio similar to pigs that received diet containing corn, concluding that integral cassava root scrapings levels up to 64% in diet presented technical feasibility.

Besides the aforementioned, the high amount of starch in cassava root makes it an alternative energy source for pig feeding (Pascual-Reas, 1997; Yin et al., 2010; Tzudir et al., 2012). Another advantage to its usage is related to its cost (Silva et al., 2008), once at certain periods of year, it has cost lower than corn, the main energy source used in pig diets.

5. Conclusion

The results of apparent digestibility coefficients, digestible nutrient contents and energy values showed high nutritional value of integral cassava root silages with yogurt as inoculant or wastewater, and also proved to be a potential corn substitute for growing pigs in the tropics.

Conflict of interest statement

We certify that there is no conflict of interests with any financial, professional or personal that might have influenced the performance or presentation of the work described in this manuscript.

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