Chemical composition and *in vitro* digestibility of silages of taro (*Colocasia esculenta* (L.) Schott) tubers for feeding pigs

W. Caicedo[1], R. Rodríguez[2], P. Lezcano[3], J. Ly[3], S. Valle[1], L. Flores[4] and F.N.A. Ferreira[5]

[1]*Secretaria Nacional de Educación Superior Ciencia Tecnología e Innovación, Quito, Ecuador*
[2]*Universidad de Granma, Centro de Estudios de Producción Animal, Bayamo, Cuba*
[3]*Instituto de Ciencia Animal, Apartado Postal 24, San José de las Lajas, Mayabeque, Cuba*
[4]*Escuela Superior Politécnica de Chimborazo, Riobamba, Ecuador*
[5]*Universidad Federal Minas Gerais, Belo Horizonte, Brasil*
Email: orlando.caicedo@yahoo.es

To assess chemical composition and *in vitro* digestibility of silages of taro tubers (*Colocasia esculenta* (L.) Schott), for feeding pigs, four silages with waste tubers were carried out. A completely randomized design with a 4x6 factorial arrangement to analyze the chemical composition was applied. Natural yogurt (-1NY), whey (-2W), whey with 5%of molasses (-3WM5) and whey with 10% of molasses (-4WM10) were evaluated as silage components. The silages time were 0, 15, 30, 60, 90 and 180 days. The *in vitro* digestibility of DM and OM with 15d of silages elaboration was investigated by means of simple classification design. The interactions treatments per day were significant ($P < 0.05$).The silage four in the 180th day show higher DM content (33.61%).The highest CP(N x 6.25) concentration(8.83%) was evidenced in silage two, in the 90th day. The lowest CF was determined in silage two in the 0 (2.85) and 60th (2.84) days. The GE was high in silage one in the 0 day (4.40 kcal g DM^{-1}).The highest *in vitro* digestibility coefficient of DM (74.65 %) and OM (76.76 %) was found in silage two. The conservation of taro tubers, between 0 and 180 d, by means of the addition of variables levels of natural yogurt, whey and sugar cane molasses, create different products with good DM, CP, GE content and low CF concentration, capable to be used in feeding pigs.

Key words: *by-products, fermentation, digestibility, preservation*

The efficient production of agricultural resources in tropical and subtropical areas, and the necessity to find, in a sustainable way, alternative sources for animal feeding are conditions that facilitate the use of silages in animal feeding (Guzmán 2010).By means of a simple and appropriate procedure, silages allows to preserve citrus residues (Llano *et al.* 2008), pineapple (Herrera *et al.* 2009) and mango (Rego *et al.* 2010),between other wastes, useful for animals intake.

In Ecuador, according to Caicedo *et al.* (2013a) there are a wide variety of feasible resources to feeding pigs, between them it is the taro (*Colocasia esculenta* (L.) Schott) .Tubers are recognized as a cheap carbohydrates source of low cost, regarding to cereals and other crops. They also present, high starch digestibility, that can reach up to 98% (Ezedinma 1987).

The use of *in vivo* conventional methods to measure of foods digestibility and ingredients that are used in diets formulation is too expensive and requires long periods to obtain evaluative results. Consequently, have been developed *in vitro* methods that have the advantage of being simple, fast and allows evaluating a great number of samples at the same time and at low cost (Boisen and Fernández 1995 and Ramos 1995).

The objective of this study was to evaluate the chemical composition and *in vitro* digestibility of silages of taro (*Colocasia esculenta* (L.) Schott) tubers for feeding pigs

Materials and Methods

This study was carried out in the facilities of the taro producer corporation of Pastaza, belonging to "Teniente Hugo Ortiz" parish, in Pastaza province, Ecuador. The weather in this area is semi-warm or humid sub-tropical, with precipitations between 4.000 and 4500 mm annually. It is located to an altitude of 950 m o.s.l, with average relative humidity of 87% and average minimum and maximum temperature of 18 to 26 ºC. Soils are classified as inceptisols, oxisols and entisols (INAMI 2013).

To formulate the silos, Caicedo *et al.* (2013b) recommendations were fallowed (table1).The micro - silos were prepared with tubers waste that, for its physical appearance, they do not fulfill the requirements established by national and international markets to use them in human feeding. Tubers were washed and milled in fresh way, in mix mill with blades and a sieve of 2.5cm, with the purpose of obtaining uniform particles.

For silages formulation, raw matters were weighed in a CAMRY digital balance, and were placed in four clean plastic tanks, with 400kg each. Ingredients were added in the fallowing order: silage1) cut tubers, natural yogurt and drinkable water for human consumption (1_NY) 2) cut tubers and whey (2_W); 3) cut tubers, molasses B (83º Brix) 5% and whey (3_MB5) and cut tubers, molasses B (83º Brix) 10 % and whey (4_MB10).

The ingredients were mixed in a homogeneous way, manually, with a wooden spatula, during15 min, at room temperature of 24 ºC. Then, the silages mixtures were introduced in polyethylene bags, at a rate of 5kg. The bags were compacted and closed hermetically with

Table 1. Formulation of taro tubers silages

Raw matter inclusion, %	Treatments			
	1_NY	2_W	3_WMB5	4_WMB10
Cut taro tubers	68	68	68	68
Drinkable water for human consumption	27	-	-	-
Molasses B (83°Brix)	-	-	5	10
Natural yogurt	5	-	-	-
Whey	-	32	27	22
Total	100	100	100	100

1_NY: Silage with natural yogurt
2_W: Silage with whey
3_WMB5: Silage with whey and 5% of molasses B (83°Brix)
4_WMB10: Silage with whey and 10% of molasses (83°Brix)

a vacuum pump to guarantee their preservation. The micro-silos were stored under roof and protected of the sun light. They were opened at 0, 15, 30, 60, 90 and 180 d after silage.

The material was analyzed for DM, CF, ash, CP (N x 6.25) content, EE and NFE, according to AOAC (2005) .The levels of NDF, ADF and lignin were measured according to van Soest *et al.* (1991).It was considered that the OM concentration was equal to the difference 100- ash percent. However, the hemicellulose was the result of the subtraction NDF-ADF, as well as the cellulose (ADF-lignin). Both expressed in percent (van Soest and Robertson 1975). The GE was determined in a Parr adiabatic calorimetric pump, model 1241. The *in vitro* digestibility of the DM (IVDMD) and OM (IVOMD) was carried out by pepsin-pancreatin-viscozime, according to Boisen and Fernández (1991).

A completely randomized design with a 4x6 factorial arrangement for chemical characterization was applied, corresponding to four silage types (table1) and six conservations time (0, 15, 30, 60, 90 and180 d). *In vitro* digestibility was asses by means of a completely randomized design and analysis of simple variance was applied, with silage of 15 elaboration days. Three replications per each treatment were carried out. All determinations were made in triplicate. The means were contrasted by the analysis of variance technique, according to the recommendations of Steel *et al.* (1997). Where significant differences ($P < 0.05$) were found, they were compared with Duncan (1995) test. The analyses were carried out with the application of the Infostat statistical program (Di Rienzo *et al.* 2012).

Results

During the conservation process, the average temperature was of 22 ºC. When opening the micro-silos, the presence of alcohol or any symptom of ensilaged materials decomposition was never found. All of them had a sweet smell.

The result of the interactions studied for chemical indexes is shown in table 2 and 3.The interactions treatments per day were significant ($P < 0.05$) for all chemical indexes evaluated:DM,OM,CP,CF, ash, EE,NFE,GE,NDF,ADF,lignin,hemicelluloses and cellulose.

The DM content was significantly ($P < 0.05$) higher in silage four in the 80th day (33.61%).While the highest OM concentration ($P < 0.05$) was determined in silage four in the 0 day (95.33%).The CF value ($P < 0.05$) was higher in silage two, in the 90th day (8.83 %).The lower CF content was determined in silage two in the 0 (2.85 %) and 60th (2.84%) days, respectively.

Silage four in the 0 day (4.67 %) showed the lower ash concentration. The higher EE content ($P < 0.05$) showed silage one, in the 30th (4.95 %) and 180th (4.95 %) days. The higher NFE concentration was evident in silage two, in the 30th (84.09 %) and180th (84.09 %) days. The GE content was shown high in all the studied variants. However, was significantly ($P < 0.05$) high in silage one, in the 0 day (18.30 kJ gDM^{-1}).

The NDF (table 3) was high ($P < 0.05$) in silage one in the 30th (18.21 %) and 180th (18.19 %) days. The lower ADF concentration ($P < 0.05$) have it silage two, in the 0 (2.55 %) and 60th (2.54 %) days. The higher lignin content ($P < 0.05$) was determined in silage four, in the 30th (2.46 %) day. The hemicelluloses decreased ($P < 0.05$) in silage four, in the 15th (9.48%) and 60th (9.48 %) days, and the cellulose increased ($P < 0.05$) in silage one, in the 30th (6.20%) and 180 th (6.19 %) days.

The results of the digestibility study, of the four taro silages are showed in table 4.In the evaluation of DM and OM *in vitro* digestibility was showed that there were significant differences ($P <0.05$).

The higher IVDMD ($P < 0.05$) coefficient had it silage two (74.65 %).In silage one, the IVDMD was lower (63.83%). Relate to IVOMD, silage two showed the higher digestibility (76.76 %) coefficient ($P < 0.05$). Similarly, silage one had the lower digestibility coefficient (65.08 %).

Table 2. Chemical composition of silages of taro tubers. Interaction treatments x days (%in dry basis)

Indicator, %	Treatments	Days of ensilages						SE±sig
			15	30	60	90	180	
DM	1_YN	27.51^{t}	27.80^{q}	28.20^{p}	28.52^{n}	29.09^{l}	29.10^{l}	0.0227
	2_W	27.60^{s}	28.20^{p}	28.51^{n}	29.32^{k}	29.55^{j}	30.23^{f}	P<0.0001
	3_WMB5	27.71^{r}	28.33^{o}	29.80^{i}	30.09^{g}	30.68^{e}	31.25^{d}	
	4_WMB10	27.82^{q}	28.91^{m}	29.91^{h}	31.92^{c}	32.94^{b}	33.61^{a}	
OM	1_YN	95.24^{c}	95.16^{d}	95.08^{e}	95.25^{c}	95.17^{d}	95.09^{e}	0.0075
	2_W	93.69^{h}	93.58^{i}	93.45^{j}	93.69^{h}	93.59^{i}	93.46^{j}	P<0.0001
	3_WMB5	93.38^{k}	93.33^{l}	93.12^{m}	93.39^{k}	93.33^{l}	93.13^{m}	
	4_WMB10	95.33^{a}	94.23^{f}	94.13^{g}	95.29^{b}	94.24^{f}	94.14^{g}	
CP	1_YN	8.33^{i}	8.58^{d}	8.27^{k}	8.32^{i}	8.58^{d}	8.27^{k}	0.0031
	2_W	8.28^{j}	8.83^{a}	8.69^{b}	8.27^{k}	8.83^{a}	8.68^{c}	P<0.0001
	3_WMB5	8.52^{f}	8.35^{h}	8.15^{l}	8.51^{f}	8.34^{h}	8.14^{l}	
	4_WMB10	8.46^{g}	8.54^{e}	8.13^{m}	8.47^{g}	8.53^{e}	8.13^{m}	
CF	1_YN	3.35^{k}	5.78^{c}	5.85^{b}	3.35^{k}	5.78^{c}	5.85^{b}	0.0029
	2_W	2.85^{n}	3.87^{j}	4.87^{h}	2.84^{n}	3.87^{j}	4.87^{h}	P<0.0001
	3_WMB5	2.88^{m}	4.49^{i}	5.20^{g}	2.88^{m}	4.49^{i}	5.21^{f}	
	4_WMB10	3.03^{l}	5.23^{e}	6.23^{a}	3.03^{l}	5.24^{d}	6.23^{a}	
Ashes	1_YN	4.76^{k}	4.84^{j}	4.92^{i}	4.76^{k}	4.83^{j}	4.92^{i}	0.0075
	2_W	6.31^{f}	6.42^{e}	6.55^{d}	6.32^{f}	6.42^{e}	6.55^{d}	P<0.0001
	3_WMB5	6.62^{c}	6.67^{b}	6.88^{a}	6.62^{c}	6.67^{b}	6.88^{a}	
	4_WMB10	4.67^{m}	5.77^{h}	5.87^{g}	4.71^{l}	5.76^{h}	5.87^{g}	
eE	1_YN	4.72^{d}	4.88^{c}	4.95a	4.72^{d}	4.89^{b}	4.95^{a}	0.0031
	2_W	2.77^{j}	2.83^{i}	2.83^{i}	2.77^{j}	2.83^{i}	2.84^{h}	P<0.0001
	3_WMB5	3.26^{g}	3.42^{f}	3.53^{e}	3.26^{g}	3.43^{f}	3.53^{e}	
	4_WMB10	2.17^{l}	2.16^{l}	2.46^{k}	1.93^{m}	2.17^{l}	2.45^{k}	
nfe	1_YN	78.85^{p}	81.88^{f}	83.88^{b}	78.84^{p}	81.86^{g}	83.86^{c}	0.0032
	2_W	79.79^{o}	81.09^{i}	84.09^{a}	79.78^{o}	81.08^{j}	84.09^{a}	P<0.0001
	3_WMB5	78.72^{q}	78.55^{r}	80.55^{n}	78.72^{q}	78.55^{r}	80.56^{m}	
	4_WMB10	81.31^{h}	80.73^{l}	82.73^{d}	81.32^{h}	80.75^{k}	82.72^{e}	
GE, kJ gDM^{-1}	1_YN	18.39^{a}	17.68^{d}	17.68^{d}	17.68^{d}	17.68^{d}	17.68^{d}	0.012
	2_W	17.60^{e}	17.81^{b}	17.51^{f}	17.81^{b}	17.47^{g}	17.51	P<0.0001
	3_WMB5	17.68^{d}	17.81^{b}	17.81^{b}	17.76^{c}	17.81^{b}	17.76^{c}	
	4_WMB10	17.76^{c}	17.51^{f}	17.76^{c}	17.51^{f}	17.76^{c}	17.76^{c}	

^{abcabcdefghijklmnopqrst} Different superscripts show significant differences(P<0.05)

Table 3. Fibrous fractionation in silages of Taro tubers. Interaction treatments x days (% in dry basis)

Indicator, %	Treatments	Days of ensilages						SE±sig
			15	30	60	90	180	
NDF	1_NY	14.72^{k}	18.12^{b}	18.21^{a}	14.73^{k}	18.12^{b}	18.19^{a}	0.0083
	2_W	13.57^{n}	17.64^{d}	17.74^{c}	13.61^{m}	17.63^{d}	17.73^{c}	P<0.0001
	3_WMB5	17.34^{h}	17.47^{g}	17.59^{e}	17.33^{h}	17.47^{g}	17.50^{f}	
	4_WMB10	13.96^{l}	14.97^{j}	16.95^{i}	13.96^{l}	14.97^{j}	16.93^{i}	
ADF	1_NY	4.83^{n}	7.46^{c}	7.56^{a}	4.84^{n}	7.45^{d}	7.55^{b}	0.003
	2_W	2.55^{r}	6.34^{j}	6.84^{e}	2.54^{r}	6.34^{j}	6.83^{f}	P<0.0001
	3_WMB5	4.18^{o}	6.27^{k}	6.57^{h}	4.17^{o}	6.25^{l}	6.56^{i}	
	4_WMB10	4.07^{p}	5.49^{m}	6.62^{g}	4.05^{q}	5.49^{m}	6.62^{g}	
Lignin	1_NY	1.10^{p}	1.32^{j}	1.36^{h}	1.11^{o}	1.33^{i}	1.35^{h}	0.0035
	2_SL	1.12^{n}	1.21^{m}	1.28^{k}	1.13^{n}	1.21^{m}	1.27^{l}	P<0.001
	3_WMB5	0.81^{s}	1.71^{f}	1.81^{e}	0.82^{r}	1.69^{g}	1.82^{e}	
	4_WMB10	0.83^{r}	2.07^{c}	2.46^{a}	0.84^{q}	2.05^{d}	2.43^{b}	
Hemicellulose	1_NY	9.90^{j}	10.66^{h}	10.65^{h}	9.89^{j}	10.67^{h}	10.65^{h}	0.0078
	2_W	11.02^{e}	11.30^{b}	10.90^{g}	11.07^{d}	11.29^{b}	10.90^{g}	P<0.0001
	3_WMB5	13.16^{a}	11.21^{c}	11.02^{e}	13.16^{a}	11.22^{c}	10.94^{f}	
	4_WMB10	9.89^{j}	9.48^{k}	10.33^{i}	9.91^{j}	9.48^{k}	10.32^{i}	
Cellulose	1_NY	3.72^{k}	6.15^{b}	6.20^{a}	3.72^{k}	6.12^{c}	6.19^{a}	0.0045
	2_W	1.43^{r}	5.13^{e}	5.56^{d}	1.42^{r}	5.14^{e}	5.56^{d}	P<0.0001
	3_WMB5	3.37^{n}	4.56^{h}	4.73^{f}	3.35^{o}	4.56^{h}	4.74^{g}	
	4_WMB10	3.24^{p}	3.42^{m}	4.16^{j}	3.21^{q}	3.44^{l}	4.19^{i}	

^{abcdefghijklmnopqrs} Different superscripts show significant differences($P < 0.05$)

Table 4. *In vitro* digestibility of DM and OM in silages of taro tubers

Variables	1_NY	2_W	3_WMB5	4_WMB10	SE ± sig
IVDMD, %	63.83^{d}	74.65^{a}	70.86^{c}	74.49^{b}	0.0029
					P < 0.0001
IVOMD, %	65.08^{d}	76.76^{a}	72.15^{c}	76.07^{b}	0.0028
					P < 0.0001

^{abcd} Different superscripts show significant differences($P < 0.05$)

Discussion

Chemical composition. The concentration of DM in the silages was in the recommended level (25-35 %) to characterized a silage of appropriate quality (McCullough 1975).In this regard, McDonald *et al.* (1981) suggested that 30% of DM was a minimum level to reduce the undesirable growth of clostridia that worse the product. The DM content of silages, until the 180th day of evaluation, were between 29.10 and 33.61%. Consequently, they can be considered good quality products for their use in animal feeding.

Regarding the CP content, the data of this research were in a concentration from 8.13 to 8.83%. Similar CP values informed Marrero *et al.* (1984) in silages of taro tubers of six months (8.5 %). Ogunlakin *et al.* (2012) referred higher results in tubers in natural way (4.93 to 5.17 %), Fetuga and Oluyemi (1976) found 3.1% in studies with cooked tubers . Apparently, by means of silage process the CP content is increased regarding to tubers in natural and cooked way. The silages CF in the four variants showed low content (2.84 to 6.23%).In researches carried out with ensiled tubers, Marrero *et al.* (1984) determined 13.4% of CF. This wide variation in CF content could be due to the used ingredients in silages formulation. Also, the nutritional composition of roots and tubers vary according to climatic conditions, cultured varieties, soil conditions and time in which the crop is made (FAO 1990 and Onwueme 1999).

The NFE (78.55 to 84.09 %) and ash (4.67 to 6.88 %) concentration in silages showed higher content, regarding to that referred by Olajide *et al.* (2011) in fermented and dryings tubers. These authors informed 73.50 % for NFE and 0.88 % for ashes. Nevertheless, in relation to the EE content (2.63 %) referred by these researches, silages showed a similar performance to this nutrient (1.93 to 4.95%).The variation in NFE values could be due to the amount of fermented carbohydrates that the silages had in this experiment.

In this study, the GE content in silages was high, with values between 17.47 and 18.39 kJ gDM^{-1} Abdulrashid and Agwunobi (2009), in tubers meal, informed 3.21 kcal g DM^{-1} (13.42 $kJ.gDM^{-1}$),lower figures to those verified in this research. Apparently, the caloric content of ensiled tubers was increased by the energy contribution of natural yogurt, whey and molasses B.

In general, silages showed variation in NDF content (13.57 to 18.21%), ADF (2.55 to7.56%), lignin (0.81 to 2.46%), hemicellulose (9.48 to13.16%) and cellulose (1.42 to 6.19%). These variations can be associated to the lack or presence of molasses in the fermented material (Guzmán *et al.* 2012).

In vitro digestibility. In researchers developed by Ly and Delgado (2005), related to *in vitro* digestibility of DM and OM, with pancreatine pepsin, in fresh and dry taro tubers, informed that DM digestibility increased when tubers were dry (66.90%). Not happened this way when they were fresh (31.50 %). Likewise, the *in vitro* digestibility of OM was higher in the dry ones (76 %), in relation to the fresh ones (38.30 %).

It has been carried out several *in vitro* digestibility researches of DM and OM in other types of tubers in natural way. Ly *et al.* (2010) informed in cassava tubers values of 66 % of DM and 68.7 % of OM. In studies made with sweet potato, Ly *et al.* (1999) informed contents of 54.5 % of DM and 62.5 % of OM. These results were lower to those obtained in the study of the four silages variants. Apparently, the ensiled process and the digestibility method applied increased the *in vitro* digestibility coefficients of DM (63.83 to 74.65 %) and OM (65.08 to 76.76 %).

From the point of view of the OM *in vitro* digestibility, the ensiled taro tubers seem to be slightly better than other tropical tubers; due to in the ensiled process by means of anaerobic fermentation, lactic acid is produced and, in presence of this one, can be recover some wastes components, like protein, minerals and lipids (López *et al.* 2006).

The conservation of taro tubers, between 0 and 180d, by means of the addition of variables levels of natural yogurt, whey and sugar cane molasses originates different products that have good content of DM, CP, GE and low concentration of CF, suitable for it use in feeding pigs.

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