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Nutritional Potential of Some Invasive Species of Macaronesia for Ruminants

C.S.A.M. Maduro Dias, C.F.M. Vouzela, H.J.D. Rosa, J.S. Madruga and A.E.S. Borba

University of the Azores, Faculty of Agricultural and Environmental Sciences, Institute of Agricultural and Environmental Research and Technology (IITAA). Rua Capitão João d'Ávila, 9700-042 Angra do Heroísmo, Açores, Portugal.

ABSTRACT

Macaronesia islands' invasive plant use in animal feed or composting may bring economic and environmental benefits to the region. Arundo donax, Pennisetum setaceum, Agave americana, and Ricinus communis, present in the three archipelagos (Canary, Azores and Madeira), were characterized chemically and biologically. A. donax and P. setaceum showed elevated crude protein (CP) content, 13.25 and 16.33 DM%, respectively, and extremely high NDF values, 75.87 and 80.83 DM%, with a DM digestibility of 55.02 to 59.77%. A. americana showed a low NDF value (22.78 to 27.94 DM%) and a very low CP value (4.24 to 5.61 DM%). However, its DM digestibility was high (79.89 to 86.33%). R. communis presented the best values for CP (24.62%) and NDF (26.56 DM%), however, due to the presence of toxic substances (ricin), it cannot be easily used in animal feed. The P. setaceum and R. communis were found to be the least gas-producing forage, with A. americana being the major producer. To increase these plants' value for animal feed, treatment with urea or NaOH to A. donax and P. setaceum, and enrichment with nitrogen to Agave is proposed. Due to its toxic properties, R. communis must be used in composting.

Keywords: Invasive plants; Nutritive valorisation; Composting; Macaronesia

***Correspondence to Author:**
A.E.S. Borba
University of the Azores, Faculty of Agricultural and Environmental Sciences, Institute of Agricultural and Environmental Research and Technology (IITAA). Rua Capitão João d'Ávila, 9700-042 Angra do Heroísmo, Açores, Portugal.

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Introduction

Invasive plants are a problem that, to a greater or lesser extent, affect the region of Macaronesia, constituting a threat to the region's endemic flora and fauna. The use of these plant species as fibre sources for industry, animal feeding or composting may be considered as complementary means of combating their propagation, as suggested by Silliman *et al.* (2014)[1].

The use of invasive plant species in animal feed has a long tradition in the Azores Islands. There are two clear periods of low grassland productivity, those being, summer (particularly August and September) and winter (from November through February). During winter, animals are usually kept in the so-called "invernadores", as an effort to protect them from adverse conditions, particularly, rain and wind (Borba *et al*., 2015)[2]

During these periods of lack of grass, often unconventional fodders are used as sources of fibre, with shrubs playing a predominant role. Of the unconventional fodders used in Azorean animal feeding, we highlight *Pittosporum undulatum* (incense), *Hedychium gardnerianum* (ginger lily) (Borba *et al.*, 2015)[2].

A review of literature indicates that there is limited information on the nutritive value of invasive plants. Some authors have carried out studies on the potential of invasive plants, namely on their chemical composition, nutritional value and toxicity (Zangerl and Berenbaum, 2005, Smith *et al.*, 2013, Burritt and Hart, 2014, Drossart *et al*., 2017, Obour *et al.,* 2017)[3,4,5,6,7]. The findings of this analysis suggest that invasive plants are far more likely to cause significant impacts on resident plant and animal richness on islands than on the continent (Pyšek *et al.,* 2012)[8]. Some authors have reported that invasive plant contribution to ecosystem services is controversial due to the, mostly negative, relationship that these species have with the native flora. However, their continued dominance in many regions warrants a more thorough evaluation of their impact, both positive and negative, on the ecosystem (Gordon, 1998, Hershner and Havens, 2008)[9,10].

The negative impact of non-native species to the loss of biological diversity (genetic, species, and ecosystem diversity) and the threat they represent to human health and welfare when they become invasive has been widely discussed in literature (Manchester and Bullock, 2000) [11] . Nonetheless, in certain instances, they can also provide conservation benefits. Furthermore, a fraction of non-native species will continue to cause biological and economic damage, as well as substantial uncertainty surrounding the prospective effects of all non-native species (Schlaepfer *et al*., 2010)[12]. For example, their influence on the bee population remains quite unclear and is still a controversial matter of debate among researchers. Non-native species can currently contribute to the ecosystem's conservation objectives, which might include, for example, providing habitat or food resources to rare species, serving as functional substitutes for extinct taxa, or providing desirable ecosystem functions (Jordaan and Downs, 2012)[13].

Invasion by exotic plants tends to be associated with the nutrient enrichment of soils. This phenomenon happens particularly on soils of naturally low fertility (Tabassum and Leishman, 2016)[14], in which, invasive species may contribute to a homogenisation of soil conditions in invaded landscapes (Dassonville *et al*., 2008)[15].

Most of the invasive plants or weeds compete with desirable vegetation and adversely affect forage production and quality. These invasive species are often extremely destructive and difficult to control, allowing infestations to persist for several years and spread to new areas. Some plants have sharp spines, while others may lead to animal fatalities, either through direct poisoning or through an accumulation of nitrates and soluble oxalates (Scott and Robbin, 2005, Panter *et al.,* 2011)[16,17].

The purpose of this study is the valorisation of natural fibres coming from vegetable invasive species in Macaronesia, such as *A. donax L.* (common cane), *Pennisetum setaceum* (known as fountain grass), *Agave americana* (similar to sisal) and *Ricinus Communis* (castor bean plant), all of them propagated without control in the three Archipelagos (Canarias, Azores and Madeira). These plants are included in the International Union for Conservation of Nature (IUCN)'s TOP100 of most dangerous invasive species.

Material and Methods

Forage collection and preparation

The current study was conducted at the Animal Nutrition Laboratory, Department of Agricultural Sciences, University of the Azores, Azores, Portugal. Samples of plants were collected on Terceira and Santa Maria islands. This region is dominated by soils from basaltic lava mantle, known as "litolic soils" according to Ricardo *et al.* (1979)[18]. They would fit in the Typic Udorthents according to Soil Taxonomy (USDA, 2014)[19,20].

Samples were harvested manually, consisting of the parts of the plant animals normally eat.

Chemical analysis

Dried samples were then ground through a 1-mm screen. These ground samples were analysed for dry matter (DM, method 930.15), crude protein (CP, method 954.01) and total ash method (942.05), according to the standard methods of AOAC (1995)[21]. Crude protein was determined by the standard micro-Kjeldahl method. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to Goering and Van Soest (1970)[22]. *In vitro* digestibility was determined using the Tilley and Terry (1963)[23] method, modified by Alexander and McGowan (1966)[24], and the juice of the rumen was obtained from a slaughterhouse, as described by Borba *et al.* (2001)[25].

In vitro Gas Production

In vitro gas production (GP) technique simulates the rumen fermentation process and it has been used to evaluate the potential of feeds to produce greenhouse gas. It is similar to the ruminal process, as gas (CO_2 and CH_4) is produced from the carbohydrate fermentation.

Each assay was repeated three times (runs). Blanks were used for each inoculum to measure the fraction of total gas production due to the substrate in inocula and these values were subtracted from the total to obtain the net GP. All treatments, for each assay, were incubated simultaneously in all runs, as per Menke *et al.* (1979)[26].

Rumen digesta was collected as described by Borba *et al.* (2001)[25]. The preparation of buffer solutions and rumen inocula was as described by Menke and Steingass (1988)[27].

The initial gas volume was recorded after 4, 8, 12, 24, 48, 72 and 96 hours of incubation.

This gas production represents the kinetic of the rumen's apparent GP and is expressed by the McDonald (1981)[28] equation. Gas production profiles were obtained after fitting the data to the exponential equation of Ørskov and McDonald (1979)[29]:

$$p = a + b\,(1 - exp^{-c\,t})$$

Where: *p* represents the gas production at time *t,* the values of *a*, *b* and *c* represent *constant* values in the exponential equation, *a*+*b* the total potential gas production (ml/g DM), and *c* the rate constant.

Results and Discussion

From the results presented in Table 1, it was observed that *A. donax* and *P. setaceum* show elevated crude protein (CP) values, 13.25 and 16.33 DM%, respectively, and extremely high NDF values (75.87 and 80.83 DM%, respectively), which leads to a DM digestibility of 55.02 and 59.77%. The *A. americana*, although with a low NDF value (22.78 and 27.94 DM% for Terceira Island and Santa Maria, respectively), presents a very low CP value (4.24 and 5.61% for Terceira and Santa Maria, respectively), lower than the 7%, which is usually considered the minimum required value for the normal functioning of microorganisms (Lazzarini *et al*., 2009)[30]. However, its dry matter digestibility is high (86.33 and 79.89% for Terceira and Santa Maria, respectively). The *R. communis* is, of all the studied samples, the one that shows the best values, 24.62 DM% for CP and 26.56 DM% for NDF.

Table 1. Composition of the different sources of fibre.

Treatment	DM	100 g DM						DMD	OMD
	(%)	CP	NDF	ADF	ADL	EE	Ash	(%)	(%)
Arundo donax	19.52	13.25	75.87	39.72	4.21	1.58	10.53	55.02	50.03
Pennisetum setaceum	18.70	16.33	80.83	41.90	4.77	1.28	16.30	59.77	51.99
Agave americana Terceira	14.88	4.24	22.78	20.04	5.50	1.69	4.49	86.33	85.43
Agave americana Santa Maria	10.09	5.61	27.94	24.42	4.39	1.45	12.06	79.89	77.15
Ricinus communis	19.27	24.62	26.56	20.02	4.38	2.30	9.59	78.06	76.34

DM – Dry Matter, CP – Crude Protein, NDF – Neutral Detergent Fibre, ADF – Acid Detergent Fibre, ADL – Acid Detergent Lignin, EE – Extract Ether, DND –Dry Matter Digestibility, OMD –Organic Matter Digestibility.

Comparing the chemical composition values of *A. donax* found in this study with those reported by other authors, we found high fibre values (NDF) greater than 65% of DM and crude protein between 9.9% of DM and 11.1% of DM (Ahmed *et al.*, 2009 and Ahmed *et al.*, 2011, N.AG.RE.F., 2013)[31,32,33]. Regarding the digestibility of DM, other authors found values comparable to those found in this study, between 47 and 52% (TagelDin, 1990, Ahmed *et al.*, 2011)[33,34]. Talapatra (1950)[35] reports a digestibility value of DM of 69% for *A. Donax* of India and N.AG.RE.F. (2013)[32] refers to a value of 66.8%. Baig and Bhagwat (2009)[36] and Behera *et al.* (2013)[37] report the galactopoietic properties of *A. donax* in dairy cows.

Table 2. Equation terms for gas production, including residual standard deviations (rsd)

	a	b	c	Lag Time (hr)	RSD
Arundo donax	-2.39	49.65	0.0419	1.2	1.24
Pennisetum setaceum	-7.56	49.1	0.0389	4.3	2.35
Agave americana Terceira	3.1	47.87	0.276	0	1.81
Agave americana Santa Maria	4.16	42.89	0.0749	0	0.99
Ricinus communis	-3.91	47.45	0.0722	1.2	1.38

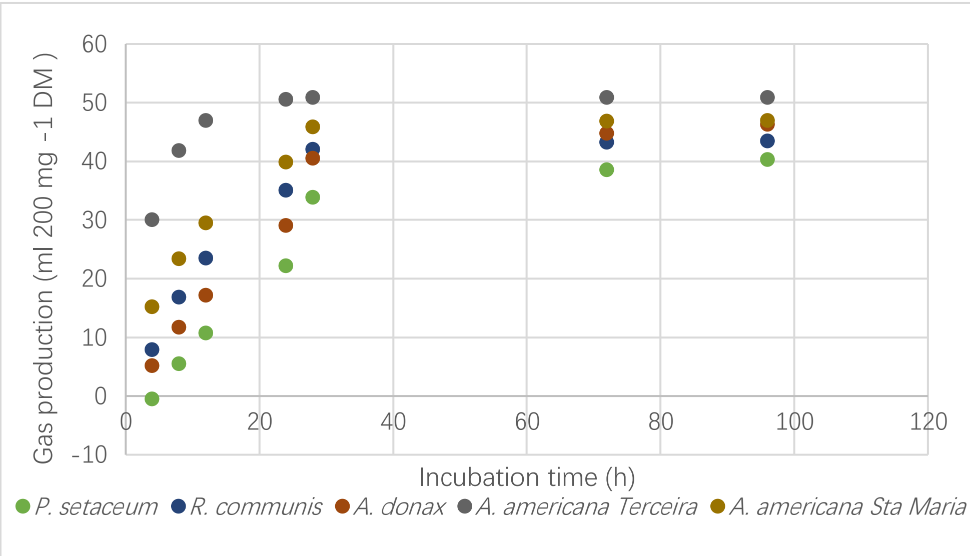

Figure 3. Pattern of *in vitro* gas production (fitted with exponential model) on incubation of invasive plants in buffered rumen fluid.

Several authors argue that the palatability of *A. donax* is low, which results in a low voluntary intake, even when the animals ingest young plants (Ahmed *et al.*, 2011, Shehata *et al.*, 2006)[33,38]. The USDA (2014a)[19] reports that young *A. donax* plants are grazed, being one of the means of control of this weed during the dry season.

P. setaceum has an average nutritive value, an extremely high NDF value and a high crude protein value, however, unlike other *Pennisetum*, it is not normally used as a feed for ruminants. According to Joubert and Cunningham (2002)[39], *P. setaceum* is an unpalatable species, possibly due to its serrated and rough leaves.

Fuentes-Rodriguez (1997)[40] research findings suggested that *Agave* generally has a low nutritional value in ruminant feed. With a low DM content (10%) and a low crude protein content (5% of DM), they are used both as an emergency maintenance feed and as part of the regular rations. Other authors reported values of 7.45% of crude protein in DM (Fraps, 1932 and Anon, 1942)[41,42]. These plants have good palatability and high humidity content (Suñigiga, 1980)[43]. For example, in Santa Maria, *Agave* is given to animals as a water source, in periods of forage shortage.

The literature presents chemical composition values for *Ricinus communis*, crude protein 23.7% between 22.5 and 24.8% of DM, NDF of 24.0%, ADF of 22.1% of DM and ADL of 2.8% of DM (Behl *et al.*, 1986, Bose *et al.,* 1988, Okorie *et al*., 1985, Oorie and Anugwa, 1987, Purushotham *et al*., 1985, 1986, Rao *et al*., 1984)[44,45,46,47,48, 49,50].

Although *Ricinus communis* is referred to as a toxic plant (Albuquerque *et al*., 2014, Tokarnia *et al*., 1975)[51,52] , some authors refer to the use of this plant in sheep feed. Lara *et al.* (2016)[53] reported values of chemical composition of *Ricinus communis* very similar to those found in this study (Table 1), that is, high values of crude protein (20.4% of DM), low NDF values (33.8% of DM) and a value digestibility of 76.8%. Barrales Heredia *et al.* (2018)[54] refer to the use of castor oil in ruminant feed since it has a high crude protein content (62.6 to 66.77% of DM).

Invasive plant *in vitro* gas production results (Table 2) shows that the initial time of fermentation (Lag Time) varies greatly from forage to plant, ranging from 0 hours to 4.3 hours. This variation is in line with previous findings (Tuah *et al.,* 1996)[55]. It was observed that the Agave from Terceira and Santa Maria have a Lag Time of 0 hours, while the *Pennisetum setaceum* presents a Lag Time of 4.3 hours. According to the gas production curves (Figure 3), *Pennisetum setaceum* and *Arundo donax* are the least gas-producing plants.

According to the gas production curves (Figure 3), *P. setaceum* and *R. communis* are the least gas-producing plants, with *A. americana* from Terceira and Santa Maria being the major producers. We highlight the low potential of gas production of this fodder, and there were no results from other authors to compare those obtained in this work. However, in studies published by Moselhy *et al.* (2014)[56], an inhibitory effect of two other invasive plants, *Pittosporum undulatum* and *Hedichium gardnerianum*, was verified in gas production.

Conclusions

It is concluded that the studied invasive plants can be used as ruminant feed in a period of shortage of forages, or as a way to control their spread. The *Ricinus communis*, due to the presence of toxic substances in this plant, is not easily used in animal feed. As a strategy to increase the value of these plants, we propose that treatment with urea or NaOH is applied to *A. donax* and *P. setaceum*, and enrichment with nitrogen to Agave, for use in animal feed. Due to its toxic properties, *R. communis* must be used in composting.

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