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Effect of sodium hydroxide treatment in ginger lily forage (*Hedychium gardnerianum*, Sheppard ex Ker-Gawl) as forage for animal feeding

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This study evaluated the effect of sodium hydroxide (NaOH) on the chemical composition (fibrous structure) and nutritive value of *Hedychium gardnerianum* (ginger lily), a fibre source traditionally used in ruminant feeding in the Azores. Ginger lily samples were manually harvested and dried in a forced-air oven at 65ºC until constant weight. Treatments were applied by spraying the ginger lily with a NaOH solution at a concentration of 0, 2, 4, 6, and 8%, at a rate of 1 L of solution per 1 kg of dry ginger lily, and waiting 7 days. The samples were subject to chemical analyses in a laboratory for the determination of the dry matter (DM), crude protein (CP), ether extract (EE), ash, NDF (neutral detergent fibre), ADF (acid detergent fibre), and ADL (acid detergent lignin). The DM digestibility (DMD) and organic matter digestibility (OMD) were determined *in vitro*. The NaOH treatment led to a significant (p<0.05) reduction of NDF and ADF and led to a significant (p<0.05) *in vitro* DMD and OMD increase, with best results obtained for an 8% NaOH concentration. It was concluded that the NaOH treatment influences the ginger lily's chemical composition, reducing the NDF and ADF concentrations, and increasing the *in vitro* DMD.

Key words: *Hedychium gardnerianum, in vitro* digestibility, NaOH treatment, roughage.

INTRODUCTION

Animal production is the main economic sector in the Azores, Portugal. The production regimen is based on grazing and is frequently confronted with fibre shortage periods, motivated by the typical pasture production fluctuations or by climate variation that impacts the grass production.

Climate changes and loss of biodiversity, along with pastures cultivated by just one or two vegetable species, have lately been referenced as leading to a search for plants originating in natural flora, as a way of switching to more sustainable animal production, capable of combining economic performance with a reduction of the environmental footprint (Dumont et al., 2013).

The use of invasive plants, such as ginger lily, besides providing an alternative source of fibre for ruminant production, leads to the reduction of the ecological footprint of animal production. For optimal use, forages should combine a high nutritive value with low pollutant

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emissions. Identifying how to best take advantage of a given region's plants is an important step in finding a good balance between a higher nutritive value and a sustainable production (Macheboeuf et al., 2014).

The first reports on using chemical treatments to improve the digestibility of fibrous feeds date back to 1881, and various products have been tested. In preceding work, namely Borba et al. (2015), ginger lily (*Hedychium gardnerianum*, Sheppard ex Ker-Gawl) was treated with urea, with inconclusive results, most likely because the treatment was not applied in a hermetic environment.

The action of the alkaline compounds occurs through the breakdown of the lignocellulosic complexes, solubilising the hemicellulose and increasing the cellulose digestibility through the expansion of the fibrous structure (Jackson, 1977; Klopfenstein, 1978).

In the Azores, the fibre shortage leads to the importation of material that could be produced in the region. This work is aimed at increasing the value of using a traditional fibre source used by Azorean farmers, which also happens to be an invasive species that causes damage to the natural vegetation of the archipelago. We also hope to test sodium hydroxide concentrations of 0, 2, 4, 6 and 8%.

MATERIALS AND METHODS

The ginger lily was harvested, in nature, in the Pico da Cruz woods (altitude of 295 m), in the Cinco Ribeiras Parish, Angra do Heroísmo, Azores, Portugal and ground in a grinding machine until left with a particle dimension of 2 to 3 cm.

Treatment with sodium hydroxide

The treatments, carried out in triplicate, consisted of spraying the dry ginger lily with sodium hydroxide solution at a concentration of 0, 2, 4, 6, and 8%, in the proportion of 1 L of the solution to 1 kg of dry ginger lily. By the end of seven days, and for each chemical treatment, samples were taken for laboratory analyses.

Chemical analysis

The studied feed sources were dried in a forced-air oven at 65ºC until constant weight. Following that, they were ground through a 1-mm screen using a Retsch mill. For chemical characterization of the forage, the Weende system was used to determine dry matter (DM, method 930.15), crude protein (CP, method 954.01), ether extract (EE, method 920.39), and total ash (method 942.05) according to the standard methods of AOAC (1990). The dry matter content of forage was determined by placing samples in a forced air oven at 105°C for 24 h. Total ash was evaluated by igniting samples in a muffle furnace at 500°C for 12 h. Crude protein was determined by the Kjeldahl method. Ether extract was measured by refluxing forage samples with petroleum ether in a Soxhlet system. Neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) were determined according to Goering and Van Soest (1970). Both NDF and ADF were expressed without residual ash. The *in vitro* dry matter digestibility and organic matter digestibility was measured according to the method of Tilley and Terry (1963), modified by Alexander and McGowan (1966).

Statistical analyses

All statistical analyses were performed using the IBM SPSS v.20 Statistics Program (SPSS Inc. Chicago, IL). The data was analysed according to one way ANOVA and regression for dry matter digestibility values. Whenever significant differences ($p<0.05$) were detected, a multiple comparison Scheffe test was carried out.

RESULTS AND DISCUSSION

The nutritive valorisation of ginger lily has been the subject of several studies (Moselhy et al., 2014; Borba et al., 2015; Moselhy et al., 2015; Maduro Dias, 2017) with the goal of promoting the use of this plant, extremely abundant in the Azores, where it is one of the main invasive species. According to Borba (1991), the *H. gardnerianum* is a poor forage, with low *in vitro* and dry matter digestibility, as determined in sheep. Of the various methods used for increasing the nutritive value of low-quality fibrous feed, we chose the sodium hydroxide treatment with concentrations of 0, 2, 4, 6, and 8%. According to Tarkov and Feist (1969) and Pires et al. (2003), the NaOH acts on the cell wall components and causes alkaline hydrolysis of the ester type covalent bonds, between the lignin and the structural carbohydrates. This, in turn, causes the solubilising of the hemicellulose and phenolic compounds with a decrease in NDF value, thus facilitating the cellulose and hemicellulose decomposition by the rumen's microorganisms.

The results relating to the effects of the sodium hydroxide chemical treatment on ginger lily's chemical composition, with corresponding significance levels, are presented in Table 1. It can be seen that the CP content was not affected ($P<0.05$) by the NaOH treatment, as was expected, given that the NaOH action is on the cell wall, which should not influence the CP concentration (Pereira Filho et al., 2003).

Regarding the cell wall, a significant effect ($p<0.05$) from the NaOH treatment was observed in the reduction of NDF content, which was more pronounced for the 8% NaOH concentration. ADF also decreased significantly ($p<0.05$) but only with the 8% NaOH treatment, where a greater effect on the hemicellulose was observed when compared with the effect on cellulose. Even though the ADL level reduced proportionally with the increase in NaOH concentration, it failed to reach a significant level ($p<0.05$). Sambusiti et al. (2012) reported that the treatment with sodium hydroxide increased the cellulose and hemicellulose hydrolysis in sorghum and wheat straws, and Arisoy (1998) found that the treatment with NaOH reduces the hemicellulose content of barley straw, which equals an increase of cellulose and lignin on the cell wall. In treatment with carnauba straw with 1 and 5% of NaOH, Carvalho et al. (2016) noted that the alkaline

Table 1. Effect of NaOH treatment in the nutritive composition of ginger lily.

Treatment	DM (%)	100 g DM						DMD (%)	OMD (%)
		CP	NDF	ADF	ADL	EE	Ash		
Control	11.27[a](±0.53)	6.27[a](±0.34)	68.31[a](±1.07)	41.75[a](±1.82)	7.30[a](±0.59)	0.94[ab](±0.08)	13.30[a](±0.61)	38.36[a](±1.44)	29.41[a](±1.54)
2% NaOH	11.47[a](±0.57)	6.13[a](±0.76)	64.73[b](±0.32)	40.12[ab](±0.64)	6.99[a](±0.14)	1.14[b](±0.14)	13.99[a](±2.30)	47.35[b](±1.18)	42.27[b](±1.23)
4% NaOH	12.03[a](±0.38)	6.26[a](±0.28)	63.43[b](±0.47)	40.53[ab](±0.31)	6.77[a](±0.24)	1.15[b](±0.16)	12.85[a](±0.27)	52.28[bc](±2.79)	46.83[bc](±1.89)
6% NaOH	11.96[a](±0.17)	6.47[a](±0.35)	59.34[c](±0.93)	38.79[ab](±0.97)	6.68[a](±0.18)	0.72[ab](±0.05)	17.33[ab](±0.83)	57.07[cd](±0.44)	48.07[bc](±0.29)
8% NaOH	11.26[a](±0.45)	6.70[a](±0.24)	55.97[d](±1.64)	37.91[b](±0.31)	6.56[a](±0.23)	0.54[a](±0.05)	22.25[b](±1.15)	61.13[d](±3.01)	50.05[c](±3.11)

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. Means that display the same index are not significantly different (p<0.05).

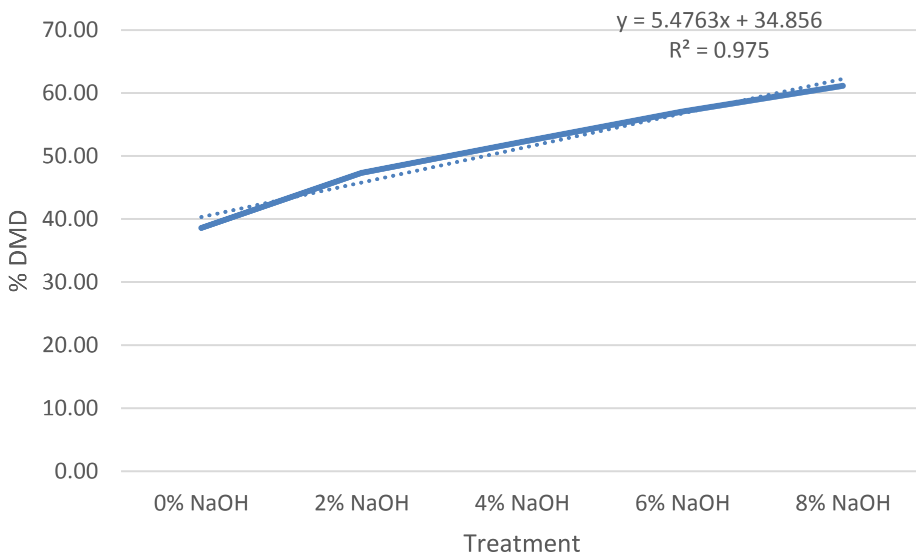

Figure 1. Effect of the NaOH treatment at different concentrations in the DM digestibility of ginger lily.

treatment allowed for the solubilisation of the hemicellulose and lignin without impacting the cellulose. The ash increases significantly ($p<0.05$) with the NaOH concentration as is referred by Arndt (1980).

The ginger lily's dry matter digestibility (DMD) increased linearly ($p<0.05$) with the increase in the NaOH concentration used in the chemical treatment (Figure 1), with an $R^2 = 0.975$. This relationship has been reported by others, namely, Arndt (1980), Utley et al. (1982), Arisoy (1998) and Granzin and McL Dryden (2003). Pereira Filho et al. (2003) observed the same effect in the *in vitro* digestibility of mimosa hay, treated with NaOH. Van Eenaeme et al. (1981) referred that the optimal NaOH concentration was 3%. The DMD increase with NaOH occurs due to the greater exposition of the cell wall components to this compost, increasing the structural carbohydrates susceptibility to digestibility (Chaudhry, 1998). Canale et al. (1988) referred that the treatment of hay with NaOH increased the digestible fraction of DM and NDF. Jami et al. (2014) observed that the semi-dry treatment of corn straw with 5% NaOH reduced the NDF contents by 14% while solubilizing 35% of hemicellulose, 8.7% of cellulose, and 11.3% of the lignin fractions. These changes resulted in a 9.1% increase in *in vitro* DM digestibility of corn straw. Organic matter digestibility (OMD) showed a similar trend to DMD (Table 1).

In a comparative study among different treatments (anhydrous ammonia, urea, sodium hydroxide, and calcium hydroxide) on the nutritive value of roughage, Pires et al. (2010) concluded that the sodium hydroxide and calcium hydroxide presented a greater efficiency in the reduction of the cell wall and increase in digestibility, compared to the anhydrous ammonia and urea. Klopfenstein et al. (1972) indicated that poor quality roughages can be treated with 3 to 5% NaOH so that, the moist mixture after ensiling is consumed readily by lambs without further treatment; also, the dry matter digestibility is increased by sufficient magnitude to potentially improve animal performance.

The best ginger lily nutritive valorisation results were obtained with higher NaOH concentrations. Care is advised, however, as pointed out by Sundstol (1984), Fahey Jr. et al. (1993), Reis et al. (1995), and Lendowski et al. (2015), as the great efficiency of sodium hydroxide in the treatment of fibrous feeds presents the disadvantage of possible contamination of the environment due to the excessive elimination of sodium from the animal urine and faeces.

Conclusions

The ginger lily (*H. gardenarium*) is a forage traditionally used in the Azores for ruminant feeds. Since it is a low-quality fibrous forage, it becomes important to find simple methods for improving its nutritive value.

The chemical treatment with sodium hydroxide influenced the ginger lily's chemical composition, reducing the neutral detergent fibre and acid detergent fibre. The use of sodium hydroxide also increased the *in vitro* dry matter digestibility of the ginger lily's organic matter.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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