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Full Length Research Paper

Enhancing the Nutritional Value of Ginger Lily Forage for Animal Feed through Urea Treatment

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Fiber availability is not always ensured in all year long grazing systems. In this context, low quality fiber feeds may be of relevance for bovine feeding. We propose, thus, to study the effect of adding 5% of urea (on a dry matter basis) on the chemical composition and nutritional value of *Hedychium gardnerianum*, Sheppard ex Ker-Gawl (ginger lily or Kahili ginger), a traditional fiber source used by Azorean farmers. Treatments were: green ginger lily as a control, addition of 5% urea on a DM basis to green ginger lily, with treatments lasting 0, 5, 10, 15 and 30 days and addition of 5% urea on a DM basis to previously dried ginger lily, at day 0. The treatment afforded a significant (P<0.05) increase in crude protein, while maintaining the neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents, and a variation in the acid detergent lignin (ADL) content. No significant improvement in *in vitro* dry matter digestibility. The treatment with urea of the green forage does not have the same effect as in other low quality fiber feeds, namely straw, since ginger lily has much higher a Crude Protein value than those other fibrous feeds.

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

INTRODUCTION

Livestock production under grazing regimes is confronted often with periods of fiber shortages, which are motivated by normal production curves of pasture or climate change that have significant influences in grass production. Current production concepts, using a minimum of concentrates while maximizing available food and low digestibility of fibrous feedstuffs gained some importance in the diet of ruminants.

However, and due to the low feeding value of these foods together with low voluntary intakes combined to low digestibility, they fail to meet the maintenance needs of ruminants. In order to improve the nutritional value of low-quality fibrous food, various treatments have been proposed: physical, biological and chemical (Jarrige, 1987).

The presence of ruminants in the Azores archipelago dates back to European settlement (with cattle, sheep and goats). However, it was for the purpose of the known cultural and economic cycle called the "industrial crops" in the late nineteenth century and especially in the second half of the twentieth century, that cattle farming, particularly dairy, has had a major expansion, making it the dominant economic activity in the archipelago.

For centuries, semi-natural grasslands (implanted after cutting the primeval forests and with a mixture of native and exotic plants) were the basis of the Azorean animal husbandry. Installed in acidic soils, these were composed essentially of grasses, including *Holcus mollis* L. and *Anthoxanthum odoratum* L. (Davies, 1962).

In a traditional grazing system in which milk production accompanied the grass production cycle, good management of pastures represented a gain for farm's profitability. In general, these pastures are located in mid/high altitudes, being therefore subject to the action of winds, high rainfall and low temperatures, which favors a main grass production period in spring with two clear periods of scarcity in both summer (particularly August and September) and winter (November through February). On the islands with the lowest average altitudes, and/or in the lowlands, there is a single famine period of forages – summer - which is nevertheless quite long (Borba, 2007). In periods of fodder shortage alternatives are common in some of the islands. These include mainly *Pittosporum undulatum* Vent. (Incense), *Hedychium gardnerianum* Sheppard ex Ker-Gawl. (ginger lily), *Morellia faya* Aiton (firetree) and *Ilex perado* Aiton ssp. *azorica* (Loes.) Tutin (Holly) (Borba, 2007). In general, the cows were fed during the winter with poor food, which does not allow them to cope with calves growth and restore the necessary weight to prepare for the next lactation, resulting in low milk yields which are then limited to just a few months.

H. gardnerianum Sheppard ex Ker-Gawler is a rhizomatous perennial herb of the Zingiberaceae family, it is known as the ginger lile. It has a stalk which can extend up to 2 m long, with oblong leaves reaching 30 cm and several yellow-orange flowers in a spike of 20 to 30 cm in length. It is an aggressive invasive weed capable of spreading rapidly and dominating large areas in the Azores (Portugal). Moreover, *H. gardnerianum* out-competes many native plants and has become a significant threat to the survival of many of them (Sjögren, 1984).

A fiber deficiency has demanded for Azorean farmers to import raw materials that could however be produced within the region. Traditional fiber sources used by Azorean farmers gain thus a new importance which requires urgent studies of its feasibility both in production and nutritious value. Ginger lily, an unconventional forage of traditional use in the Azores has a low nutritional value. Among the available treatments to increase the nutritional value, urea treatment was selected due to its cheap price and availability. Furthermore, it attacks the cell wall and provides nitrogen enrichment, making it available to use in the protein synthesis by the rumen microbiota. The urea treatment was carried out with the aim of improving the nutritional value of the ginger lily, like for other roughages.

MATERIALS AND METHODS

Forage collection and preparation

The current study was conducted in the Animal Nutrition Lab, Department of Agricultural Sciences, University of the Azores, located in Angra do Heroísmo, Terceira, Azores, Portugal. The whole-plant (leaves and pseudo stems) was manually harvested at the beginning of the flowering stage (April, 2014) about 15 cm above the soil, in Mata das Veredas (295 m altitude), Terra Chã, Municipality of Angra do Heroísmo. The forage was chopped using a laboratory type chopper at length of 2 to 3 cm.

Experimental design

The authors studied the effect of treatment time and form on the nutritional value of ginger lily. For this purpose, the following treatments were performed (in triplicate):

(C) Ginger lily control,
(U) Ginger lily treated with 5% urea (DM basis).

The ginger lily treatment duration times were 0 (U0), 5 (U5), 10 (U10) and 15 (U-15) days.

The treatment was performed by spraying the samples with a urea solution. For each treatment, 3 kg sample were placed in a plastic box with lid. All treatment was made in green ginger lily. After treatment, the samples were dried in a forced air oven at 65°C for 72 h.

Chemical analysis

Dried samples were then ground through 1 mm screen using a Retsch mill (GmbH, 5657 HAAN, Germany). Ground samples were analyzed 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). Briefly, 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 600°C for 12 h. Crude protein was determined by standard micro-Kjeldahl method using digestion equipment (Kjeldatherm System KT 40, Gerhart Laboratory Instruments, Bonn, Germany) and an automated Kjeltec 2300 Auto-analyzer apparatus for distillation and titration (Foss Electric, Copenhagen, Denmark). Where, neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Goering and Van Soest (1970). Both NDF and ADF were expressed without residual ash. *In vitro* digestibility was determined by (Tilley and Terry, 1963) method and modified by Alexander and McGowan (1966).

Statistical treatment

ANOVA was performed, followed by the Scheffe multiple comparison test whenever significant ($p<0.05$) were detected.

RESULTS AND DISCUSSION

The *H. gardnerianum* is a poor forage with low digestibility *in vivo* and low dry matter intake, measured in sheep (Borba, 1991). The tests carried out by the authors are used to select a method that allows a nutritional valorization of this fodder, which is a major source of fiber in cattle's feed in some Azorean islands. From the methods used, the authors chose the treatment with urea, together with the chemical treatment carried out, allows an enrichment of forage's nitrogen levels.

Much has been speculated about the mode of action of ammonia on the straw. It is accepted that reticulum-rumen's bacteria attack the free cellulose by cellulases, but are not able to break the connection lignin-cellulose. Thus, the ammonia will have on the cell walls an action which results in the rupture of the xylan chains and a physical action whose effect is an increase in the capacity of absorption of water. Since the cell wall carbohydrates and lignin account for over 70% of the organic matter of straw, those combined effects lead to increased solubility of the organic matter in the reticulum-rumen, therefore, its availability for microbial fermentation, increasing the nutritional value (Borba, 2006).

The ammonification of low quality forages results in an increased intake (20 to 40%) due to the decrease in rumen retention time and increased rate of passage (Balch and Champling, 1965; Thornton and Minson, 1973; Ogi et al., 1979). The increasing digestibility of dry matter, organic matter and cellulose are generally small or even zero in medium quality forage. The increase in digestibility of organic matter resulting from the ammonification, due to the increased digestibility of ADF and NDF fraction by breaking the links between hemicellulose and lignin (Ogi et al., 1979). According Fadel et al. (2004), the rice straw ammonification translates into an increase of digestibility of dry matter of 55.16 to 62.12%, which may be due to increased hydration rate of the treated straw and / or the effect on flexibility, solubility and fragility of treated straw.

The authors' treatments with urea used a concentration of 5% of the dry matter. Ideal urea application rates are arguable. Among the concerns urea utilization raises are its toxicity (Brandini, 1996) and its influence on rumen motility (Goularte et al., 2010). It is widely accepted that the optimal application rates are between 4 and 6 kg urea per 100 kg DM. The most used application rate is 5 kg (Schiere and Ibrahim, 1989). However, Quashie (2014) states that for the treatment of rice straws, the optimum concentration of urea is 6.5% DM, in a treatment of 21 days at a humidity of 40%. Carvalho et al. (2006) concluded that when treating the sugarcane with increased levels of urea, the minimum level of PB that provided a rumen function was 7%, obtained with the addition of 2.62% urea. But also they found that levels of 5.0 and 7.5% urea (9.91 and 12,985 respectively) have contributed to the growth of microbial population and thus to a better feed efficiency.

After data analysis, concerning dry matter values (Figure 1), there is a statistically significant decrease ($P<0.05$) of dry matter content with the treatment: urea 5 days of treatment (U5) to urea 10 days of treatment (U10) and 15 days of treatment (U15) as compared to the control (C). Similar results were found by other authors, including Kohdaparast et al. (2011), Wanapat et al. (2013) and Hassan et al. (2011). For the zero hour treatment level (U0) there were no significant differences ($P>0.05$) in the dry matter content, which also is pointed out by different authors (Oluokun, 2005; Aregawi et al., 2013) and even Akraim et al. (2013) reported an increase in dry matter of barley straw treated with urea. t refer to the appearance of molds to a greater or lesser extent in prolonged treatments.

The crude protein shows an increase with the addition of urea (Figure 2), and it was found that this treatment is greatest in U0, similar results were found by Moselhy et al. (2015). The explanation for this in our opinion is due to the fact of not having been a ureolysis so intense, since there was no time treatment, the sample was dried over urea immediately after addition. Long treatments with urea originate proteolysis, which leads to a loss of nitrogen in ammoniacal form by evaporation.

The increase in the content of crude protein in samples treated with urea is mentioned by several authors being one of the advantages of this method of chemical treatments in relation to others, such as treatment with sodium hydroxide (Sirohi and Rai, 1999; Oluokun, 2005; Kohdaparast et al., 2011; Akraim et al., 2013; Aregawi et al., 2013).

Treatments with other fibrous forages including straw were carried out in a sealed environment to prevent volatilization of the ammonia. In our case, the boxes where the treatments were performed were not airtight, making gas exchange with the exterior possible and ammonia volatilization may thus have occurred.

Regarding fiber in particular NDF and ADF values (Figure 3 and 4), in general, there was not a noticeable action of urea, Oluokun (2005) also did not found changes on fiber while Kohdaparast et al. (2011) disclose variations of NDF from 79.2 to 78.8% and of ADF from 58.8 to 60.6%, in canola straw treated with 4% urea. Other authors have reported significant decreases in the two fractions is the case of Hassan et al. (2011), Aregawi et al. (2013) and Akraim et al. (2013).

With regard to the ADL values (Figure 5), they revealed a significant increase ($P<0.05$) in U0 and U5 treatments compared to control. Aregawi et al. (2013), report a non-significant decrease in ADL and Reis et al. (2001) reported significant decreases ($P<0.05$) ADL, in hay treated with urea in a 5.4% DM.

Figures 6 and 7 refer to cellulose and hemicellulose respectively, the authors can see a trend of decreased cellulose, relative to the control, although this is not

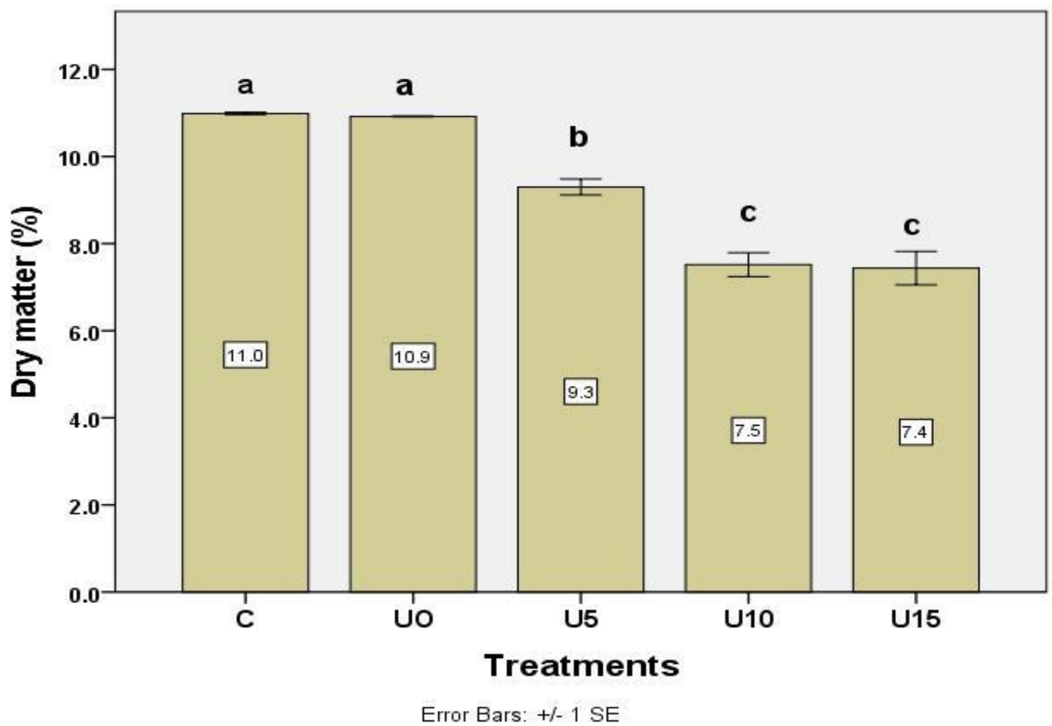

Figure 1. Effect of treatment on the average dry matter content of *Hedychium gardnerianum* forage. Averages that display the same index are not significantly (P<0.05) different. Error bars represent the standard error.

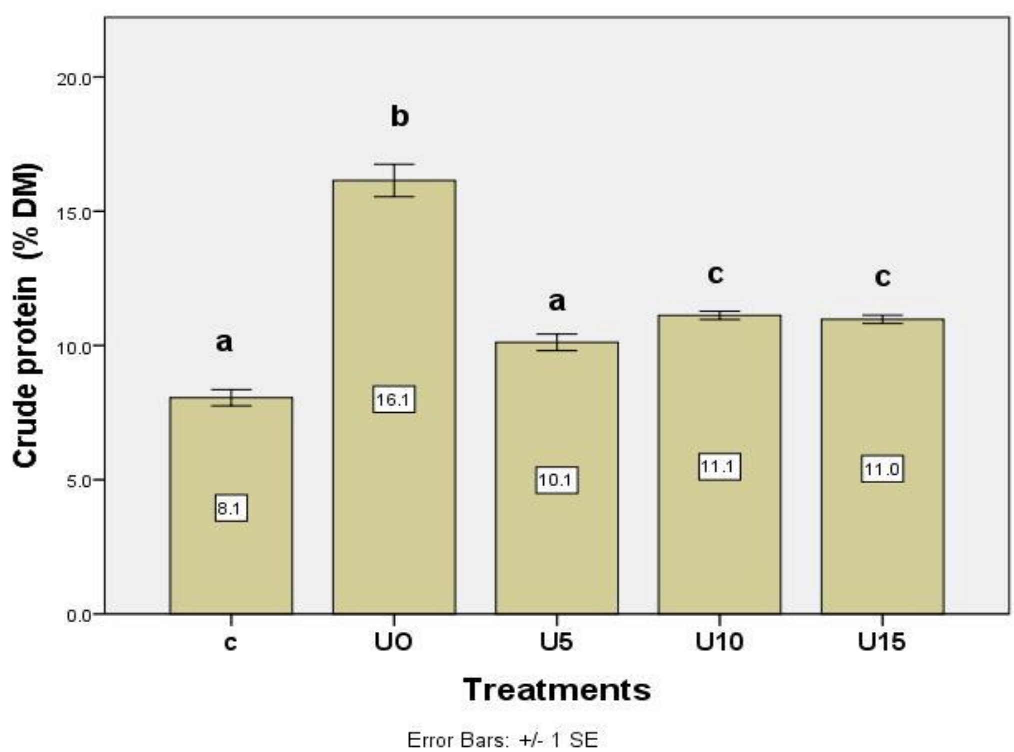

Figure 2. Effect of treatment on the average Crude Protein content of *Hedychium gardnerianum* forage. Averages that display the same index are not significantly (P<0.05) different. Error bars represent the standard error.

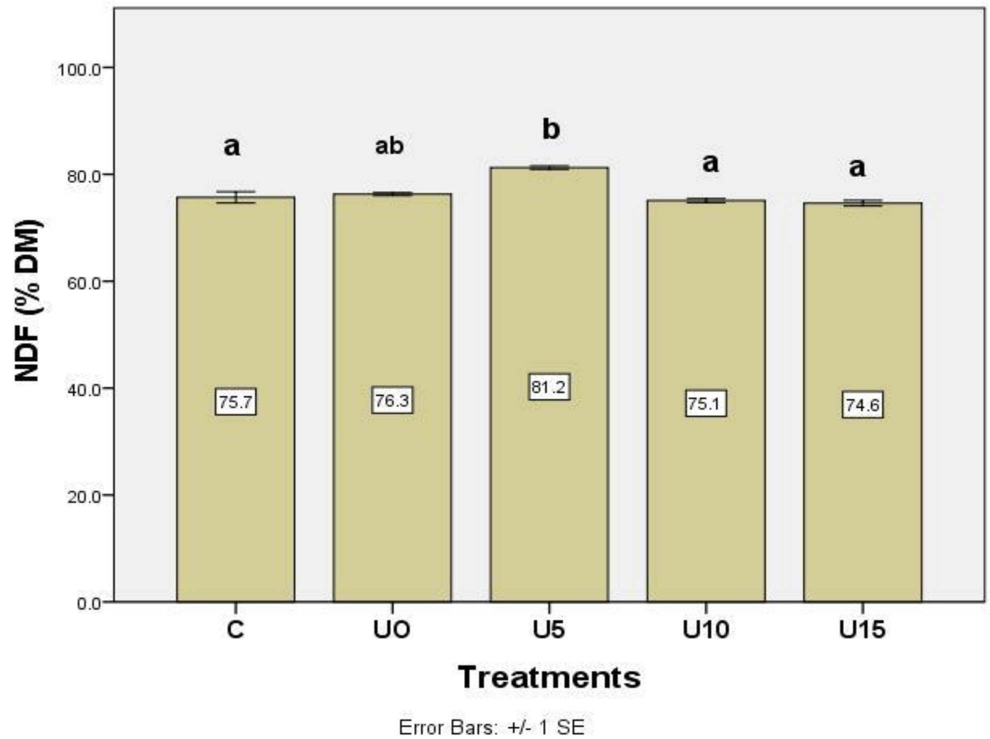

Figure 3. Effect of treatment on the average NDF content of *Hedychium gardnerianum* forage. Averages that display the same index are not significantly (P<0.05) different. Error bars represent the standard error.

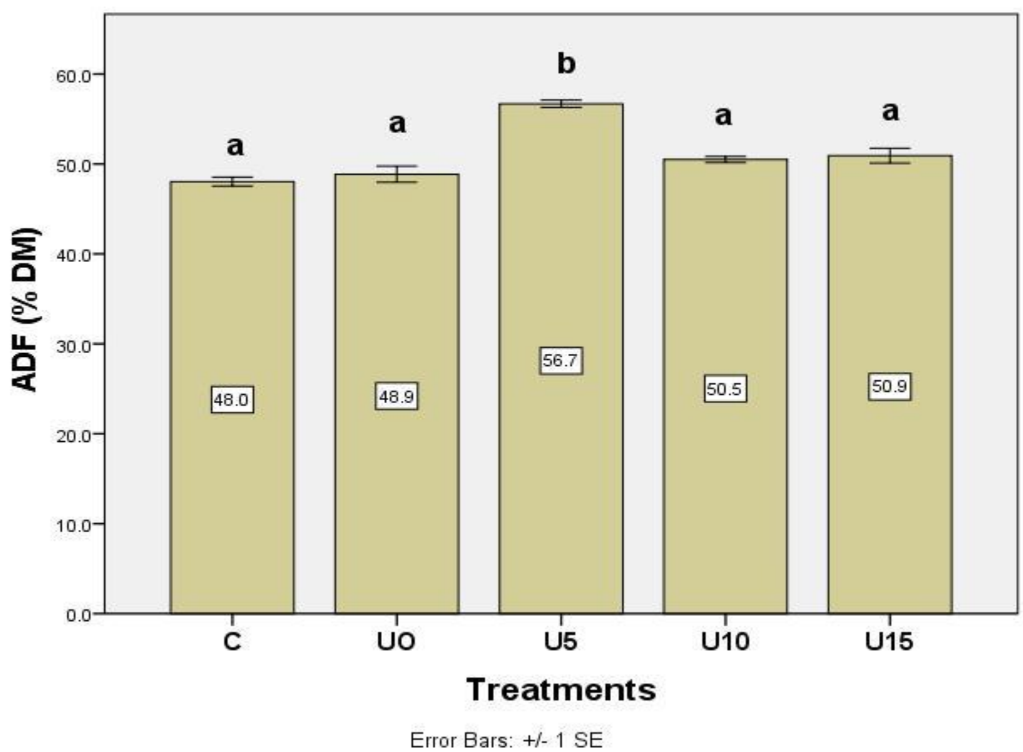

Figure 4. Effect of treatment on the average ADF content of *Hedychium gardnerianum* forage. Averages that display the same index are not significantly (P<0.05) different. Error bars represent the standard error.

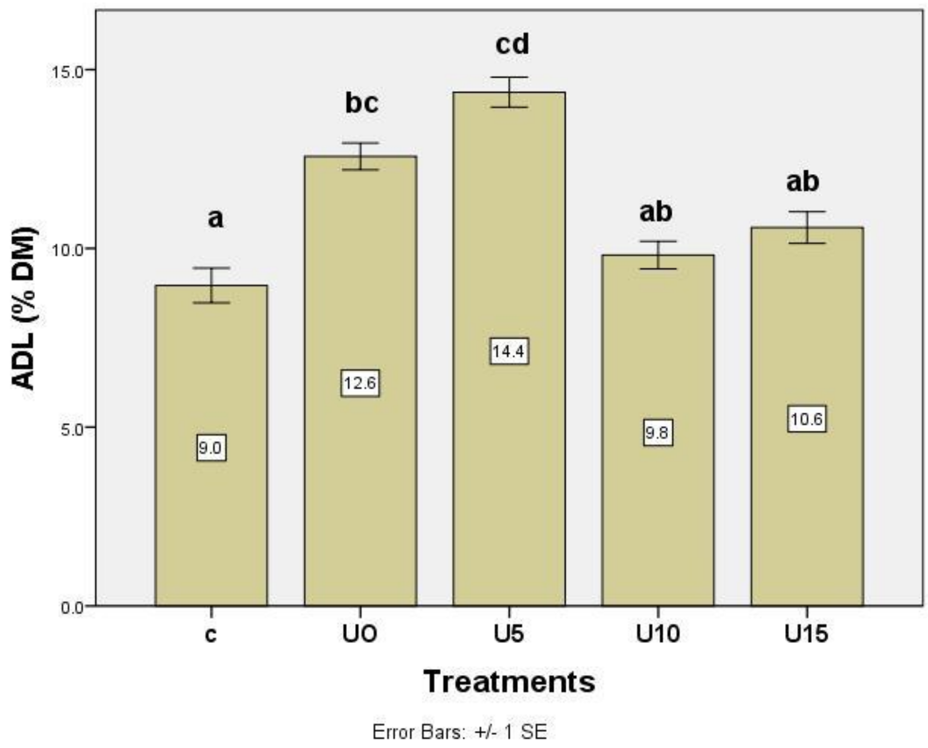

Figure 5. Effect of treatment on the average ADL content of *Hedychium gardnerianum* forage. Averages that display the same index are not significantly (P<0.05) different. Error bars represent the standard error.

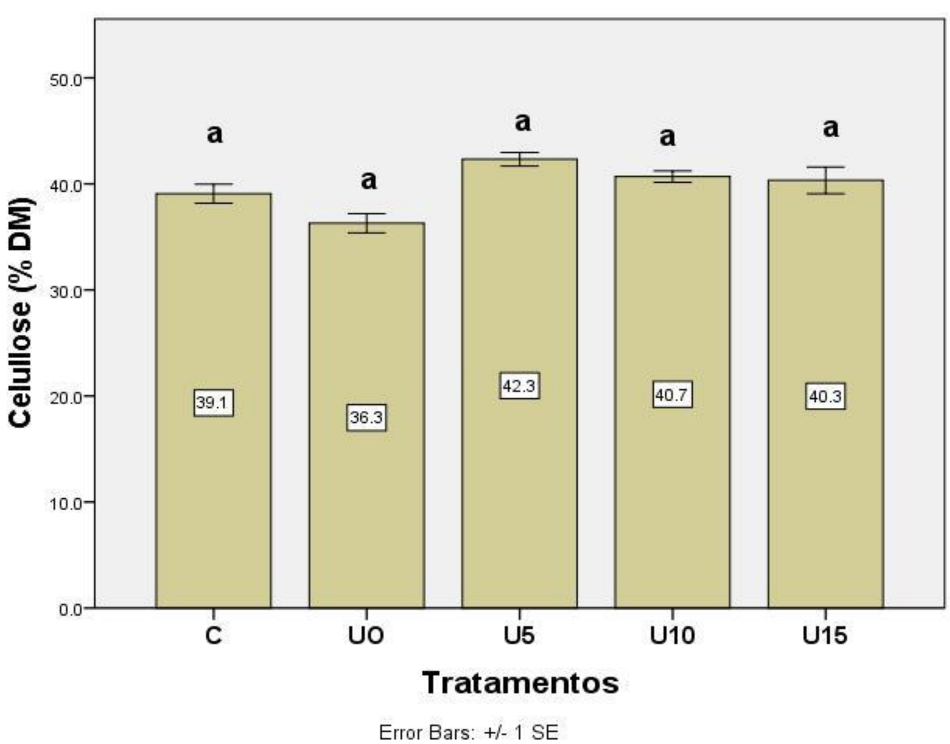

Figure 6. Effect of treatment on the average cellulose content of *Hedychium gardnerianum* forage. Averages that display the same index are not significantly (P<0.05) different. Error bars represent the standard error.

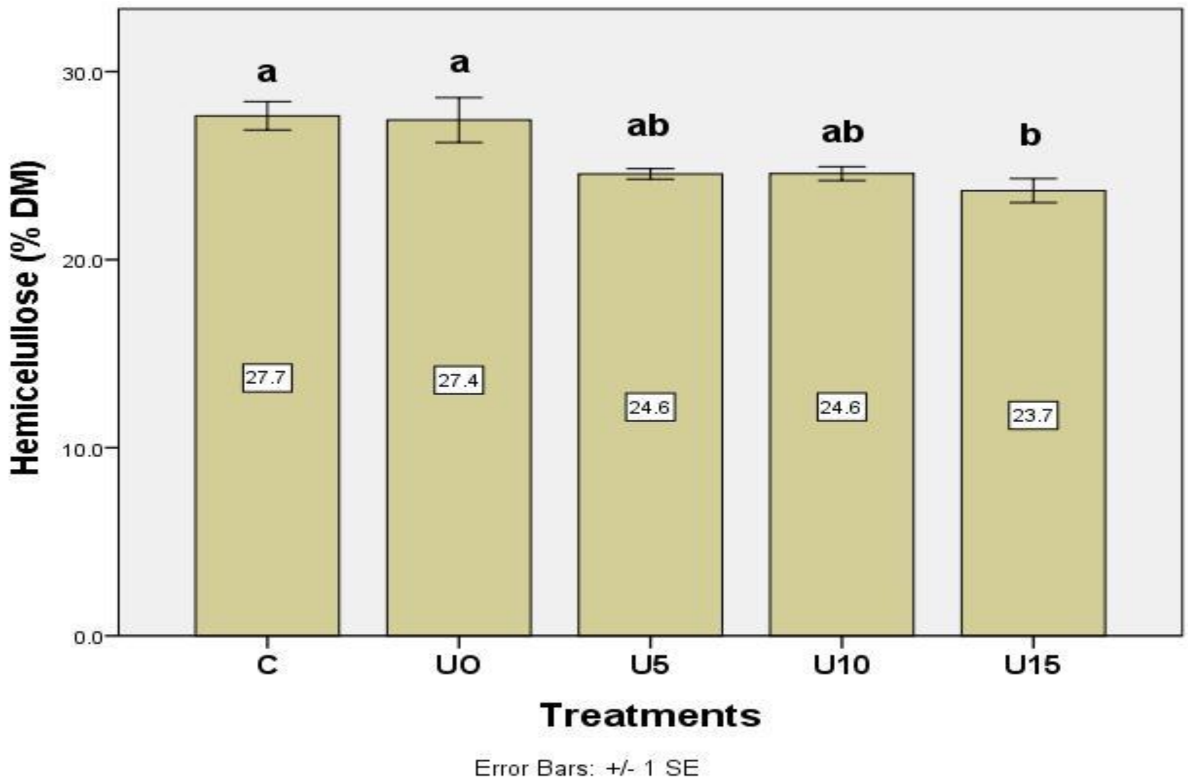

Figure 7. Effect of treatment on the average Hemicellulose content of *Hedychium gardnerianum* forage. Averages that display the same index are not significantly (P<0.05) different. Error bars represent the standard error.

statistically significant. The same tendency is observed for hemicellulose, most relevant in the sample treatment U15, the one that is statistically (P<0.05) different from control. Aregawi et al. (2013) who observed a significant (P<0.01) decrease in the hemicellulose and cellulose on their treatments of sesame straw. Reis et al. (2001) reported significant decreases (P<0.05) from the hemicellulose but not observe any effect of the treatment on the content of the hay cellulose and lignin.

In Figure 8, the Ash values of U10 and U15 treatments showed a statistically different percentage (P<0.05) increase in the treatment with urea when compared to U5 treatment. These results are in agreement with report by some authors such as Oluokun (2005), Hassan et al. (2011) and Akraim et al. (2013). However, Kohdaparast et al. (2011) observed maintaining the Ash values of canola straw treated with 4% urea.

As regards to digestibility of dry matter (Figure 9), a significant difference (P<0.05) between the U0 and U5 treatments may be explained by the content of crude protein, as indicated by Jarrige (1987), which argues the complement of fibrous foods with nitrogen increases the nitrogen constituents degraded in the reticulum-rumen, which provides a nitrogen source for microbial population, thus increasing their activity. This trend is also observed for the digestibility of organic matter (Figure 10) in a more relevant way.

Treatment with ammonia will result in additional enrichment in non-protein nitrogen of importance for the reticulum-rumen microbiota in feeds with low nitrogen content such as straw. Treatment with ammonia almost doubles the nitrogen content in straw. However, other authors mention that the effects of urea treatment are more visible when the forage has crude protein content below 7% (Lazzarini et al., 2009). Below this level, the microbial activity in the rumen is severely limited. For this reason, the treatment with urea results in straws in a significant increase in digestibility. Wanapat et al. (2013), observed a significant increase (P<0.01) in Dry Matter digestibility when treating rice straw (2.7% CP on a DM basis) with 3% urea on a DM basis. Hassan et al. (2011) describe a significant increase in DM digestibility (P<0.05) in wheat straw fermented with 4% urea and 4% molasses, with an initial CP value of 2.90 and a final value of 15.18. Sirohi and Rai (1999) observed synergy between urea and lime (powder) in the treatment of wheat straw, which efficiently increased the content of CP, the *in vitro* and *in sacco* digestibility of DM and OM, in an optimal treatment concentration of 4% urea and 4% lime. Aregawi et al. (2013) indicate an increase from 34.8 to 43.5% when treating sesame straw with 4% urea.

Urea treatment is regarded in general as an effective treatment method for low quality fiber foods such as straw and thus upgraded their nutritional value. As

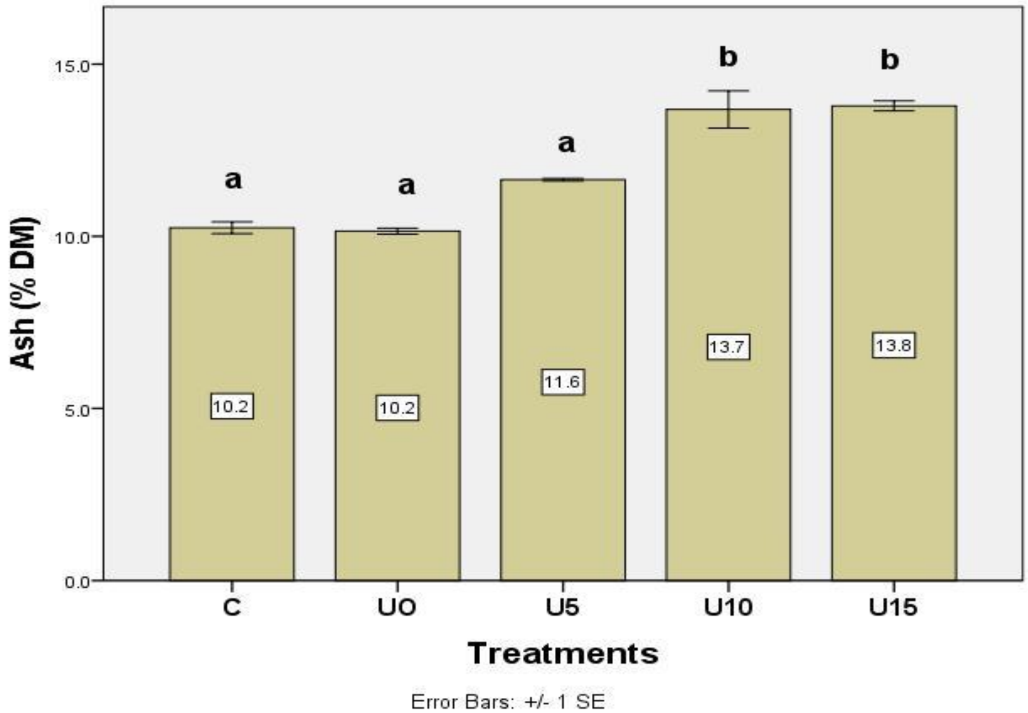

Figure 8. Effect of treatment on the average Ash content of *Hedychium gardnerianum* forage. Averages that display the same index are not significantly (P<0.05) different. Error bars represent the standard error.

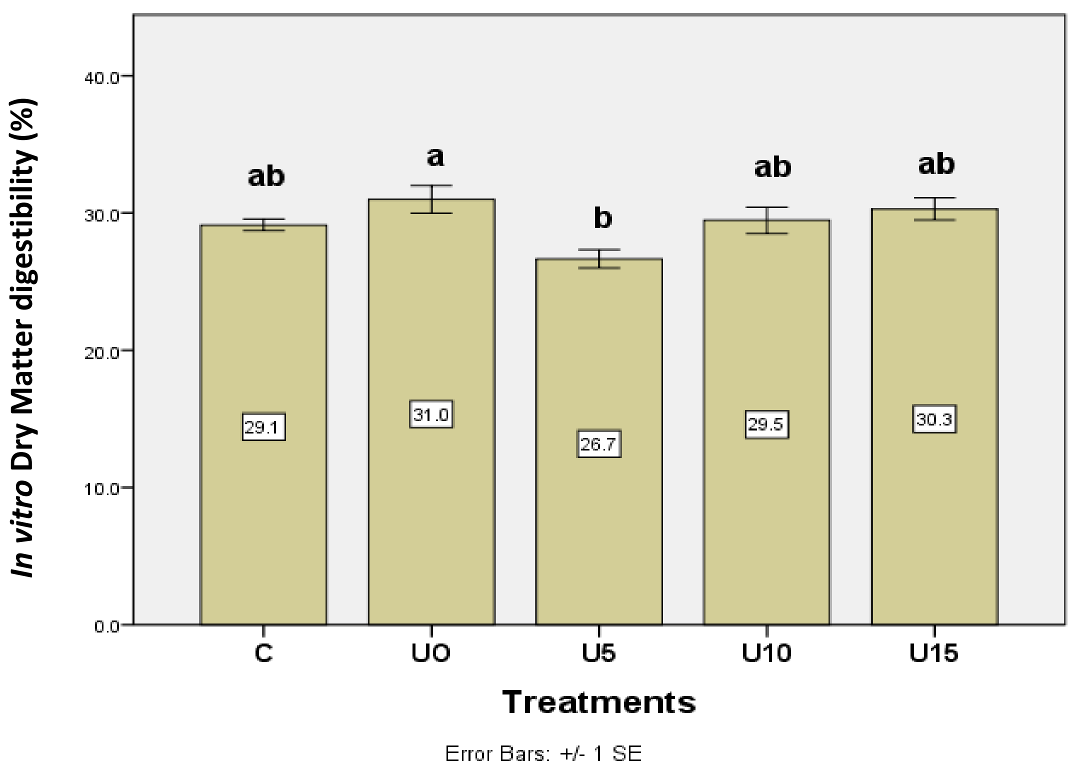

Figure 9. Effect of treatment on the average *in vitro* digestibility of dry matter of *Hedychium gardnerianum* forage. Averages that display the same index are not significantly (P<0.05) different. Error bars represent the standard error.

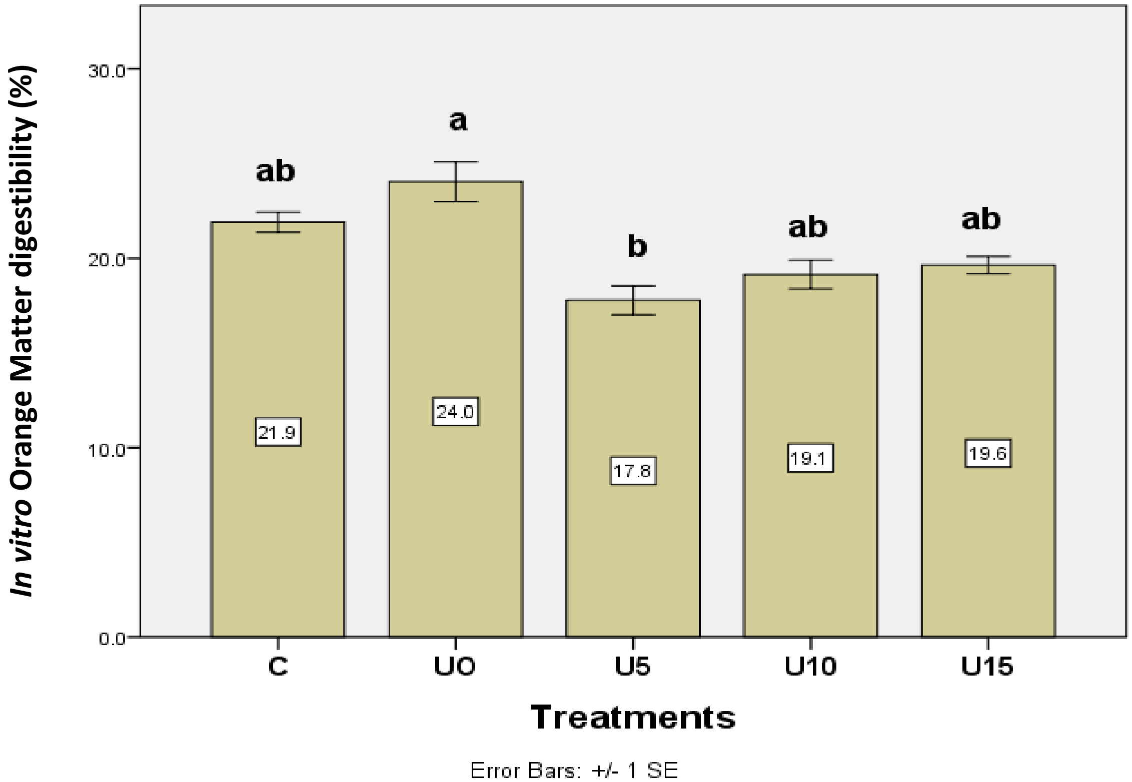

Figure 10. Effect of treatment on the average *in vitro* digestibility of organic matter of *Hedychium gardnerianum* forage. Averages that display the same index are not significantly (P<0.05) different. Error bars represent the standard error.

mentioned in Jabbar et al. (2009), different variants have been used in this treatment with the aim of simplifying their usage by farmers. Polyorach and Wanapat (2014) concluded that this is a simple, affordable method for the nutritional valorization of straw in an assay that involved treatment with urea and calcium hydroxide.

In a comparative study on the effect of various treatments (anhydrous ammonia, urea, sodium hydroxide and calcium hydroxide) on the nutritional value of roughage, Pires et al. (2010) concluded that sodium hydroxide and calcium hydroxide show a higher efficiency on reducing the content in cell wall materials and increasing the digestibility of the treated roughage than anhydrous ammonia and urea.

The crude protein content of ginger lily is above 7% level required for the normal functioning of the rumen microbiota, as reported by Lazzarini et al. (2009). In our understanding, this accounts for the low effect of urea addition on its nutritional value.

In the present assay, urea treatment was carried out on green forage with high water content, a CP content of 8.05% DM in non-hermetic plastic containers according with the methodology of Quashie (2014). Treatments with sodium hydroxide shall also be performed in the future to assess whether treating with this alkali would afford a greater efficiency in the degradation of *H. gardnerianum* cell wall.

Conclusions

H. gardnerianum is poor and low nutritional level forage. To allow for its use as a fiber feed for ruminants, it is important to find a simple method to improve its nutritional value. When used in green forage, urea treatment does not have the same effect as when it is applied to low-quality fiber feeds, such as straw, since ginger lily has a much higher Crude Protein value than straw. This is possibly the main conclusion that can be drawn from this present work.

New treatments should be envisaged using dried ginger lily, not only by applying urea, but also sodium hydroxide, which should have a more pronounced effect on the degradation of the cell wall of this forage, thus improving its nutritional value.

Conflict of interests

The authors have not declared any conflict of interests.

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