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NUTRITIONAL VALUE OF *OPUNTIA FICUS-INDICA* CLADODES FROM PORTUGUESE ECOTYPES

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Abstract

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The use of *Opuntia ficus-indica* cladodes as a forage for ruminants has been very important in the semi-arid and arid regions of the world. *O. ficus-indica* cladodes can be fed to small ruminants especially in periods of the year when there is low quality and quantity of pasture. In Mediterranean regions like South of Portugal during the rainy season the availability of pasture is quantitatively and qualitatively satisfactory, but in critical times of the year the shortage and low nutritive value of forages causes decreased productivity in the ruminant's production of milk and meat. The aim of this study was to evaluate the nutritional profile of the cladodes from five different Portuguese ecotypes of O. *ficus-indica*, in comparison with cultivar "Gialla", and also evaluate its potential use as a feed for ruminants. Among populations' significant differences were found in crude protein and ash content, and different groups were unfolded. In general, *O. ficus-indica* has a low content of DM, CP and NDF and high content in NFC and EM. Given the importance that DM, PB and the NDF have for nutrition and feeding of ruminants we conclude that *O. ficus-indica* can be used in feeding small ruminants provided that animals have access to dry forage and a feed source with high CP content. Used as fodder, *O. ficus-indica* seems to be an optional interesting feed for small ruminants in driest period of the year.

Keywords: Opuntia ficus-indica, spineless cactus, nutritive value, animal feed, Mediterranean region

List of abbreviations: ADF – acid detergent fiber; ADL – acid detergent lignin; CP – crude protein; cv – cultivar; DM – dry matter; ME – metabolizable energy; NDF – neutral detergent fiber; NFC – non fiber carbohydrates; OFI – *Opuntia ficus-indica*; TDN – total digestible nutrients

Introduction

Opuntia ficus-indica (L.) Miller is a species from the Cactaceae family with the center of origin and domestication in Mexico. It is widely distributed in other regions of the World, such as Africa, Australia and Mediterranean basin, where it grows in the most diverse ecological conditions (Sáenz et al., 2006). The introduction of this species in Iberian Peninsula has occurred, probably at the end of the 15th century, after the discovery of America, spreading later throughout the Mediterranean basin (Le Houerou, 1996; Kiesling, 1998; Anderson, 2001). In Portugal, *O. ficus-indica* is located, usually, with a typical ruderal behavior, at the edge of roads and paths. Cultivated due to edible fruits and hedges establishment, it is widely naturalized (Reis et al., 2014). The two forms of the species, *O. ficus-indica* f. *inermis* Weber and *O. ficus-indica* f. *amyclaea* (Ten.) Schelle are found in Portugal, occurring also intermediate types regarding the spines presence. In Portugal, as in other Mediterranean regions, inlands areas are under severe drought during extensive summers, in particular, and global warming is expected to affect them deeply in the near future. *O. ficus-indica,* by its morpho-physiological characteristics and multiple economic uses, represent an alternative crop for those regions.

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The use of OFI cladodes as a forage for ruminants has been very important in the semi-arid and arid regions. In these areas, long drought periods are common with high summer temperatures and low winter temperatures. These factors cause both low forage production and availability. In Mediterranean regions like South of Portugal during the rainy season the availability of pasture is quantitatively and qualitatively satisfactory, but in critical times of the year the shortage and low nutritive value of forages causes decreased productivity in the ruminant's production of milk and meat. Cactus pear can play a stabilizing role in agriculture as it can prevent stock losses during droughts, save natural grazing from over-grazing, increase farm income and alleviate poverty in rural areas. Although it has been considered poor in terms of crude fiber and crude protein, *O. ficus-indica* is considered to be high in *in-vitro* digestibility and in water content and it is often the only source of green forage in the dry season (Silva and Santos, 2007). According Suñigiga (1980), these plants have good palatability and high humidity content.

A strategy often used for improving the performance of ruminants in Mediterranean and semiarid regions is adequate feed management during periods of scarce forage. In some cases were used cactus pear as a forage to feed sheep (Ben Salem and Smith, 2008; Rekik et al., 2010; Costa et al., 2012), dairy goats (Costa et al., 2009; Andrade-Montemayor et al., 2011) and dairy cows (Silva and Santos, 2007; Vilela et al., 2010). Other authors evaluated the cactus pear supplementation and its contribution as a source of water for sheep (Tegegne et al., 2007) and dairy goats (Costa et al., 2009).

There is lack of information regarding the nutritional value of the cladodes from different Portuguese ecotypes of *O. ficus-indica*. The aim of this study was to evaluate the nutritional profile of the cladodes from these ecotypes, in comparison with cultivar (cv) "Gialla", and also evaluate its potential use as a feed for ruminants. The results will be compared among themselves and with published values.

Materials and Methods

On April 2012, mature cladodes of OFI were collected in fifteen individuals from five different ecotypes growing in the Center and Southern regions of Portugal (Table 1). Fifteen cladodes of each population were single planted during May 2012 at Scholl of Agriculture of Castelo Branco, Portugal (39º 49' 17.00'' N; 7º 27' 41.00'' W, elev. 365 m). The cv "Gialla was included as comparison term. All of them are spineless cactus (*O. ficus-indica*).

The experimental design consisted of a randomized complete block design with three replicates, each replicate consisting of a row of 5 plants. The plant spacing was 1.5 x 2.5 m (2667 plants/ha). The experiment was carried out in a granitic soil type, with pH 6.1 and low content of organic matter. Nitrogen, phosphorus and potassium fertilizers were applied at the rate of 40 kg/ha each to reduce possible differences in soil fertility. No irrigation, as no tillage was used. Weeds were controlled by mechanical mowing at each three months.

The Köppen-Geiger climate classification for Castelo Branco is Csa. The average annual temperature in Castelo Branco is 15.9°C. July and August are the driest and hottest months with temperatures above 24ºC, on average. The months of December, January, and February are the coldest with average temperatures below 10ºC. About 783 mm of precipitation falls annually. In winter there is much more rainfall than in summer. Most precipitation falls in December, with an average of 124 mm.

One sample from each of the three replicates was collected in September 2013 (end of dry season). Each sample was a composite of one-year-cladodes randomly harvested in five individuals of each ecotype. In the Laboratory cladodes were cut into 25 cm^2 pieces using a sharp knife. All the cladode pieces were cut into two halves to facilitate drying, and then were dried in a force draught oven at 65ºC (± 5ºC) during 72 hours to constant mass. First moisture was determined and cladodes pieces were milled through a laboratory mill with a one millimeter sieve. The dried plant material was stored in tightly sealed plastic bottles for later chemical analysis.

Each cladode sample were chemical analyzed for total dry matter (DM), total ash (Ash), crude protein (CP) and ether extract (EE) according AOAC (2000) and neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) according to the procedures described by Van Soest et al. (1991). The CP was calculated as taken percent nitrogen by 6.25 (Ruddell et al., 2002). Hemicellulose was determined by difference from NDF – ADF and cellulose was determined by the difference from ADF – ADL. Non fiber carbohydrates (NFC) was calculated by difference whereby the sum of NDF, CP, EE and Ash in percentage are subtracted from 1000 [NFC (g/kgDM) = 1000 – (CP + EE + Ash + NDF)] (NRC, 2001). Total digestible nutrients (TDN) was calculated

Table 1
Origin of the populations of *Opuntia ficus-indica* studied

Ecotype/cultivar	Origin	Altitude, m
PT1 ecotype	Portalegre	372
PT2 ecotype	Arronches	293
PT3 ecotype	Cacela-a-Velha	20
PT4 ecotype	Monforte da Beira	260
PT5 ecotype	Idanha-a-Velha	275
"Gialla" cultivar	Sesimbra	150

by prediction equation described by Bath and Marble (1989) cited by Coppock (1997) [TDN (%) = 82.38 – (0.7515 x ADF %)]. Metabolizable energy (ME) for ruminants was calculated by prediction equations proposed by NRC (2007) [ME (MJ/kgDM) = (TDN% x 3.6)/100 x 4.184]. With respect to the original equation, this formula includes DM x 4.184 that account for conversion ME data from Mcal to MJ.

Data were subjected to analysis of variance (ANOVA) using the General Linear Model available in IBM SPSS version 21 and Tukey test was used to detect significant differences (P < 0.05) among treatment means.

Results and Discussion

The average nutritional value of the cladodes from the different populations of *O. ficus-indica* studied is presented in Table 2.

No statistically significant difference was found between the DM of the different samples. Considering the DM values reported for cactus by NRC (2007) (26%) and Cordova-Torres et al. (2009) (15.5 to 16.5%) the average DM content of the different OFI populations studied (13.75% ± 1.24) was generally low. The highest DM content (14.58% ± 1.14) was observed for the PT2 ecotype and the lower DM content was observed in PT1 ecotype (12.85% ± 1.62). However our results are higher than those reported by Mciteka (2008) (9.13% DM), Fuentes-Rodriguez (1997) (11.3% DM), Rekik et al. (2010) (9.7% DM), Tegegne et al. (2007) (12.2% DM) and are in the same range values when compared with the results reported by Andrade-Montemayor (2011) (8 to 15% DM), Silva and Santos (2007) (7.62 to 14.4% DM) and Costa et al. (2009) (10 to 14% DM). The differences may be explained by variations in the age of the analyzed cladodes, harvest time and variation at genotype level. Dry matter content tends to in-

Table 2
Nutritional value of the *Opuntia ficus-indica* cladodes, on a dry matter basis, in the different populations studied

	PT1ecotype	PT2ecotype	PT3ecotype	PT4ecotype	PT5ecotype	cv "Gialla"	Total
DM, %	12.85 ±1.62	14.58 ±1.14	14.10 ±0.67	13.03 ±0.86	13.74 ±0.86	14.17 ±1.43	13.75^{ns} ±1.24
ME, MJ/kgDM	11.16 ±0.20	11.26 ±0.42	11.27 ±0.08	11.17 ±0.15	11.38 ±0.16	11.24 ±0.13	11.24^{ns} ±0.22
TDN, %	73.79 ±1.324	74.41 ±2.78	74.48 ±0.56	73.83 ±1.01	75.20 ±1.08	74.31 ±0.83	74.34^{ns} ±1.43
CP, g/kgDM	69.94^{b} ±1.13	72.57^{ab} ±7.37	82.52^{a} ±9.55	78.44^{ab} ±7.74	68.01^{b} ±5.11	72.45^{ab} ±8.11	73.99 ±8.26
EE, g/kgDM	15.71 ±1.24	15.65 ±2.95	14.43 ±1.01	13.58 ±1.91	14.10 ±1.51	14.70 ±0.62	14.70^{ns} ±1.77
NDF, g/kgDM	198.99 ±13.35	183.85 ±37.66	186.05 ±28.90	198.05 ±31.75	164.67 ±16.12	179.30 ±13.23	185.15^{ns} ±26.33
Hem, g/kgDM	84.65 ±18.94	77.78 ±4.33	80.97 ±24.50	84.26 ±21.54	69.19 ±17.89	71.85 ±13.98	78.12^{ns} ±17.76
ADF, g/kgDM	114.35 ±17.62	106.06 ±36.97	105.08 ±7.39	113.79 ±13.43	95.49 ±14.32	107.45 ±11.00	107.04^{ns} ±18.99
Cel, g/kgDM	105.82 ±19.65	96.83 ±32.06	94.30 ±6.03	105.54 ±12.04	88.33 ±11.81	98.33 ±9.83	98.19^{ns} ±17.33
ADL, g/kgDM	8.52 ±2.49	9.24 ±5.13	10.79 ±2.69	8.25 ±1.89	7.16 ±2.65	9.12 ±2.09	8.85^{ns} ±3.01
NFC, g/kgDM	629.63 ±23.32	641.77 ±42.32	636.87 ±19.95	612.38 ±50.98	665.58 ±13.05	641.70 ±15.55	637.99^{ns} ±32.87
Ash, g/kgDM	85.73^{ab} ±11.57	86.17^{ab} ±5.86	80.12^{b} ±4.98	97.55^{a} ±11.48	87.63^{ab} ±5.17	91.85^{ab} ±8.25	88.18 ±9.49

$^{a\ b}$ – Means with different alphabetic superscripts in same line differ significantly (P<0.05); ± standard deviation; ^{ns} – P>0,05; DM – dry matter; ME – metabolizable energy; TDN – total digestible nutrients; CP – crude protein; EE – ether extract; NDF – neutral detergent fiber; Hem – hemicellulose; ADF – acid detergent fiber; Cel – cellulose; ADL – acid detergent lignin; NFC – non fiber carbohydrates.

crease with the age of the cladode (Tegegne, 2001). The high water content of the *Opuntia* cladodes makes it a bulky feed and therefore, poses a real problem when it has to be transported over long distances. However, the high-water level in cactus pear represents an important alternative to supply water requirements of animals in arid and semi-arid regions, where water may be a limiting factor for animal production. Water intake on dairy goats is markedly reduced when cactus pear is part of the diet (Costa et al., 2009). Nefzaoui and Ben Salem (1998) showed that water intake from free available water is zero when the daily cladodes consumption by sheep is about 300 g of dry matter.

The results in Table 2 indicated that there were no significant differences (P > 0.05) in ME and TDN contents among different OFI ecotypes and cv "Gialla". The ME content varied between 11.16 MJ/kgDM (± 0.20) for PT1 ecotype and 11.38 MJ/kgDM (± 0.16) for PT5 ecotype and the TDN content varied between 73.79% (± 1.324) (PT1 ecotype) and 75.20% (± 1.08) (PT5 ecotype). Our results are higher for ME considering NRC (2007) (9.62 MJ/kgDM) and Costa et al. (2012) (9.2 MJ/kgDM) as well for TDN are higher than range values 60.8%-68.6% (NRC, 2007; Vilela et al., 2010; Costa et al., 2012).

According to the results shown in Table 2 the OFI populations studied showed statistically significant differences for CP content (P < 0.05) which varied between 68.01 g/kgDM (± 5.11) (PT5 ecotype) and 82.52 g/kgDM (± 9.55) (PT3 ecotype). The CP content of cv "Gialla" was 72.45 g/kgDM (± 8.11). The average CP content of the different OFI populations analyzed (73.99 g/kgDM ± 8.26) was higher than that reported by Magalhães (2004) (51.4 g/kgDM), NRC (2007) (50.0 g/kgDM), Tegegne et al. (2007) (50.6 g/kgDM), Mciteka (2008) (55.4 g/kgDM), Villegas-Diaz et al. (2008) (59.0 g/kgDM), Abidi et al. (2009) (38.0 g/kgDM), Rekik et al. (2010) (44.0 g/kgDM) and Vilela et al. (2010) (44.0 g/kgDM). Eventually, the highest values determined by us may be related to the age of the cladodes used in our study (one year old cladodes) or differences in the availability of nitrogen in the soil. Teles et al. (1997) reported a CP content of 110.3 g/kgDM, a much higher value than the results we have obtained. According to Ben Salem and Smith (2008), increasing the content of CP cladodes of OFI when it aims to feed animals should be considered in the breeding programs. Nitrogen fertilization is another possibility to reach this later objective.

The EE average contents of the different OFI ecotypes and cv "Gialla" was 14.70 g/kgDM (± 1.77) and varied between 13.58 g/kgDM (±1.91) for the PT4 ecotype and 15.71 g/kgDM (± 1.24) for the PT1 ecotype. Several authors reported values of EE between 21 g/kgDM and 23 g/kgDM (NRC, 2007; Mciteka, 2008; Vilela et al., 2010) which are highest than those determined by us and by Tegegne et al. (2007) (11.9 g/kgDM).

The NDF content varied from 164.67 g/kgDM (± 16.12) to 198.99 g/kgDM (± 13.35) respectively for the ecotypes PT5 and PT1. According to the results in Table 2, the average NDF content of the different populations of OFI (185.15 g/kgDM ± 26.33) was relatively lower than the NDF content reported by NRC (2007) (290.0 g/kgDM), Tegegne et al. (2007) (238.8 g/kgDM), Vilela et al. (2010) (314.0 g/kgDM), Abidi et al. (2009) (251 g/kgDM), Rekik et al. (2010) (306 g/kgDM), Villegas-Diaz et al. (2008) (435 g/kgDM), Andrade-Montemayor et al. (2011) (460 g/kgDM) and Costa et al. (2012) (312 g/kgDM). This difference may be related with the young age of cladodes used in this study, which have lower values in the cell wall contents.

According to the results shown in Table 2 the ADF content of the different OFI cladodes varied between 95.49 g/kgDM (± 14.32) (PT5 ecotype) and 114.35 g/kgDM (± 17.62) (PT1 ecotype). Some authors reported in their studies with *O. ficus-indica* higher values ranging between 136.6 g/kgDM and 287 g/kgDM (Magalhães, 2004; NRC, 2007; Tegegne et al., 2007; Mciteka, 2008; Villegas-Diaz et al., 2008; Cordova-Torres et al., 2009; Vilela et al., 2010; Andrade-Montemayor et al., 2011; Costa et al., 2012). Both NDF and ADF contents indicate that O. *ficus-indica* cladodes could not be regarded as a sole roughage source.

In Table 2, the average hemicellulose content in this study was 78.12 g/kgDM (± 17.76). The hemicellulose content varied from 69.19 g/kgDM (± 17.89) for ecotype PT5 to 84.65 (± 18.94) for ecotype PT1. This values were lower than that reported by Costa et al. (2012) (95 g/kgDM) and higher than the value reported by NRC (2007) (60.0 g/kgDM). The average cellulose content (98.19 g/kgDM ± 17.33) was lower than 131.8 g/kgDM (Tegegne et al., 2007) and 123 g/kgDM (Vilela et al., 2010) (Table 2). The cellulose content of the different OFI populations varied between 88.33 g/kgDM (± 11.81) (PT5 ecotype) and 105.82 g/kgDM (± 19.65) (PT1 ecotype) (Table 2).

The highest ADL content was recorded for PT3 ecotype (10.79 g/kgDM ± 2.69) and the lowest for PT5 (7.16 g/kgDM ± 2.65) (Table 2). Our results are lower than the values reported by Tegegne et al. (2007) (30.6 g/kgDM) and Vilela et al. (2010) (32 g/kgDM).

The results in Table 2 showed that the NFC content varied from 612.38 g/kgDM (± 50.98) (PT4 ecotype) to 665.58 g/kgDM (± 13.05) (PT5 ecotype). These results are higher than values reported in other studies which varied between 469 g/kgDM and 530 g/kgDM (Magalhães, 2004; NRC, 2007; Tegegne et al., 2007; Vilela et al., 2010; Costa et al., 2012).

There were significant differences (P < 0.05) in ash content between different OFI populations (Table 2). The ash content varied between 80.12 g/kgDM (± 4.98) to 97.55 g/kgDM (± 11.48). Several authors reported that ash content of *Opuntia* cladodes may vary between 131 g/kgDM and 255 g/kgDM (Fuentes-Rodriguez, 1997; NRC, 2007; Tegegne et al., 2007; Mciteka, 2008; Andrade-Montemayor et al., 2011).

Conclusions

Analyzing the results obtained we conclude that among the Portuguese populations of *O. ficus-indica* studied the ecotype PT3 was the most suitable for feeding ruminants. The cladodes of this ecotype are spineless and also have higher CP and EM levels when compared to the other Portuguese ecotypes and cv "Gialla". In general, *O. ficus-indica* has a low content of DM, CP and NDF and high content in NFC and EM. Given the importance that DM, CP and the NDF have for nutrition and feeding of ruminants we conclude that the *O. ficus-indica* can be used in feeding small ruminants provided that animals have access to dry forage and a feed source with high CP content. Used as fodder, *O. ficus-indica* seems to be an interesting feed option for small ruminants in driest period of the year, when there is low quality and quantity of pasture. If the main purpose of cladodes production is roughage for ruminants feeding, potential breeding programs should be focused on the ecotype PT3 and its CP and NFC content.

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