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Season and rainfall gradient effects on condensed tannin concentrations of woody rangeland species

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ABSTRACT

Shrubs and trees in warm climate rangelands play multiple roles including providing ruminants with forage. Condensed tannins (CT) in these species can have negative and positive effects on those ruminants so quantifying them is crucial to their management. The objective of this study was to measure CT concentrations of key woody perennials during distinct seasons in Pernambuco, Brazil. The species were collected along a 432 to 607 to 1200-mm rainfall gradient. When season differences were identified, CT concentration declined ($P \leq 0.05$) during the dry season compared to the rainy season. There was distinct correlation in CT concentration and aridity with dissimilarity cluster formation. *Myracrodruon urundeuva* Allemão [62.3 ± 8.5 g kg^{-1} dry matter (DM)] and *Schinopsis brasiliensis* Engl. (61.53 ± 14.8 g kg^{-1} DM) had the greatest ($P \leq 0.05$) concentration of CT while *Cordia leucocephala* Moric (10.9 ± 10.9 g kg^{-1} DM) and *Oxalis insipid* St. Hil. (19.3 ± 8.2 g kg^{-1} DM) had the least. Conservation or reseeding these species in rangeland may depend on whether their CT concentrations are beneficial to wildlife or domesticated livestock.

Key words: Folin-Denis method, forage, phenolics

Efeito do gradiente de precipitação e da época do ano sobre a concentração de taninos condensados em espécies lenhosas nativas da Caatinga

RESUMO

Arbustos e árvores nas pastagens nativas de clima quente desempenham múltiplas funções, incluindo o suprimento de forragem para os ruminantes. Os taninos condensados (TC) nestas espécies podem ter efeitos negativos e positivos nos ruminantes e por isso é importante quantificá-los para adequada utilização. O objetivo deste estudo foi medir as concentrações de TC em espécies perenes lenhosas chaves durante diferentes épocas do ano em Pernambuco, Brasil. As espécies foram coletadas ao longo de um gradiente de precipitação (432 a 1200 mm ano^{-1}). A concentração de TC diminuiu ($P \leq 0,05$) da estação seca para a estação chuvosa. Houve correlação distinta na concentração de TC e aridez, com formação de grupos de dissimilaridade. *Myracrodruon urundeuva* Allemão [62,3 ± 8,5 g kg^{-1} de matéria seca (MS)] e *Schinopsis brasiliensis* Engl. (61,53 ± 8,14 g kg^{-1} de MS) tiveram a maior ($P \leq 0,05$) concentração de TC, enquanto *Cordia leucocephala* Moric (10,9 ± 10,9 g kg^{-1} de MS) e *Oxalis insipida* St. Hil. (19,3 ± 8,2 g kg^{-1} de MS) tiveram a menor concentração. A conservação ou o cultivo destas espécies na Caatinga depende se as suas concentrações TC são benéficas para a vida selvagem e os animais domesticados.

Palavras-chave: método Folin-Denis, forragem, compostos fenólicos

Introduction

Arboreal and brush browse species, especially legumes, are an important feed source for ruminants in rangeland and silvopastoral systems, because at the Caatinga herbaceous layer is founded ephemeral grasses and dicotiledonous (Santos et al., 2010) and when they are perennials they provide low crude protein as at the Zona da Mata (Cavalcanti Filho et al., 2008). These perennials often contain CT that can be important for plant protection (Muir, 2011; Adams et al., 2013). These can change with biotic and abiotic stresses as well as ontology in the plant (Beelen et al., 2006; Muir, 2011; Tharayil et al., 2011; Naumann et al., 2013).

Beneficial effects of plant CT for ruminants that consume them include rumen methane emission mitigation, efficient use of ingested proteins, changes in urine N, gastro-intestinal parasite suppression, and decreases in insect larval survival in fecal material (Heckendorn et al., 2007; Oliveira & Berchielli, 2007; Terril et al., 2007; Littlefield et al., 2011; Tedeschi et al., 2014). Condensed tannins can, however, accumulate to concentrations over 20% (Wolfe et al., 2008) which can reduce palatability and produce anti-nutritional effects in ruminants (Krueger et al., 2010). Ruminant browsers are often more tolerant of CT in their diet than grazers. There is evidence that both wild and domesticated browsers temporarily neutralize CT by excreting salivary proline with high binding affinity to these compounds (Waghorn & McNabb, 2003; Shimada, 2006).

The objective of this survey was to determine CT concentration of woody perennial species with browse and agro-forestry potential in Pernambuco, Brazil. Two factors were examined: 1. the effect of season on the same species and 2. distance from the coast, roughly equivalent to increasing aridity.

Material and Methods

The collection of plant material was undertaken on the Instituto Agronômico de Pernambuco's research centers at Itambé, Caruaru and Serra Talhada, Brazil. Itambé is located within the northern forest region of Pernambuco (07°25' S; 35°06' W) at 179 m altitude. This region has a warm dry season from October to January, average annual temperature is 24ºC and average annual rainfall is approximately 1400-mm (CPRM, 2005a).The vegetation is classified as tropical deciduous or semi-deciduous forest with a gently undulating topography (IPA, 1994). The soil is a distrophic Tb red-yellow clay with a prominent A horizon of medium clay texture (Embrapa, 2006).

The Caruaru site is located in the Pernambuco wasteland (08°17'S and 35°58'W) with a 554 m altitude. It has a tropical rainfall climate with a dry summer, an annual mean temperature of 25ºC and a 551-mm long-term annual rainfall falling between February and September months. The soils are ultisol and alfisol planosols, with clay texture and medium to high fertility (CPRM, 2005b). Vegetation is classified as tropical deciduous or semi-deciduous forest with a mildly undulating topography (IPA, 1994).

Serra Talhada is located in the Pajeú hinterland of Pernambuco (7°59'S and 38°17'W) with a 429-m altitude. The climate is tropical semiarid, mean annual temperature is 25.7ºC and mean annual rainfall is 432-mm falling mostly between November and April months. Vegetation is primarily a hiper xerophilic Caatinga consisting of shrubland, thorn forest and some deciduous forest in a gently undulating topography. Soils are predominantly shallow, well-drained luvisols of medium to high natural fertility (CPRM, 2005c).

Botanical specimens were collected to verify the identity of target species. These were keyed and stored at the Sérgio Tavares Herbarium of the Federal Rural Univeristy of Pernambuco.

Leaves and stems with up to 5-mm diameter were collected from the dominant arboreal and brush species for CT analyses of each location. Condensed tannin concentration, expressed as dry matter, was determined by the Folin-Denis method using tannic acid standard as described by Bezerra Neto & Barreto (2011).

Sampling encompassed two dry and two rainy seasons at each location. At Itambé, dry season samples were collected in December 2002 and November to December 2003 while rainy season samples were collected in February, July and September 2003. At Caruaru, dry season sampling took place in December 2002 and January and November to December 2003 while rainy season sampling took place in March, April and July 2003. At Serra Talhada, dry season sampling took place in August and October 2003 while rainy season sampling was carried out in February and March 2003 (Figure 1).

The experimental design was completely randomized with a species by season factorial arrangement with four replications by specie by local for an analysis of variance. The experimental unit consisted of individual plants at each location. The variable means were compared by means of an F test or, where multiple means were involved, a Scott-Knott test. Differences were considered significant at $P \leq 0.05$ unless otherwise noted. Dependent variables (list) were submitted to a multivariate analysis for those that retained a maximum variance (Factor 1 = 80.1%; Factor 2 = 19.9%). Dependent

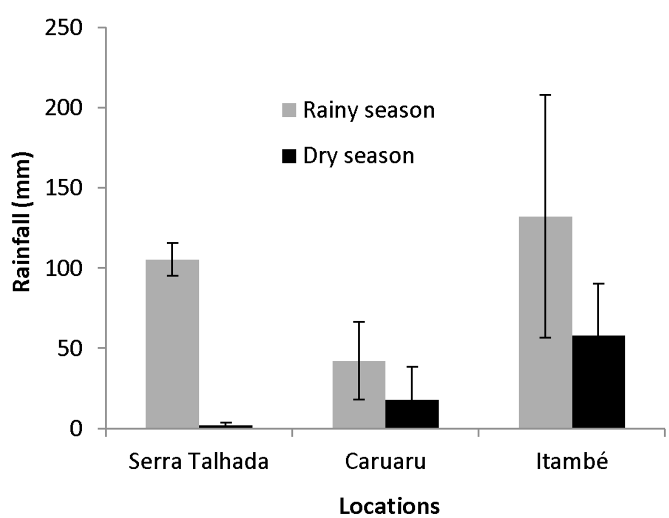

Figure 1. Rainfall (mm) averages of dry and rainy seasons for three locations in Pernambuco, Brazil (Agritempo, 2014)

variables were also submitted to a Tocher cluster analysis using the software Statistica Version 7 (StatSoft Inc., 2004).

Results and Discussion

At Itambé the legumes had 10.6% greater CT concentrations during the rainy compared to the dry season, with *M. cultratum* and *L. leucocephala* contributing the most to this difference (Table 1). *Chomelia* sp. and *M. caesalpiniaefolia* had the greatest concentrations of all species surveyed, ranging up to 42 g kg^{-1} DM.

At Caruaru, only *C. pyramidalis* had 33% greater CT concentrations in the dry season compared to the rainy (species by season interaction (*P≤0,05)* Table 2). *Oxalis insipida* had lower average CT concentrations than the other entries which ranged up to 42.4 g kg^{-1} DM. Multivariate analysis indicated that CT concentrations at Itambé and Caruaru were similar with 80.1% of variability in the Factor 1 explained by location (Figure 2).

At Serra Talhada, mean dry season CT concentration for all species was 31.5% less than for the same species in the rainy season (Table 3). From the rainy season to the dry season *C. leucocephala* reduced its CT by 72.9%. *Myracrodruon urundeuva* and *S. brasiliensis* had the greatest average CT concentration while *M. tenuiflora* had greater average concentrations than the remaining entries. The species from this location formed a distinct group compared to the other two locations (Figure 2).

Table 1. Condensed tannin concentrations of key browse species at Itambé, PE Brazil during the dry and rainy seasons

Species	Condensed tannins (g kg^{-1} dry matter)‡		
	Dry season	Rainy season	Average
Chomelia sp.	41.1 ± 2.2	41.7 ± 2.1	41.4A ± 1.5
Casearia sylvestris Sw.	37.6 ± 2.2	38.7 ± 3.4	38.2B ± 2.0
Machaerium cultratum Pittier	29.1 ± 2.4	39.7 ± 2.5	35.2B ± 2.2
Mimosa caesalpiniaefolia Benth	41.4 ± 2.9	42.5 ± 1.8	42.0A ± 2.1
Leucaena leucocephala (Lam.) de Wit	31.4 ± 4.1	39.6 ± 3.1	35.5B ± 2.1
Total	36.5b ± 2.1	40,4a ± 1,2	38,5 ± 0,9

‡Mean ± standard error. Means followed by different lower case letter in the same line differ according to an F test (P≤0.05) while those followed by different upper case letters in the same column differ according to a Scott-Knott multiple mean separation (P≤0.05).

Table 2. Condensed tannin concentrations of key browse species at Caruaru, PE Brazil during the dry and rainy seasons

Species	Condensed tannins (g kg^{-1} dry matter)‡		
	Dry season	Rainy season	Average
Prosopis julifora (Sw.) DC	25.4 ± 3.7	38.6 ± 3.6	33.3A ± 2.9
Senna spectabilis (DC.) H.S. Irwin & Barneby	33.9 ± 4.0	37.8 ± 3.6	35.6A ± 2.7
Caesalpinia pyramidalis Tul.	49.6 ± 7.7a	37.3 ± 3.8b	42.4A ± 4.0
Oxalis insipida St. Hil.	19.3 ± 8.2	21.0 ± 6.7	20.4B ± 5.1
Piptadenia stipulacea (Benth.) Ducke	37.8 ± 2.6	38.8 ± 3.8	38.4A ± 2.4
Mimosa arenosa Willd	38.1 ± 2.5	39.5 ± 4.3	38.8A ± 2.4
Croton rhamnifolius Kunth.	32.4 ± 3.8	40.4 ± 3.6	36.8A ± 2.7
*Platymiscium floribundum*Vogel	36.8 ± 3.7	40.4 ± 3.5	38.7A ± 2.5
Total	34.8 ± 1.7	36.7 ± 1.6	35.8 ± 1.2

‡Mean ± standard error. Means followed by different lower case letter in the same line differ according to an F test (P≤0.05) while those followed by different upper case letters in the same column differ according to a Scott-Knott multiple mean separation (P≤0.05).

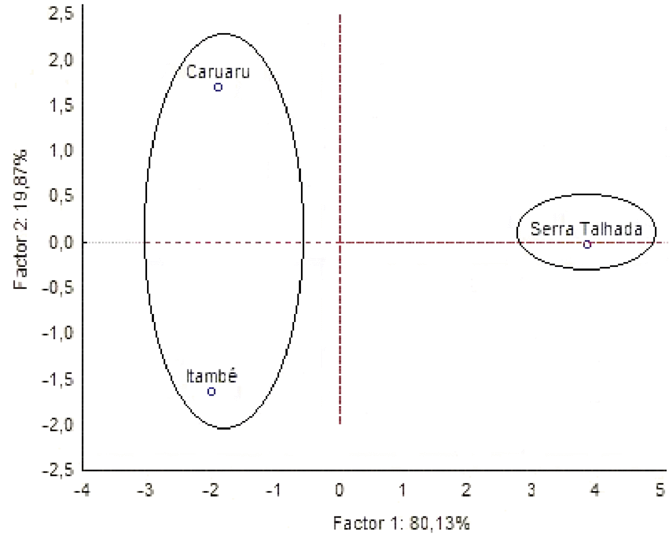

Figure 2. Dissimilarity projection and cluster formation of condensed tannin concentration means of species averaged over two seasons with locations accounting for 89.1% of the differences

Table 3. Condensed tannin concentrations of key browse species at Serra Talhada, PE Brazil during the dry and rainy seasons

Species	Condensed tannin (g kg^{-1} dry matter)‡		
	Dry season	Rainy season	Average
Anadenanthera colubrina (Vell.) Brenan var. *cebil* (Griseb) Altschul	23.9 ± 6.2	37.9 ± 5.0	31.5C ± 4.3
Myracrodruon urundeuva Allemão	51.8 ± 11.7	72.8 ± 11.4	62.3A ± 8.5
Schinopsis brasiliensis Engl.	48.5 ± 23.7	78.9 ± 12.2	61.5A ± 14.8
Caesalpinia cf. bracteosa Tul	35.3 ± 3.4	45.8 ± 2.1	40.5C ± 2.7
Amburana cearenses (Allemão) A.C.Smith	19.8 ± 6.6	36.8 ± 7.8	28.3C ± 5.7
Ziziphus joazeiro Mart.	25.5 ± 2.0	31.2 ± 9.7	27.9C ± 4.0
Mimosa tenuiflora (Willd.) Poir.	48.8 ± 7.5	44.2 ± 2.3	46.3B ± 3.6
Croton sp.	25.3 ± 6.4	36.0 ± 5.9	31.1C ± 4.4
Cordia leucocephala Moric	10.9b ± 10.9	40.3a ± 7.4	25.6C ± 8.2
Bauhnia cf. subclavata Benth.	18.2 ± 10.8	34.9 ± 8.5	25.3C ± 7.4
Euphorbia sp.	29.6 ± 6.1	53.7 ± 6.4	43.4C ± 5.5
Aspidosperma pyrifolium Mart.	18.4 ± 6.2	38.6 ± 7.0	30.5C ± 5.7
Sideroxylum obtusifolium (Roem. & Schult) T.D.Penn	28.0 ± 3.5	39.9 ± 9.4	34.0C ± 5.2
Spondias tuberosa Arr. Cam.	36.7 ± 3.7	41.9 ± 12.1	39.3C ± 5.9
Total	30.7b ± 2.6	44.8a ± 2.3	38.0 ± 1.8

‡Mean ± standard error. Means followed by different lower case letter in the same line differ according to an F test (P≤0.05) while those followed by different upper case letters in the same column differ according to a Scott-Knott multiple mean separation (P≤0.05).

Beelen et al. (2006) surveyed CT concentrations of browse species, by butanol-HCl method, in the Caatinga of Sobral, Brazil and observed a wide range: 173 to 310 g kg^{-1} DM for *M. tenuiflora*, the least concentration still nearly four times that measured in Serra Talhada; 179 to 201 g kg^{-1} DM in *M. caesalpinifolia*, the least concentration still over four times that measured in Itambé; 104 to 127 g kg^{-1} DM in *B. cheilantha* which was not evaluated in the Pernambuco study. These differences may have resulted from collecting all leaves and stems in the Pernambuco study while the Sobral study evaluated younger leaves; morphology and ontogeny can play an important role in plant CT concentration (Tharayil et al., 2011; Cooper et al., 2014).

High concentrations of CT in plants can lead to reduced intake by ruminants, primarily due to reduced palatability and digestibility (Krueger et al., 2010). On the other hand, the presence of moderate concentrations can have positive effects on ruminant health and nutrition due to biological actions (Muir, 2011). The threshold for net positive versus negative effects on herbivores is dependent on many factors but usually occurs around 20 to 40 g kg^{-1} DM (Vitti et al., 2005).

This threshold may vary according to CT characteristics, quantifying analytical procedure, nutrition, and ruminant species or class (Waghorn & McNabb, 2003; Beelen et al., 2006). Talbot & Finzi (2008), working with *Quercus rubra* L. (5.63 g CT kg^{-1} DM), *Tsuga Canadensis* L. (0.33 g TC kg^{-1} DM) and *Acer saccharum* Marsh. (24 g TC kg^{-1} DM), observed that protein precipitation was greater for *T. canadensis* (0.51 mg mg^{1} CT) than for *Q. rubra* (0.34 mg mg^{-1} CT). Littlefield et al. (2011) observed that *Desmodium paniculatum* (L.) DC. had 76.5% less CT concentration than *Acacia angustissima* var. *hirta* (Nutt.) B.L. Rob. Despite this difference, *D. paniculatum* had greater negative effects on *Musca domestica* (L.) larval development than *A. angustissima.*

Conclusions

The survey showed that there was a wide range of CT concentrations among the species sampled. It also indicated that concentrations, when they did differ among seasons, increase during the rainy season. This reduction was more apparent in the semi-arid climate compared to the greater rainfall regions so that low soil moisture and greater ambient temperatures appear to favor the accumulation of CT in browse material. Because vegetation growth is limited by these climatic factors, it is possible that greater investment in protection of what little growth occurs will favor plant survival compared to regions where browse regrowth is not as limited by rainfall and hot temperatures.

All the species surveyed had CT concentrations within the limit that ruminants tolerate, according to the literature. This would indicate that most of these species, already known to be useful browse species, have CT concentrations that benefit dietary protein nutrition and gastro-intestinal parasite suppression without overwhelming negative effects on overall diet palatability (animal intake) or digestibility. Further research into the strength of CT biological activity for these browse species would verify these hypotheses. Because of their current and potentially expanded silvo-pastoral use, further studies into CT concentration and biological activity of these species in response to browsing is merited.

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