CONTENTS OF SOLUBLE PHENOLIC COMPOUNDS OF CAPITULLA OF ERIOCAULACEAE

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The contents of soluble phenolic compounds were measured in capitulla of 86 specimens of Eriocaulaceae, embracing 69 species and 8 genera. High values (weight/weight) were found in species of *Paepalanthus* (3.1% on average), although some species of this genus exhibited low amounts. Intermediate values (about 1.5%) were found for species of *Eriocaulon, Lachnoulon* and *Tonina,* while species of *Leiothriz, Philodice, Rondonanthus* and *Syngonanthus* presented values in general below 1%. The content of phenolic compounds of capitulla of Eriocaulaceae is not a reliable taxonomic character at the specific hierarchic level, but at the generic level and above it is potentially useful. The results are discussed in relation to their contribution to the taxonomy of Eriocaulaceae.

Key words: phenolic compounds, Eriocaulaceae, chemotaxonomy.

INTRODUCTION

There is a great deal of speculation regarding the uses of the impressive amounts of everlasting plants that are harvested in several areas of "campos rupestres" and then shipped to many countries[1]. It is often speculated that capitulla of these plants contain biologically active compounds that might account for the fact that these plants may sometimes be stored for several years without being damaged by insects, rats or other animals. Systematic investigations have searched for substances with biological activity, mainly pyrethrins[2]. Recent research discovered a new phenolic compound present in exceptionally high amounts in capitulla of *Paepalanthus bromelioides* Silv., an Eriocaulaceae endemic in Serra do Cipó (MG, Brazil)[3]. The compound is an isocoumarin that was shown to be active against a broad range of bacteria. This finding stimulates more investigations to uncover substances of Eriocaulaceae with pharmacological action.

On the other hand, high amounts of phenolics in everlasting plants are undesirable for ornamental plants, as post-harvest oxidation of these compounds leads to a darkening of the capitulla. Thus, the search for potentially useful phenolic compounds may lead to a broadening of the as yet very narrow range of economic exploitation of Eriocaulaceae from "campos rupestres" to include plants with post-harvest darkening which have not yet been assigned any commercial use.

This paper reports results of the contents of soluble phenols of dried capitulla of Eriocaulaceae. The data may be important with respect to the following items: 1) orienting future investigations of the chemistry of natural products of Eriocaulaceae; 2) the taxonomy and 3) ecology of the Eriocaulaceae.

RESULTS AND DISCUSSION

The contents of soluble phenols are presented in Table 1. The results suggest that species of *Paepalanthus* are more promising than species of other genera as sources of phenotic compounds. The mean contents (weigh/weight) of phenolic compounds of capitulla of species of the main genera of Eriocaulaceae are: *Paepalanthus,* 3.1%; *Syngonanthus,* 0.8%; and *Leiothrix,* 0.6% (Fig. 1). It can be observed in Table 1 and Fig. 1 that exceptionally high values are related only to species of *Paepalanthus*. In contrast, the lowest figures correspond to species of *Syngonanthus* and *Leiothrix,* more often to species of the latter genus. It is worth pointing out that the everlasting plants with high commercial value as ornamentals are most commonly species of *Syngonanthus,* as for example, *S. brasiliana, S. elegans* and *S. magnificus,* all of which presenting contents of soluble phenols that do not exceed 0.5% (Table 1). Capitulla of *L. flavescens,* a highly prized ornamental outside the genus *Syngonanthus,* also have soluble phenol contents below 0.5% (Table 1). It seems that figures above this amount turn out to be increasingly detrimental, inasmuch as they probably favour a rapid post-harvest darkening of the capitulla. For example, capitulla of *P. comans,* with values ranging from 0.7% to 1% (Table 1), show an evident post-harvest darkening. However, it must also be taken into account the fact that structural characteristics of the phenols have a great influence in their lability to oxidation. It is evident that, under the same conditions, some phenols are more readily oxidized than others.

Notwithstanding the inconvenience of high contents of soluble phenols in capitulla of everlasting plants in connection with their utilization as ornamentals, the most interesting species of Eriocaulaceae as sources of secondary metabolites seem to be those with high contents of phenolic compounds, at least as long as our limited knowledge of the chemistry of the family stands.

Paepalanthus is as a very heterogenous genus, although values for phenolic compounds never fall below 0.7% among its species (Table 1). On the other hand, *Leiothrix* and *Syngonanthus* exhibit a great internal homogeneity and also a great similarity, when results of the present work are considered (Table 1, Fig. 1). Similar conclusions were also drawn from a previous chemotaxonomic research[5]. A comparison of the distribution of the data among the species of the three above mentioned genera indicates that *Paepalanthus* stands out for its high values of phenolic contents (Table 1, Fig. 1).

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Table 1. Contents of total soluble phenolic substances of capitulla of Eriocaulaceae.

Specimens	Voucher*	%
Eriocaulon		
1. *E. aquatile* Koern	Hatschbach 53073	1.3
2. *E. crassiscapum* Bong	SPF 15708	1.8
3. *E. elichrysoides* Bong.	CFSC 5050	1.3
4. *E. ligulatum* (Vell.) L.B. Smith	CFCR 7996	1.8
Lachnocaulon		
5. *L. minus* (Chapman) Small**	Bozena 11355	1.4
Leiothrix		
Subg. *Leiothrix*		
6. *L. flagellaris* (Giul.) Ruhl. var. *flagellaris*	CFCR 4689	0.6
7. *L. flagellaris* (Giul.) Ruhl. var. *pedunculosa* (Ruhl.) Giul.	CFCR 12228	0.2
8. *L. flagellaris* (Giul.) Ruhl. var. *pedunculosa* (Ruhl.) Giul.	CFCR 12236	0.5
9. *L. flagellaris* (Giul.) Ruhl. var. *pedunculosa* (Ruhl.) Giul.	CFCR 12240	0.6
10. *L. flagellaris* (Giul.) Ruhl. var. *pedunculosa* (Ruhl.) Giul.	SPF 16279	0.4
11. *L. Luxurians* (Koern.) Ruhl.	CFCR 12229	0.5
12. *L. spiralis* (Koern.) Ruhl.	CFCR 11343	0.4
13. *L. spiralis* (Koern.) Ruhl.	CFCR 11345	0.2
14. *L. vivipara* (Bong.) Ruhl.	CFCR 12237	0.4
Subg. *Rheocaulon* Ruhl.		
15. *L. fluitans* (Mart.) Ruhl.	CFCR 3841	1.4
Subg. *Trichocalyx* (Koern.) Giul. comb. nov.		
16. *L. crassifolia* (Bong.) Ruhl.	CFSC 8544	0.5
17. *L. crassifolia* (Bong.) Ruhl.	CFCR 9748	0.2
18. *L. curvifolia* (Bong.) Ruhl. var. *curvifolia*	CFCR 12243	0.3
19. *L. curvifolia* (Bong.) Ruhl. var. *mucronata* (Bong.) Giull.	CFCR 11340	0.3
20. *L. distichoclada* Herzog	CFCR 1700	0.8
21. *L. echinocephala* Ruhl.	CFCR 9776	1.1
22. *L. flavenscens* (Bong.) Ruhl.	CFCR 4287	0.4
23. *L. fulgida* Ruhl.	CFCR 5610	0.2
24. *L. fulgida* Ruhl.	CFCR 12235	0.3
25. *L. hirsuta* (Wikstr.) Ruhl. var. *blanchetiana* (Koern.) Ruhl.	CFCR 1380	0.8
26. *L. hirsuta* (Wikstr.) Ruhl. var. *hirsuta*	CFCR 1560	0.7
Paepalanthus		
Subg. *Paepalocephalus* Ruhl.		
Sect. *Actinocephalus* Koern.		
27. *P. bifrons* Silv.	CFCR 9782	1.0
28. *P. brachypus* (Bong.) Kunth.	CFCR 11778	1.5
29. *P. hilairei* Koern.	CFCR 9728	1.5
30. *P. polyanthus* (Bong.) Kunth.	CFCR 56	4.0
31. *P. rigidus* (Bong.) Kunth.	CFCR 9775	1.6
Sect. *Diphyomene* Ruhl.		
32. *P. flaccidus* (Bong.) Kunth.	CFCR 2235	2.6
33. *P. speciosus* (Bong.) Koern.	CFSC 8486	1.8
34. *P. speciosus* (Bong.) Koern.	Menezes 1215	2.2
35. *P. speciosus* (Bong.) Koern.	Menezes 1218	1.9
Sect. *Dyostiche* Ruhl.		
36. *P. distichophyllus* Mart.	Duarte 2200	3.0
Sect. *Eriocaulopsis* Ruhl.		
Subsect. *Aphorocaulon*		
37. *P. geniculatus* (Bong.) Kunth.	CFSC 3961	1.6
38. *P. incanus* (Bong.) Koern.	CFCR 9749	0.7
39. *P. incanus* (Bong.) Koern.	SPF 16242	2.0
40. *P. macrocephalus* (Bong.) Koern.	CFCR 1732	3.8
41. *P. macrocephalus* (Bong.) Koern.	CFCR 9482	1.0
42. *P. macrocephalus* (Bong.) Koern.	CFCR 11083	2.9
Subset. *Eupaepalanthus*		
Ser. *Dimeri*		
43. *P. elongatus* (Bong.) Koern.	CFCR 3665	1.2
Ser. *Leptocephali*		
44. *P. manicatus* V.A. Pouls	BHCB 5980	8.9
Ser. *Rosulati*		
45. *P. pulvinatus* N.E. Br.	CFCR 1448	4.5
Ser. *Variabiles*		
46. *P. inopinatus* Mold.	CFCR 1701	3.6
47. *P. klotzschianus* Koern.	Hatsch. 51438	3.8
48. *P. luetzelburgii* Herzog	CFCR 1528	2.6
49. *P.* aff. *parvifolius* Silv.	CFCR 28	3.1
50. *P. pubescens* Koern.	CFCR 4208	2.4
51. *P. pulchellus* Herzog	Harley 20678	1.7
52. *P. saxatilis* (Bong.) Koern.	CFCR 9723	2.7
Subsect. *Polyactis*		
53. *P. microphyllus* (Giul.) Kunth.	CFCR 5610	3.6
Subg. *Platycaulon* Mart.		
54. *P. bromelioides* Silv.	CFSC 9068	8.2
55. *P.* cf. *hydra Ruhl.*	CFCR 9199	6.4
56. *P. macropodus* Ruhl.	CFSC 5646	3.6
57. *P. planifolius* (Bong.) Koern.	CFCR 12188	8.4
Subg. *Xeractis* Mart.		
58. *P. aculeatus* Silv.	CFCR 4201	3.6
59. *P. argenteus* (Bong.) Koern. var. *argenteus*	CFCR 3650	0.9
60. *P. comans* Silv.	CFCR 3601	1.0
61. *P. comans* Silv.	CFCR 8781	0.8
62. *P. comans* Silv.	CFCR 9778	0.7
63. *P. latifolius*	CFCR 9573	1.4
64. *P. nigrescens* Silv.	CFCR 4198	0.7
65. *P. paulinus* Ruhl.	CFSC 4271	3.1
Philodice		
66. *P. hoffmannsegii*	Pott s/n	0.8
Rondonanthus		
67. *R. duidae* (Gleason) Hensold & Giul.***	Huber 9539	0.8
Syngonanthus		
Sect. *Carpocephalus* Ruhl.		
68. *S. caulescens* (Poir.) Ruhl.	W. Hoehne 947	0.3
69. *S. caulescens* (Poir.) Ruhl.	CFCR 3792	0.5
Sect. *Dimorphocaulon* Ruhl.		
70. *S. fertilis* (Koern.) Ruhl.	Guedes 815	1.2
71. *S. fuscescens* Ruhl.	CFCR 8005	1.7
72. *S. gracilis* (Koern.) Ruhl.	CFCR 9719	0.6
73. *S. laricifolius* (Gardn.) Ruhl.	CFCR 9747	0.7
74. *S. laricifolius* (Gardn.) Ruhl.	SPF 16296	0.7
75. *S. nitens* (Bong.) Ruhl.	CFCR 5780	0.4
Sect. *Eulepis* Bong.		
76. *S. elegans* (Koern.) Ruhl.	CFSC 10851	0.5
77. *S. magnificus* Giul.	CFCR 5513	0.5
78. *S. mucugensis* Giul.		0.9
79. *S. niveus* (Bong.) Ruhl.	CFCR 9725	0.6
80. *S. niveus* (Bong.) Ruhl.	CFSC 5650	0.6
81. *S. rupprechtianus* (Koern.) Ruhl.	CFCR 9753	0.3
82. *S. suberosus* Giul.	CFCR 10273	0.9
Sect. *Thysanocephalus* Koern.		
83. *S. brasiliana* Giul.	CFCR 10199	0.4
84. *S. flexuosus* Silv.	CFCR 5048	1.2
Tonina		
85. *T. fluviatilis* Aubl.	Duarte 6070	2.3

* CFCR – Collection Flora of "Campos Rupestres"
CFSC – Collection Flora of Serra do Cipó
** Specimen from South Carolina, USA
*** Specimen from Bolivar, Venezuela

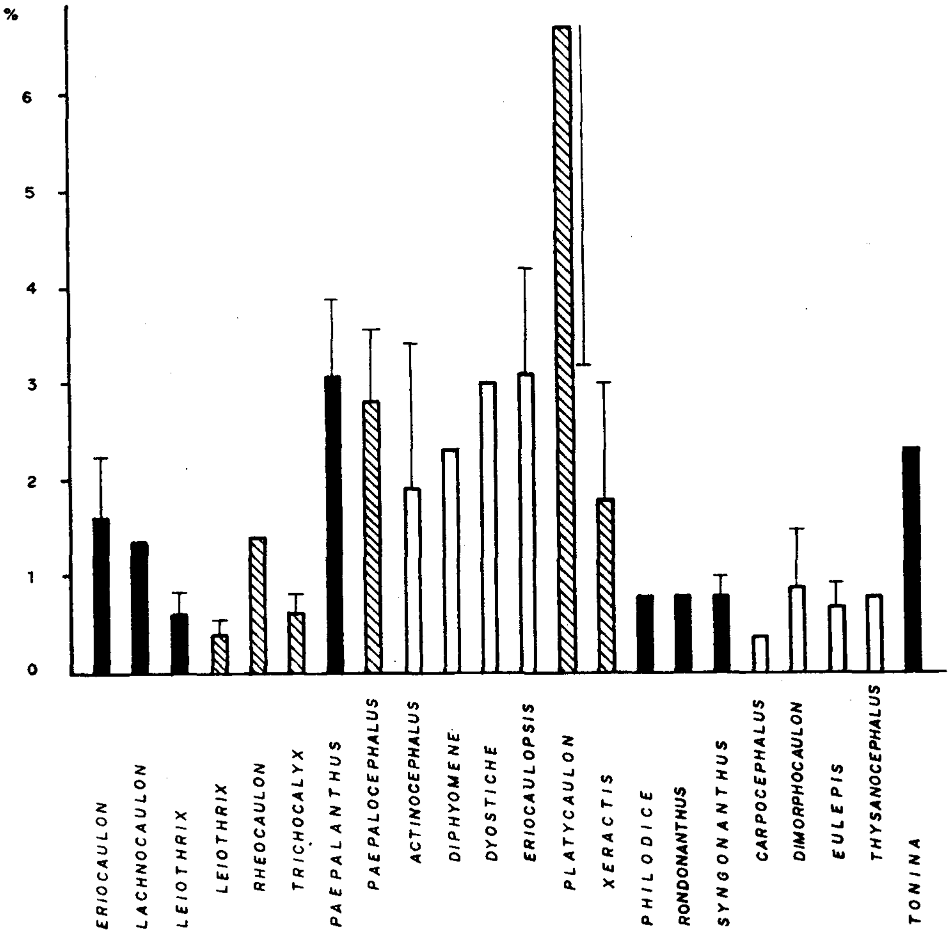

Figura 1. *Average percent (weight/weight) of phenolic compounds of capitulla of taxa of Eriocaulaceae.*

Species of five additional genera (*Eriocaulon, Lachnocaulon, Philodice, Rondonanthus* and *Tonina*) were also includes in the present work, although with much narrower samplings. All four species of *Eriocaulon* presented relatively high and very similar contents of phenolic compounds (1.6% on average, Table 1, Fig. 1). The great similarity of the values of the species of *Eriocaulon* runs parallel to the general concept that it represents a very well characterized taxon[6]. *Lachnocaulon* is another genus normally assumed to be well defined, but its distribution is confined to the Northern Hemisphere. From this genus, only *L. minus* was here studied; this species was shown to be very similar to those of *Eriocaulon,* with a content of phenolic compounds of 1.4% (Table 1, Fig.1). Two other small genera, *Philodice* and *Rondonanthus,* also appear in the present report, each represented by one species; coincident results (0.8%, Table 1, Fig. 1) were found for both species. Giulietti (in preparation) suggests a segregation of some taxa of *Paepalanthus* to erect the new genus *Rondonanthus.* It is true that relatively low amounts of phenolic compounds, such as that of *R. duidae,* can be found among some species of *Paepalanthus;* however, the general picture for the latter genus is characterized by amounts of phenolic compounds significantly higher. A rapid inspection of the data of Fig. 1 readily reveals a sharp discrepancy between *Paepalanthus* and *Rondonanthus duidae,* so that our data do support the proposed taxonomic rearrangement.

Tonina fluviatilis, the only representative of its genus in this work, stands out for its high amount of capitullum phenolic compounds (2.3%), which is only surpassed by values of *Paepalanthus* (Table 1, Fig. 1).

The information in Table 1 and Fig. 1 may have some taxonomic significante also at the infrageneric hierarchic level. Among the subgenera of *Leiothrix,* subgenus *Leiothrix* presents the lowest values (0.4% on average, Table 1, Fig. 1), followed by *Trichocalyx* (0.6% on average); subgenus *Rheocaulon,* here represented only by *L. fluitans,* revealed the highest value in *Leiothrix* (1.4%, Table 1, Fig. 1). A comparison of the subgenera of *Leiothrix* wider representation in this work, i.e. *Leiothrix* and *Trichocalyx,* shows that the latter is a relatively heterogenous taxon, as opposed to the former (Table 1, Fig. 1).

Among the subgenera of *Paepalanthus, Platycaulon* is distinguished by exceptionally high values, reaching 6.7% of phenolic compounds on average (Table 1, Fig. 1). In contrast, *Xeractis* presents modest values and also a high homogeneity, so that it represents, in *Paepalanthus,* the taxon with the lowest standard deviation of the contents of capitullum soluble phenolic compounds. *Dyostiche* and *Eriocaulopsis* are sections of subgenus *Paepalocephalus* with values higher than *Actinocephalus* and *Diphyomene* (Fig. 1). However, one must regard the taxonomic consistency of the present contents of capitullum phenolics with great suspicion at the sectional hierarchic level and below, due chiefly to the narrow sampling of many sections. The consistency of this character is likely to be low at such levels; in fact, a wide variation is observed among the phenolic contents of the three specimens of *P. macrocephalus* and the two specimens of *P. incanus* (section *Eriocaulopsis*, Table 1). The ratio mean/standard deviation for *Eriocaulopsis* is only 1.6. Similar conclusions can be drawn from data of Table 1 in connection with species of *Syngonanthus*.

Giulietti[6] argues that *Paepalanthus* and *Syngonanthus* (specially the former) are artificial genera, and thus very heterogenous. The results of the present work lend support to this claim, but only as far as *Paepalanthus* is concerned.

In terms of phylogeny, there is a widely held belief that chemical characters evolve in taxa following a stepwise simplification of chemical profiles[7,8,9]. An adaptation of these ideas to the results of the present investigation leads to the conclusion that, at the generic level, *Paepalanthus* holds a basal phyletic position in Eriocaulaceae, for it is in species of this genus that higher phenolic contents are found. Parallel to these high figures runs a wide heterogeneity of the values, which is another condition of primitivity. *Eriocaulon, Lachnocaulon* and *Tonina,* with phenolic contents around 1.5%, hold an intermediate position, while *Leiothrix, Philodice, Rondonanthus* and *Syngonanthus,* with phenolic contents commonly below 1%, should be regarded as the most advanced genera, according to the results of the present work.

From an ecological viewpoint, it is noteworthy that aquatic Eriocaulaceae tend toward higher contents, as compared to terrestrial congeners. Among the species of *Leiothrix,* for example, *L. fluitans* diverges from its terrestrial congeners which commonly present low amounts of phenolic compounds (Table 1). Another example of aquatic Eriocaulaceae with high content of phenolic compounds is *Tonina fluviatilis* (Table 1). For the time being, it is still not possible to decide wether the high phenolic contents of such species is the result of an eventual plesiomorphic condition or a contingency of the aquatic environment.

FINAL COMMENTS

The percent of phenolic compounds of capitulla of Eriocaulaceae is a taxonomic character potentially useful at the hierarchic levels of genus and subgenus. Although it is not discriminant enough to permit the distinction of all taxa, the character does reveal similarities and discrepancies that are coherent with evidence from comparative morphology. The character reveals also a potential phylogenetic importance.

It is surprising that a quantitative characteristic such as the percent of phenolic compounds turns out to be potentially useful in taxonomy, for it is normally found that quantitative characters tend to be too plastic[10]. In fact, the intraspecific variation observed in Table 1 for several taxa is relatively high. Thus this character is taxonomically not reliable at the specific level. Nonetheless, at higher hierarchic levels it may provide interesting and reliable taxonomic information, as long as significant samplings of the taxa under consideration are assayed.

EXPERIMENTAL

The search covered 86 specimens, belonging to 69 species and 8 genera. All samples were taken from dried specimens of the Herbarium of the Institute of Biosciences of the University of São Paulo (SPF). The list of specimens is given in Table 1.

Whenever possible, the involucral bracts were removed. The capitulla were then pulverized and soluble phenols were extracted by means of three successive 15 min treatments with hot 70% ethanol. The phenol contents of the alcoholic solutions were measured by the method of Folin-Denis[4], using gallic acid as a standard reference.

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