Phytochemistry, 1969, Vol. 8, pp. 1503 to 1507. Pergamon Press. Printed in England.

SHORT COMMUNICATION

BETACYANINS OF THE FAMILY CACTACEAE*†

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(*Received* 12 *February* 1969)

Abstract—Thirty-four species of the family Cactaceae have been investigated for their betacyanin content. All the species examined contain betanin and many of them also phyllocactin. Betanidin and some new betacyanins have a more limited occurrence.

INTRODUCTION

THE FAMILY Cactaceae is a group of perhaps more than 2000 species (about 200 genera) mostly of tropical and subtropical areas of North and South America. The systematic position of the Cactaceae is a matter of some dispute. In Engler's classification[1] this family is treated as a separate order (Opuntiales) placed near the Myrtales among the Archichlamydeae. In more modern classifications the Cactaceae are treated as a family of the order Centrospermae which, as recently suggested by Mabry,[2] might be recognized as containing the ten betacyanin families Chenopodiaceae, Amaranthaceae, Portulacaceae, Nyctaginaceae, Phytolaccaceae, Stegnospermaceae, Aizoaceae, Basellaceae, Cactaceae and Didieriaceae. Until now, only about fifty species of the family Cactaceae, which is taxonomically divided into three sub-families Peireskioideae, Opuntioideae and Cactoideae, have been described as containing betacyanins.[3–5] Even more limited is the number of species investigated in detail to ascertain the precise nature of the pigments. The present paper deals with the identification and quantitative determination of betacyanins in thirty-four species of the Cactaceae.

RESULTS AND DISCUSSION

The results of surveying thirty-four species of the family Cactaceae are reported inTable 1. The qualitative distribution of betacyanins was similar in most species, although there were distinct quantitative differences. Betanin (I), usually accompanied by minor amounts of its C-15 diastereoisomer isobetanin, was identified in all the species and was often the predominant pigment. Phyllocactin (II) and its diastereoisomer isophyllocactin were found in most of the Cactaceae investigated, and the free aglycone betanidin in five species out of the thirty-four examined.

* Part IX of the series "Pigments of Centrospermae"; for Part VIII, see *Phytochem.* **8**, 731 (1969).

† This work was supported by the Consiglio Nazionale delle Ricerche.

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[2] T. J. MABRY, A. TAYLOR and B. L. TURNER, *Phytochem.* **2**, 61 (1963).

[3] A. S. DREIDING, in *Recent Developments in the Chemistry of Natural Phenolic Compounds* (edited by W. D. OLLIS), p. 194, Pergamon Press, London (1961).

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[5] A. WOHLPART and T. J. MABRY, *Taxon* **17**, 148 (1968).

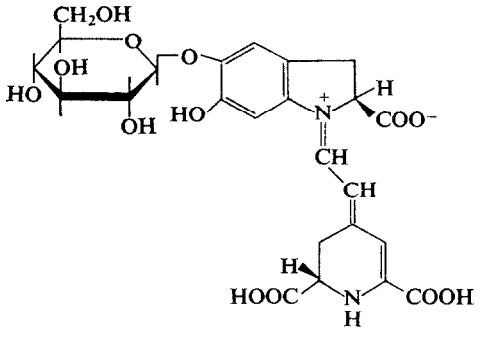
TABLE 1. THE QUANTITATIVE DISTRIBUTION OF BETACYANINS IN SOME CACTACEAE.
THE VALUES GIVEN ARE A PERCENTAGE OF TOTAL BETACYANINS

	Plant part	Percentage of each betacyanin						
		Betanin	Isobetanin	Phyllocactin	Isophyllocactin	Betanidin	Isobetanidin	Others
PEIRESKIOIDEAE								
Rhodocactus grandifolius (Haw.) Knuth	fl.	90·2	+	+				9·8 (A)
OPUNTIOIDEAE								
Opuntia bergeriana Web.	fr.	89·6	5·4	+	+	5·0		
O. engelmannii SD.	fl.	95·1						4·9 (B)
	fr.	96·8	1·2	2·0				
O. guatemalensis Br. and R.	fr.	90·3						9·7 (C)
O. monacantha Haw.	fl.	71·9	28·1					
	fr.	30·2	24·8			15·5	9·6	19·9 (D)
O. paraguayensis K. Sch.	fr.	79·4	19·6	1·0				
O. polyacantha Haw.	fr.	76·5	17·3			6·2		
O. ritteri Berg.	fr.	78·8	20·3	0·9				
O. streptacantha Lem.	fr.	67·3	23·9	6·4	2·4			
O. tomentella Berg.	fr.	60·0	16·9	23·1	+			
O. tomentosa SD.	fr.	69·2	21·1	9·7	+			
Nopalea dejecta SD.	fr.	71·4	27·5	0·9				
CACTOIDEAE								
Epicactus cultivars: Frau dr. Ziegler	fl.	19·1	2·0	63·2	15·7			
Epicactus cultivars: Erfold	fl.	3·9	15·9	74·0	6·2			
Epicactus cultivars: Curt Backeberg	fl.	1·9	+	87·9	10·2			
Epicactus cultivars: Ernest Seydeleri	fl.	6·3	10·7	75·5	7·5			
Aporocactus flagelliformis (L.) Lem.	fl.	35·4		59·8				4·3 (E)
Borzicactus sepium (H. B. K.) Br. and R.	fl.	30·0	+	35·4	34·6			
Cleistocactus jujuyensis (Backbg.) Backbg.	fl.	70·3		29·7				
C. parviflorus (K. Sch.) Goss.	fl.	90·3		+	4·8	4·9		
C. smaragdiflorus (Web.) Br. and R.	fl.	16·2		83·8				
C. strausii (Heese) Backbg.	fl.	16·1	9·8	43·3	30·8			
Haageocereus acranthus (Vpl.) Backbg.	fl.	15·7	14·5	36·8	33·0			
Soehrensia bruchii (Br. and R.) Backbg.	fl.	65·5	10·7	11·0	5·0			7·8 (F)

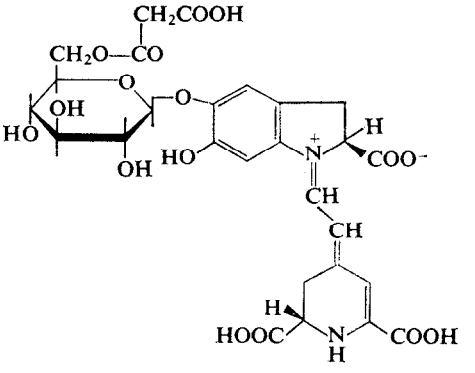
TABLE 2—(*cont.*)

Eriocereus guelichii (Spez.) Berg.	fr.	23·0	18·2	40·7	18·1		
Stenocereus stellatus (Pfeiff.) Ricc.	fl.	24·6	4·9	20·5	+		10·3 (G); 39·7 (H)
Cereus comarapanus Card.	fl.	29·7	14·8	25·2	30·3		
C. stenogonus K. Sch.	fl.	31·2	18·7	30·4	19·7		
× *Heliaporus smithii* (Pfeiff.) Rowl.	fl.	18·9	3·8	60·9	16·4		
Pilosocereus glaucescens (Lab.) Byl. and Rowl.	fr.	68·3	+	31·7	+		
P. nobilis (Haw.) Byl. and Rowl.	fr.	61·4	+	37·6	+		
P. leucocephalus (Pos.) Byl. and Rowl.	fr.	70·3	+	24·6	+	5·1	
Mammillaria centricirrha Lem.	fr.	26·2	3·1	63·9	6·8		
M. magnimamma Haw.	fr.	34·8	+	65·2	+		
M. magnimamma var. *divergens* (DC.) Borg.	fr.	10·2	9·8	80·0	+		
M. neumanniana Lem.	fr.	30·9	+	50·2	18·9		
M. seitziana Mart.	fr.	24·9	15·0	60·1	+		
M. zuccariniana Mart.	fr.	25·3	9·9	45·2	19·6		

Key: fl. = flowers; fr. = fruits; + indicates a trace.



(I) Betanin



(II) Phyllocactin

In addition to the compounds identified, a few species contain, generally in moderate amounts, other pigments whose properties are different from those of the known betacyanins. The structural elucidation of these new compounds, whose electrophoretic properties are presented in Table 2, awaits the isolation of larger quantities, possibly from better sources.

TABLE 2. PROPERTIES OF NEW BETACYANINS FROM PLANTS OF THE CACTACEAE

Pigment	E_b* (pH 4·5)	E_b* (pH 2·4)
A	0·30	0·27
B	0·31	0·20
C	0·28	0·18
D	0·43	0·35
E	0·72	0·66
F	0·68	0·68
G	0·36	0·15
H	0·79	0·65

* Migration in paper electrophoresis relative to betanin.

Since only 34 of some 2000 described Cactaceae species were available for examination, no general conclusion can be drawn as for the possible taxonomic significance of the betacyanin distribution. Lack of species differentiation and a general similarity throughout the family are apparent, so it would seem that the betacyanin patterns in the Cactaceae have limited taxonomic interest. The only point of systematic value which emerges from the quantitative data in Table 1 is that phyllocactin is present in consistent amounts in the subfamily Cactoideae, whereas in the Peireskioideae and Opuntioideae it is either present as a small percentage of total betacyanin or is completely absent.

EXPERIMENTAL

Plant Material

Flowers and fruits were collected from plants growing at the University of Catania Botanic Garden. The plant material was worked up immediately after collection or stored at −20°.

Extraction of Plant Material

Plant material was extracted with water and total betacyanin was isolated by chromatography on strongly acid exchange resin, as described elsewhere.[4]

Identification of Betacyanins

Betacyanins were identified by comparison of retention data on polyamide column with those of authentic compounds and by co-electrophoresis (Camag high-voltage equipment; potential gradient 75 V/cm; electrolytes used: formic acid 0·1 M (pH 2·4) and pyridine formate 0·05 M (pH 4·5)) with reference samples. When sufficient material was available, the identification was substantiated by enzymatic or chemical degradation: betanin and isobetanin by treatment with β-glucosidase gave betanidin and isobetanidin, respectively, and glucose; phyllocactin on acid hydrolysis gave malonic acid, glucose and a mixture of betanidin and isobetanidin.

Quantitative Determination of Betacyanins

Sample of the total betacyanin fraction was subjected to preparative electrophoresis. Individual betacyanins were eluted with water and determined by measuring E_{max} and comparing with known $E^{1\%}_{1cm}$ values at λ_{max} for pure pigments (betanin and isobetanin: 1120; phyllocactin and isophyllocactin: 740; betanidin and isobetanidin: 1290). For those pigments whose $E^{1\%}_{1cm}$ values were not known, E_{max} was assumed to be 1000.