THE ISOLATION AND ANALYSIS OF POLYURONIDE MATERIALS FROM THE BARREL CACTUS, ECHINOCACTUS WISLIZENII

by

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INTRODUCTION

A. The Barrel Cactus

The Echinocactus Wislizenii is the common bisnaga or barrel cactus found in the vicinity of Tucson. It is a columnar cactus usually 2 to 10 feet high, 1 to 2 feet in diameter in normal specimens; the stem is nearly always unbranched and cylindrical. Like all members of the genus Echinocactus (as well as the genera Cereus and Echinocereus), the stem is ribbed vertically, bearing a large number of areoles or clusters of spines. In the Echinocactus Wislizenii there are commonly about four central spines, red to white in color, the principal one turned somewhat downward and strongly hooked at the apex, the others nearly straight, 2 to 4 inches long, often more than 1/8 of an inch broad, tapering only at the apices, markedly cross-ribbed, stout and rigid.(1) It is this central hooked spine which gives this species, as well as a number of other cacti, the common name of "fishhook cactus"; it is said that the Indians use these spines as fishhooks.

The Echinocactus Wislizenii flowers in July and August, producing at the top of the plant orange-red or, rarely, yellow flowers about 1 1/2 inches in diameter. The fruit is yellow, narrowly ovoid, 1 1/4 to 1 3/4 inches long and 1 to 1 1/2 inches in diameter[2]; it ripens in early winter and is a favorite food for deer and rodents. This species grows on alluvial flats, grassy mesas, rocky hillsides, or in mountain canyons at 1,200 to 5,000 feet elevation; and is found from southern Arizona and Sonora to the western tip of Texas and Chihuahua.[1]

A search of the literature reveals that the chemical constitution of the Echinocactus Wislizenii has received very little attention and has not been subjected to the type of investigation described in this thesis. Table I gives a comparison of the analyses of the outer rind and inner pulp of a specimen from the Tucson area, as reported by MacDougal, Long, and Brown.[3]

Table I

Percentage Analysis of Echinocactus Wislizenii

	Rind	Inner Pulp
Moisture	91.88	94.58
Dry weight	8.12	5.42
Crude protein*	2.31	0.50
Crude fat*	1.11	1.01

*Expressed as percentage of dry weight.

Table II gives a comparison of the analyses of a section through the trunk and of the fruit, as given by Griffiths and Hare.(4)

Table II

Percentage Analysis of the Trunk and Fruit of Echinocactus Wislizenii

	Trunk	Fruit
Spines	0.62	
Water	87.81	78.26
Ash	1.70	1.47
Crude protein	0.71	2.80
Crude fat	0.13	2.50
Nitrogen-free extract	7.49	9.56
Crude fiber	2.16	5.41
Organic matter	10.49	20.27

The only detailed investigation of the carbohydrates of the cacti is that of Spoehr on the Opuntia or prickly pear cacti which will be referred to later.(5)

It may be mentioned that the principal chemical constituent of the barrel cactus,- water, - has long been known to the desert traveler. If the top of the cactus is cut off and the white pulp mashed down, a milky liquid soon collects in the hollow thus formed; this liquid is wholesome and not unpalatable and has saved from death many a traveler whose water supply has been exhausted.(6) This species is also the usual raw material for the manufacture of cactus candy.

B. The Polyuronides

The term "polyuronide" is applied to those polysaccharides containing one or more uronic acid molecules joined to various sugar units and possibly other groups, such as methyl groups joined by ether or ester linkings, acetyl groups joined by ester linkings, or metal ions. A uronic acid is an acid derived from a hexose sugar by oxidation of the primary alcohol group of the molecule to a carboxyl group. In natural products the only uronic acids so far found are glucuronic, galacturonic, and mannuronic acids. The two former have been found in many plant materials, while mannuronic acid has been found only in the gel-forming carbohydrates of certain marine algae.(7)

The polyuronide substances occurring in plants are of three general types: gums and mucilages, pectic

materials, and hemicelluloses. The nomenclature in the field of the polyuronides is very unsatisfactory and the lines of demarcation between the various types are not sharp. In general the gums and mucilages together with pectic materials are classed as "acidic polyuronides," in contrast to the "neutral polyuronides" or hemicelluloses. That is, the gums, mucilages, and pectic materials possess acidic properties due to the presence of free uronic acid groups; while the hemicelluloses, whose uronic acid groups in situ are not free, do not possess such properties. The nomenclature, occurrence, and constitution of the polyuronides are discussed in detail by Norman[8] and by Onslow.[9] The question of the origin and role of the polyuronides in the plant and whether or not they are associated with cellulose and lignin has not been answered satisfactorily, although many theories have been proposed; Norman,[10] Anderson,[11] Haworth,[12] Schorger,[13] and de Chalmot.[14] Norman[15] points out the significant fact

> ....that the sugar units commonly found in plant hemicelluloses belong to two distinct configurational groups and that in purified....preparations the appearance of units from both groups is unusual. The two groups are (i) Glucose series: d-glucose, d-glucuronic acid, and d-xylose, (ii) Galactose series: d-galactose, d-galacturonic acid, and l-arabinose.

The term "gum" is generally reserved for a pathological product of plants, usually occurring as an exudation from

a wound in the bark of trees or in fruits; gum arabic, lemon gum, and mesquite gum are examples. A mucilage is defined as any water-soluble polyuronide occurring in the normal plant; they may occur in any part of the plant, but are usually most abundant in the seeds.[16] Onslow considers both gums and mucilages to be abnormal products of the cell wall. The mucilages and water-soluble gums give viscid, mucilaginous solutions with water.

The pectic materials are a group of closely related "acidic polyuronides" which have been more extensively investigated than either the hemicelluloses or gums. The literature in this field is treated exhaustively by Branfoot.[17] The basic unit may be considered to be pectic acid, which is predominantly a polygalacturonic acid, though containing in addition some sugar units. The pectic substances occur very widely distributed in plants. The cell wall of young and green plant tissue and the middle lamella of older tissues are pectic in nature. Fruits of all types contain considerable quantities of pectic materials. They are found to the greatest extent in fleshy and succulent tissues.[18]

The hemicelluloses are cell-wall constituents of plants which are not dissolved out by water alone, but are dissolved by sodium hydroxide, and which are readily

hydrolyzed by hot dilute mineral acids to give various sugars. The sugars obtained are usually mixtures of pentoses and hexoses, along with uronic acids.

EXPERIMENTAL

A. The Raw Material

The material used in this investigation was collected in the vicinity of Tucson; it consisted of two cacti about 2 feet high and 1 1/2 feet in diameter, together with several pounds of the ripe fruit (collected in November and December). The outer green rind and the hard inner core were cut away and discarded. The soft white tissue was used in the investigation. Approximately 22 kilograms of this pulp were obtained from the two cacti. Analysis showed the presence of 95% moisture. The 22 kilograms of moist pulp therefore contained 1,100 grams of dry material.

B. The Isolation of Polyuronide Materials

Extract A:

The material obtained as described above was passed through a meat grinder and the liquid pressed out by hand through two layers of cloth. Approximately 70% by weight of the original material was obtained as liquid. Fraction A was precipitated by the addition of 3 to 5 volumes of 85% ethanol to the liquid. The precipitated material was centrifuged out and allowed to stand in 95% ethanol

for several days. It then was filtered off on a Buchner funnel and dried, first on a porous plate and then in vacuo. The material thus obtained was a fine, buff colored powder weighing 69.6 grams.

Extract B:

The pulp, after extraction of fraction A, was placed in several 6-liter florence flasks, covered with distilled water, and heated under reflux in a bath of boiling water for 2 hours. The hot suspension was filtered on a large Buchner funnel through two layers of cloth. Extract B was precipitated from the filtrate by the addition of 3-4 volumes of 85% ethanol. The precipitated material was treated as described for Extract A. The final product was a fine, buff colored powder, weighing 28.4 grams.

Extract C:

The pulp from the extraction of fraction B was placed in 6-liter flasks, covered with 0.05 normal hydrochloric acid, and heated under reflux in a bath of boiling water for 2 hours. The liquid was at once expressed by filtering on a Buchner funnel through two layers of cloth. Fraction C was precipitated from the acid filtrate by the addition of 3-4 volumes of 85% ethanol. This precipitate was dried as described above, and 137.9 grams of a fine, gray powder were obtained.

Extract D:

The pulp from the extraction of fraction C was covered with a 5% solution of ammonium hydroxide and allowed to stand at room temperature for some weeks. This suspension was pressed through two layers of cloth on a Buchner funnel. The alkaline filtrate was first neutralized with dilute hydrochloric acid, and the precipitation of Extract D completed by the addition of 3 volumes of 85% ethanol. The yield was 191.9 grams of a light-buff colored powder.

Extract N:

After extraction of fraction D, the pulp was placed in 6-liter flasks, covered with a 4% solution of sodium hydroxide, and allowed to stand at room temperatures for 4-5 days. The liquid was filtered through two layers of cloth and called fraction N. It was precipitated by neutralizing the filtrate with dilute hydrochloric acid and adding 3 volumes of 85% ethanol. No attempt was made to fractionate Extract N. The yield was 39.3 grams of a fine, white powder. A summary of the yields of the various fractions is given in Table III.

Extract FM or Mucilage from the Fruit:

The ripe fruit was run through a meat grinder. The resulting pulp was covered with distilled water and heated in a bath of boiling water for 2 hours. It was

Table III

Yield of Polyuronides from
Echinocactus Wislizenii

Fraction	Grams (crude)	Percentage yield
A	69.6	6.3
B	28.4	2.6
C	137.9	12.5
D	191.9	17.5
N	39.3	3.6
Total yield	467.1	42.5

allowed to cool and the liquid pressed by hand through a double layer of cloth. This gave a clear, honey-colored, very mucilaginous solution. The mucilage was precipitated by addition of 6 volumes of 85% ethanol, and isolated in the regular way. The pulp was again covered with water and the procedure repeated. A total yield of 52.0 grams of mucilage was obtained. It was a tan colored powder.

C. Methods of Analysis

Moisture:

The percentage moisture was determined in fractions A, B, N, and FM by drying to constant weight in an oven at 105° C. It was found that at this temperature fractions C and D charred to a considerable extent. Therefore, in these two cases, moisture was determined by drying in the

oven at 90° C. All fractions required a period of two days to reach constant weight.

Ash:

Samples were charred at a low heat until all volatile matter had been driven off; they were then ignited at the full heat of the Tirrill burner for successive periods of 1/2 hour each until they had reached constant weight.

A complete qualitative analysis of the ash of Extract A by the semi-micro methods of Hogness and Johnson[19] showed the presence of large amounts of calcium ions and of carbonate ions, smaller amounts of aluminum, magnesium, and phosphate, and traces of ferric iron, potassium, sodium, sulfate, chloride, and silicate. This agrees very closely with the average value of the analyses of the ashes from a number of species of cacti, reported by Griffiths and Hare.[20]

The results are given in Table IV. They are calculated to a moisture-free, ash-free basis.

Hexose Uronic Acid:

This determination is essentially that of Lefevre and Tollens[21] with modifications by Dickson, Otterson, and Link.[22] The method and apparatus used are described in detail by Krznarich.[23] In this investigation a further modification was introduced, in that the barium hydroxide solution used to absorb the carbon dioxide evolved contained 3% barium

chloride. Barium chloride in this concentration is said by Lindner[24] to prevent the precipitation of basic carbonates of barium and to prevent the hydrolysis of barium carbonate, both of which reactions tend to introduce errors into the determination.

Pentosan:

The percentage pentosan was determined as directed by Browne.[25] The furfural was precipitated with phloroglucinol and the weight of phloroglucide converted to araban by Krober's tables, after correction for the furfural from uronic acid.[26]

The percentage methyl pentosan was determined by the methods of Tollens and Ellett as modified by Haywood.[27] The weight of phloroglucide equivalent to methyl pentose was converted to rhamnosan by means of the tables of Tollens, Ellett, and Mayer.

Methoxyl:

A semi-micro modification of the Zeisel method was used in this determination.[28] A full description of the procedure and apparatus is given by Bennett.[29] The theoretical values for methoxyl were calculated from the percentage carbon dioxide, since it is known that the methoxyl is joined to the uronic acid.

Table IV

Analyses of Polyuronides

Fraction	A	B	C	D	N	FM
Moisture	0.05	3.6	9.95	6.83	0.68	4.4
Ash	30.9	21.9	10.1	4.1	2.1	5.01
Carbon dioxide	2.19	5.586	10.01	8.243	5.992	4.813
Uronic acid anhydride	8.78	22.34	40.04	32.97	23.97	19.25
Methoxyl	0.71	1.55	2.0	0.48	1.7	2.3
Araban	7.50	7.04	14.6	19.33	52.78	16.5
Rhamnosan	0.00	3.9	5.86	8.54	9.76	10.1
X-body	30.3**	26.8**	34.21	13.8	2.5	3.87
Hexosan*	83.01	65.2	7.1	24.9	9.3	48.0
Methoxyl units per uronic acid	0.46	0.40	0.28	0.082	0.41	0.68

*Calculated by difference
**Calculated on a moisture-free basis

D. Hydrolysis of the Polyuronides

X-body:

Portions of each of the fractions were mixed with 25 times their weight of a 5% sulfuric acid solution. The mixtures were heated in a bath of boiling water for 16 hours. The residue remaining at the end of this time was filtered out, dried in the oven at 105° C., and weighed. The yields of this residue, termed "X-body," are given in Table IV. The X-bodies from the hydrolyses of fractions A and B consisted predominantly of large, white, needle-like crystals; both residues charred only slightly on heating and did not melt at a red heat. Since the amounts of X-body found corresponded closely to the amount of ash found in the original material, and since the ash of Extract A was composed mostly of calcium carbonate, it appears that the X-bodies from the hydrolysis of fractions A and B were calcium sulfate. The amount of X-body was ignored in these two cases when calculating the amount of hexosan present.

Large residues were obtained on hydrolysis of fractions C and D. This was to be expected, since during the extraction of these two fractions some of the pulp itself was pressed through the cloth; such pulp would consist mainly of cellulose, which is very resistant to hydrolysis by dilute acids. An attempt was made to establish the

presence of cellulose in the X-body obtained from the hydrolysis of Extract D. The attempt was based on the theory that if the residue were cellulose, on hydrolysis by the method of Monier-Williams[30] it should give d-glucose; if the residue were unhydrolyzed Extract D, which was pectic in nature, it should give d-galactose, l-arabinose, l-rhamnose, or d-galacturonic acid[31] - but no glucose.

The material was ground to pass a 60-mesh screen and chlorinated once to remove any lignin. Five grams of the resulting white powder were mixed with 25 ml. of 72% sulfuric acid and allowed to stand at room temperatures for one week. The mixture was then diluted to 2.5 liters and heated to boiling under reflux for 16 hours. The residue still remaining after this treatment was filtered out, dried, and found to weigh 2.65 grams. The filtrate was neutralized with barium carbonate, and the precipitated barium sulfate filtered off. After decolorizing once with charcoal, the solution was concentrated <u>in vacuo</u> to a thick syrup weighing 2.0 grams. The sugars present in this syrup were then identified as follows:

(a) Bial's Orcinol[32] test was positive, indicating the presence of pentoses.

(b) The naphthoresorcin test was negative; that is, no color appeared in the benzene layer. But when the

benzene was poured off and ether added, a red-violet color appeared in the ether layer, again indicating the presence of pentose or methyl pentose.[33]

(c) Oxidation with strong nitric acid gave mucic acid (white crystals, insoluble in water, melting at 214° C. with decomposition), but no saccharic acid. This indicates the presence of d-galactose or d-galacturonic acid and the absence of more than 1/2 gram of d-glucose or d-glucuronic acid.[34]

These results, then, would indicate that less than 10% of the X-body could have been cellulose, since less than half of it was hydrolyzed by the Monier-Williams method which gives 90% yields of crystalline d-glucose from cotton cellulose, and no glucose was found in the hydrolyzate. That the X-body consisted at least partially of unhydrolyzed Extract D is shown by a hexose uronic acid determination on the original X-body, showing the presence of 26.80% uronic acid anhyrdride (about half that in Extract D), and the presence of pentose and galactose in the hydrolyzate. It was assumed that the X-body from fraction C is similar in composition, although no tests were made to confirm this assumption.

The X-bodies from the hydrolyses of fractions N and FM were small and were probably mostly inorganic material,

cellulose, etc., which, as in the case of fractions C and D, would have been removed by a preliminary purification.

In fractions C, D, N, and FM the X-body was added into the total determined percentage analysis in calculating the hexosan by difference.

Isolation of Barium Salts and Sugars:

The filtrate obtained after the removal of the X-body as described above was neutralized with solid barium carbonate and the precipitated barium sulfate filtered out. After decolorizing with charcoal, the filtrate was concentrated *in vacuo* and the barium salts precipitated with 95% ethanol, as described by Scott[35]. They were redissolved, decolorized, and reprecipitated once. The resulting light yellow, flocculent precipitate of barium salts was filtered off on a hardened filter paper and dried, first on a porous plate and then in the Abderhalden vacuum drier at the temperature of boiling water for 2-4 days and analyzed.

The alcoholic solution of the sugars obtained as described by Scott[35] was concentrated *in vacuo* to a small volume, and any remaining barium salts precipitated by pouring slowly with constant stirring into 95% ethanol. The resulting suspension was allowed to stand over night. The barium salts were then filtered out and the clear filtrate again concentrated *in vacuo*, this time to a thick

syrup. Qualitative analyses were made on this syrup.

Analyses of the Barium Salts:

At the time of writing, the analyses of the barium salts are not complete. The results to date are included in Table V. The theoretical percentages of carbon dioxide shown are calculated assuming one barium atom per two uronic acid complexes. From the very low percentage carbon dioxide and rotation of barium salt A, it is evident that this is not polyuronide material. Although no further attempt was made to identify this substance, it probably consists of inorganic material dissolved out of the charcoal used in decolorizing.

In barium salts C and D, the percentages carbon dioxide would indicate that the uronic acid was combined with one pentose and with two pentose units respectively. However, it will be noticed that: (a) both pentose and methylpentose occur in the two fractions, and (b) that the total percentage of pentose plus methylpentose falls far short of the theoretical values for barium salts containing a uronic acid and one or two pentose units. Further experiment would be necessary to establish the nature of these salts.

The barium salts from all fractions except A gave a positive color test (30) for pentose sugars. The presence of

Table V

Analyses of the Barium Salts

Fraction	A	C	D	FM	Theoretical		
					With one pentose	With two pentoses	With three pentoses
Carbon dioxide	0.74	11.53	8.501	6.748	11.18	8.38	6.69
Specific rotation	-2.93°						
Araban		13.8	8.48		34.6	53.5	60.5
Rhanmosan		6.1	6.8				

d-galacturonic acid in barium salts D and FM was shown by the method of Heidelberger and Goebel.(36)

Five-tenths of a gram of barium salts, 25 cc. of normal hydrochloric acid, and 0.5 cc. of bromine were placed in a flask attached by means of a ground glass stopper to a reflux condenser. This mixture was heated in a bath of boiling water for 16 hours. More bromine was added from time to time. At the end of this period the bromine was removed by evaporation under reduced pressure. The solution was concentrated in vacuo and the mixture set in the refrigerator to crystallize. The crystals were filtered off and after recrystallization from ammonium

hydroxide were identified as mucic acid by their melting point of 217° C. (with decomposition). This proves the presence of non-methylated d-galacturonic acid, since by this method only galacturonic acid could give mucic acid. It does not prove the absence of d-glucuronic acid.

Identification of the Sugars:

The identification of the sugars from the hydrolysis of the fractions is not complete at the time of writing. The sugar syrup from fraction A gave a negative test for pentoses,[32] a positive skatole test for hexoses,[37] and a negative Rosenthaler's test for methylpentoses.[38] Mannose was identified as the phenylhydrazone[39]; no tests were made for the presence of d-glucose and d-galactose.

The sugars from fraction FM gave a negative test for pentose sugars, and a positive test for methylpentoses. Galactose was identified by oxidation to mucic acid,[40] and the mucic acid identified by its melting point.

In Tables IV and V the percentages of pentose and methylpentose are expressed as "Araban" and "Rhamnosan" respectively. The presence of these sugars has not been proved; but because of the presence of d-galacturonic acid and d-galactose, the possibility of finding d-xylose is small (see quotation, p. 5), and, while rhamnose is very widely distributed in plants, fucose has been reported in only a few cases.

DISCUSSION

Methoxyl

The methoxyl content of all fractions is peculiar in showing the presence of methoxyl units, but in amounts corresponding to from one methoxyl unit per ten uronic acids up to two methoxyl units per three uronic acids. The analyses of the barium salts, when complete, should indicate whether this is because of the presence of some methylated and some unmethylated uronic acid units, or because of incomplete removal of ethanol during drying.

Extracts A, B, and FM

According to MacDougal[41], Long, and Brown the sap of the inner portion of the Echinocactus Wislizenii is approximately 0.01 normal with respect to hydrogen ion, due to the presence of organic acids. Fraction A, therefore, strictly speaking, is not a water-soluble portion; but for our purposes may be considered as such. Fractions A and B then represent the mucilage from the cactus, while fraction FM is the mucilage from the fruit. The analyses (Table IV) show that the fractions are not dissimilar. The mucilage from the fruit appears to contain greater

amounts of pentose and methylpentose, and less hexose than that from the cactus. Fraction A contains much less uronic acid anyhdride than either of the other two, and contains no methylpentose. An interesting possibility arises that the mucilage from the fruit may contain a different series of sugars from the mucilage of the cactus. That is, d-galacturonic acid and d-galactose have been identified in Extract FM; while the only sugar so far determined from Extract A is d-mannose, a sugar more closely related to d-glucose than to d-galactose. However, d-galactose and d-galacturonic acid have not been proved absent from fractions A and B. The mannose may occur in Extract A as a water-soluble mannan or galacto-mannan, as it does in the mucilage from palo verde bean.(42) This would account for the much lower percentage uronic acid anhydride and higher hexosan content of fraction A as compared to B and FM.

Extracts C and D

These fractions were extracted with the usual pectin solvents and therefore should be pectic in nature. However, although the uronic acid contents are 10-15% higher than in any of the other fractions, they are still much lower than the 61-84% listed by Norman(43) for pectic materials from various sources. This would suggest that the pectic

materials present are contaminated with hemicellulose or mucilage. This may or may not be supported by the presence of methylpentose, since some workers consider methylpentose to be an invariant constituent of pectin, while others do not consider it a part of the true pectic material. It will be noticed that the ratio of methoxyl to uronic acid groups is smaller in these two than in any other fractions.

Extract N

This fraction was extracted with dilute sodium hydroxide, the usual reagent for hemicellulose. This fraction, however, has a much higher uronic acid content than is usual in such preparations. The main difference in the analysis of this fraction from that of the other polyuronide materials from the barrel cactus is the high pentosan content. This is characteristic of hemicelluloses.

Comparison with the Work of Others

This is not the first time sugars of the d-galactose series have been reported in cacti. In 1902, Harley[44] reported d-galactose and l-arabinose in the mucilage from Opuntia vulgaris. Sands and Klass[45] found d-galacturonic acid, l-arabinose, l-rhamnose, and d-galactose in the gum from the cholla, Opuntia fulgida. These workers found that

the rhamnose was attached directly to the uronic acid, while the galactose was attached to the rhamnose and the arabinose was on the end of the chain. Results in the present investigation seem to indicate that in the polyuronides from Echinocactus Wislizenii the galactose is at the end of the chain and is split off easiest on hydrolysis; while in some fractions the rhamnose, and in others the arabinose, is attached directly to the galacturonic acid.

In contrast to the above cases Spoehr (46) isolated d-glucuronic acid, d-glucose, d-xylose (which, in accord with the old convention, he calls "l-xylose"), and d-fructose; he also showed the absence of d-galactose and d-galacturonic acid in Opuntia phaeacantha.

SUMMARY

1. Polyuronide materials were isolated from the barrel cactus, Echinocactus Wislizenii, and from the fruit of the cactus.

2. Forty-two and five-tenths per cent (42.5%) of the dry weight of the cactus was obtained as polyuronide material.

3. The mucilages from the cactus contain a lower percentage of pentose and methylpentose and a higher percentage of hexose than the mucilage from the fruit.

4. The pectic and hemicellulose fractions were apparently mixtures, containing both pectic material and hemicelluloses or mucilages.

5. The fractions were not purified; and on hydrolysis, residues or X-bodies were obtained from all fractions. In the two mucilage fractions from the cactus, this X-body was shown to be inorganic material. In the pectin fraction, it was probably unhydrolyzed polyuronides containing possibly some cellulose.

6. D-galacturonic acid and d-galactose were identified in the mucilage from the fruit. D-galacturonic acid

and d-mannose were identified in certain fractions from the cactus.

7. The uronic acid units present apparently are only partially methylated.

8. It is impossible to make a general statement about the sugars present in the cacti in general or even in species of the same genera; nevertheless, the mucilages from the Echinocactus Wislizenii and its fruit are similar in composition and structure to the gum of Opuntia fulgida.

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