PECTIC CONTENT OF PLANT MATERIALS

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Many plants and plant materials such as wood (**2**), tea (**25**), tobacco (**15**), cotton (**16**), hops (**13**), ramie (**11**), flax (**12**), grass (**6**), potato (**10**), plantain seed (**20**), celery (**9**), limes (**22**), guava (**1**), bergamot (**23**), and root hairs (**21**), have been shown to contain pectic compounds. Because different methods of extraction and analysis were employed, it is impossible to make comparative studies from these data of the pectic composition, types of pectic materials, and distribution of pectic compounds in these plants. A systematic study, employing uniform treatment of the pectic materials of leaves, cereal grains, apples, and citrus fruits, was conducted by NANJI and NORMAN (**18**). They determined water-soluble pectin, oxalic-acid-soluble pectin and ammonium-oxalate-soluble pectin. These data were interpreted as representing pectic material present as pectin, pectin in combination with metallic ions, and pectic acid. This interpretation was based on the theory that protopectin is an insoluble calcium, magnesium, or iron salt (**19**), and that treatment with oxalic acid and ammonium oxalate dissolved the pectin and pectates combined in this manner. More recent studies, however, (**3, 4, 14, 17, 24**), lead to the conclusion that the pectic molecule is essentially a long-chain, poly-galacturonic molecule combined through intermolecular forces and anhydride structure to form the insoluble protopectin layers of the cell wall and middle lamella. Single treatment with water or acid does not remove any definite pectic compound, but yields a part of a series of pectic substances; continued hydrolysis progressively dissolves the entire protopectin layer.

The lack of quantitative data for comparison of the distribution of pectin in the plant phyla has led to the present study. A large number of plants and plant materials have been included, and in order to obtain comparative data for the concentrations of each pectic fraction present, a system of extraction involving successive stages of hydrolysis was employed. The first stage involves the removal of the water soluble pectin; the second, the easily hydrolyzable protopectin; and the third, the difficultly hydrolyzable protopectin. These analyses have been supplemented by data on gelling power of the pectic material.

Extraction and analyses

One hundred grams of the material was ground in a sausage mill; 500 ml. of water were added, and the mixture was heated for one hour at 90° C., evaporated water being replaced during the heating. The pulp was then pressed free of the liquid and returned for a second extraction with 500 ml. of water containing 0.155 ml. H_2SO_4 (pH = 1.5). The pulp was again

TABLE I

PECTIN CONTENT OF VARIOUS PLANT TISSUES

PLANT	EXTRACT NO.	PECTIN AS CALCIUM PECTATE		PECTIN AS ALCOHOL PRECIPITATE		GELLING PROPERTIES
		WET BASIS	DRY BASIS	WET BASIS	DRY BASIS	
		%	%	%	%	
Apple (*Pyrus malus*)	1	0.37	2.46	0.22	1.36	Good
	2	1.00	6.67	0.21	1.35	
	3	0.23	1.37	0.18	1.20	
	Total	1.60	10.50	0.61	3.91	
Carrot (*Daucus carota*)	1	0.97	10.80	0.64	7.12	None
	2	0.33	3.68	0.62	6.89	
	3	0.21	2.34	0.41	4.56	
	Total	1.51	16.82	1.67	18.75	
Cranberry (*Vaccinium macrocarpon*	1	0.31	2.21	0.38	2.71	Some
	2	0.34	1.64	0.22	1.57	
	3	0.04	2.85	0.12	0.86	
	Total	0.69	6.70	0.72	5.14	
Fern (*Pteridium aquilinum* var. *pubescens* Underwood	1	0.57	1.78	0.17	0.53	Good
	2	0.37	1.16	0.76	2.37	
	3	0.21	0.61	0.26	0.81	
	Total	1.15	3.55	1.19	3.71	
Grape (*vitis vinifera*)	1	0.34	1.36	0.48	1.92	Some
	2	0.96	3.84	0.55	2.40	
	3	0.38	1.52	0.37	1.48	
	Total	1.68	6.72	1.40	5.80	
High bush cranberry (berry) (*Viburnum opulus*)	1	2.45	14.0	0.16	0.91	Good
	2	2.82	16.1	0.32	1.83	
	3	3.59	20.5	.....	.....	
	Total	8.86	50.6	0.48	2.74	
High bush cranberry (stored 3 months at 10° C.)	1	1.08	6.18	0.71	4.06	Slight
	2	1.28	7.32	0.62	3.54	
	3	0.53	3.03	0.38	2.17	
	Total	2.89	16.53	1.71	9.77	
Mountain ash (berry) (*Pyrus americana*)	1	0.90	2.57	0.22	0.63	Good
	2	0.96	2.74	0.98	2.79	
	3	0.88	2.51	.....	.....	
	Total	2.74	7.82	1.20	3.42	
Mountain ash (stored 3 months at 10° C.)	1	0.38	1.09	0.39	1.11	Slight
	2	0.19	0.54	0.49	1.40	
	3	0.01	0.03	0.21	0.60	
	Total	0.58	1.66	1.09	3.11	

TABLE I (*Continued*)

PECTIC CONTENT OF VARIOUS PLANT TISSUES

PLANT	EXTRACT NO.	PECTIN AS CALCIUM PECTATE		PECTIN AS ALCOHOL PRECIPITATE		GELLING PROPERTIES
		WET BASIS	DRY BASIS	WET BASIS	DRY BASIS	
		%	%	%	%	
Pea (hull) (*Pisum sativum*)	1	0.45	3.21	0.08	0.57	Good
	2	0.67	4.78	0.81	5.78	
	3	0.11	0.79	0.08	0.57	
	Total	1.23	8.78	0.97	6.92	
Scotch broom (*Cytisus scoparius*)	1	0.14	0.35	0.12	0.30	Good
	2	1.16	2.90	0.57	1.43	
	3	0.68	1.70	0.43	1.07	
	Total	1.98	4.95	1.12	2.80	
Snow berry (berry) (*Symphoricarpus racemosus*)	1	0.27	1.69	0.01	0.06	Some
	2	0.53	3.31	0.41	1.60	
	3	1.50	9.37	1.00	6.25	
	Total	2.30	14.37	1.42	7.91	
Sow thistle (*Sonchus oleraceus*)	1	0.37	2.18	0.07	0.41	Good
	2	0.72	4.24	0.42	2.47	
	3	0.35	2.06	0.18	1.06	
	Total	1.44	8.48	0.67	3.94	
St. John's wort (bud) (*Hypericum calycinum*)	1	1.10	4.08	0.13	4.82	Good
	2	2.69	9.62	5.03	18.60	
	3	1.17	4.34	0.69	2.56	
	Total	4.96	18.04	5.85	25.98	
St. John's wort (stem)	1	0.83	1.93	0.06	0.14	Good
	2	1.18	2.75	2.24	7.27	
	3	0.92	2.14	0.54	1.25	
	Total	2.93	6.82	2.84	8.66	

pressed and returned for a third extraction; the same quantity of the acid solution previously used was added and a 2-hr. extraction was employed. The filtrates obtained from the three extractions were each made up to one liter, and aliquot parts were used for analysis. Data on the pectin content of various plants, as determined both by the method of calcium pectate precipitation (**22**) and by the method of alcohol precipitation, are given in table I, with calculations to the dry basis. Data on the pectin content of vegetables, obtained by the method of alcohol precipitation, are shown in table II with calculations to the dry basis. Data on the pectin content of apples according to this method of treatment are included in table I to serve for comparison with other published analyses.

TABLE II

PECTIC CONTENT OF VARIOUS VEGETABLES

PLANT	EXTRACT NO.	PECTIN AS ALCOHOL PRECIPITATE		GELLING PROPERTIES
		WET BASIS	DRY BASIS	
		%	%	
Artichoke (*Cynara scolymus*)	1	1.28	7.12	Slight
	2	0.87	4.83	
	3	0.34	1.89	
	Total	2.49	13.84	
Asparagus (*Asparagus officinalis*)	1	0.29	4.15	None
	2	1.56	22.10	
	3	0.16	2.29	
	Total	2.01	28.54	
Beet (top) (*Beta vulgaris*)	1	0.32	6.40	None
	2	0.43	8.63	
	3	0.41	8.20	
	Total	1.16	23.23	
Beet (root)	1	0.32	2.00	None
	2	0.47	2.94	
	3	0.39	2.44	
	Total	1.18	7.38	
Broccoli (*Brassica oleracea*)	1	0.84	6.46	None
	2	1.07	8.15	
	3	0.54	4.16	
	Total	2.45	18.77	
Brussels sprout (*Brassica oleracea* L. var. *gemmifera* Zenker)	1	0.69	3.83	None
	2	0.94	5.22	
	3	0.81	4.50	
	Total	2.44	13.55	
Celery (*Apium graveolens*)	1	0.40	5.72	None
	2	0.44	6.28	
	3	0.15	2.14	
	Total	0.99	14.14	
Dandelion (*Taraxacum officinalis*)	1	2.11	8.80	None
	2	2.21	9.22	
	3	3.15	13.10	
	Total	7.47	31.42	
Lettuce (*Lactuca sativa*)	1	0.13	4.33	Slight
	2	0.28	9.34	
	3	0.24	11.32	
	Total	0.75	24.99	
Onion (*Allium cepa*)	1	0.36	3.00	None
	2	0.72	6.00	
	3	0.32	2.67	
	Total	1.40	11.67	

TABLE II (*Continued*)

PECTIC CONTENT OF VARIOUS VEGETABLES

PLANT	EXTRACT NO.	PECTIN AS ALCOHOL PRECIPITATE		GELLING PROPERTIES
		WET BASIS	DRY BASIS	
		%	%	
Parsnip (*Pastinaca sativa*)	1	0.83	5.22	None
	2	1.10	6.88	
	3	1.20	7.50	
	Total	3.13	19.60	
Potato (*Solanum tuberosum*)	1	0.81	3.52	None
	2	1.17	5.08	
	3	0.77	3.35	
	Total	2.75	11.95	
Rhubarb (*Rheum rhaponticum*)	1	2.42	30.4	Slight
	2	2.84	35.5	
	3	2.00	25.0	
	Total	7.26	90.9	
Rutabaga (*Brassica napobrassica* Mill.)	1	0.39	2.17	None
	2	0.71	3.97	
	3	0.47	2.61	
	Total	1.57	8.75	
Spinach (*Spinacea oleracea* L.)	1	0.96	3.00	None
	2	0.47	3.91	
	3	0.61	5.08	
	Total	2.04	11.99	
Squash (*Cucurbita moschata*)	1	0.20	1.82	None
	2	0.50	4.54	
	3	0.80	7.28	
	Total	1.50	13.64	
Sweet potato (*Ipomoea batatas*)	1	1.63	4.80	None
	2	0.99	2.91	
	3	0.95	2.79	
	Total	3.57	10.50	
Swiss chard (*Beta vulgaris* var. *cicla* L.)	1	0.22	4.40	None
	2	3.17	63.40	
	3	0.15	3.00	
	Total	3.54	70.80	
Tomato (*Lycopersicum esculentum*)	1	0.32	5.33	None
	2	0.19	3.17	
	3	0.11	1.84	
	Total	0.62	10.34	
Turnip (*Brassica campestris* var. turnip)	1	0.44	3.38	None
	2	0.39	3.00	
	3	0.44	3.38	
	Total	1.27	9.76	

Tests of the gelling power of the alcohol precipitate were made as follows: The filtrate from an one-hour extraction of 100 gm. of the material with 500 ml. of water containing 0.155 ml. H_2SO_4 was added to two volumes of 95 per cent. alcohol. The precipitated pectin was separated, dried, and one gram of it with one gram tartaric acid was dissolved in 55 ml. of water, and 100 gm. of sucrose added. The mixture was boiled until a weight of 150 gm. was attained. The strength of the jelly was estimated after standing for 24 hours.

Discussion

The data of tables I and II disclose several interesting points concerning concentration, properties, and changes of pectin in plant materials.

Among plants of the same family or genus there is no apparent correlation in amount of the three types of pectic material. In the case of *Pyrus malus* the predominant type is that obtained by hot water extraction, while *Pyrus americana* shows approximately equal concentrations of each type. Certain correlation is exhibited by the members of the genus Brassica in the predominance of the hot water soluble pectin.

All the plants studied are rapidly growing and BUSTON's (**5**) hypothesis that pectic materials develop under conditions of rapid growth is confirmed. The table shows that slower growing, woody plants, such as Scotch broom, sow thistle, and bracken fern contain but small quantities of pectic material while the fast growing vegetables contain large quantities. On the other hand, it is evident that conditions of high pectin content and fast growth do not favor the formation of the gelling type of pectin. Plants that possess pectin of high gelling power usually contain less than 10 per cent. of pectin on the dry basis, while those of low gelling power are of the vegetable type and contain more than 10 per cent. pectin.

The plant pericarps, such as those of fruits and berries, are the usual source of gelling pectin. It is shown that stems and branches of plants may also yield pectin of the gelling type, as in the cases of Scotch broom, bracken fern, sow thistle, and St. John's wort. Other sources of gelling pectin are mountain ash, high bush cranberry, cranberry, snow berry, St. John's wort buds, and pea-hulls.

The natural process of pectin alteration in plants follows a course of protopectin hydrolysis followed by hydrolysis of soluble pectic compounds and pectates (**7, 8**). From data concerning the change of pectic material during storage in mountain ash, and high bush cranberry, it is concluded that during ripening the type of pectin that is obtained by the third extraction undergoes the most rapid change of the three types of pectic compounds. There is an accompanying decrease in amount of the pectic material of the types derived by the first and second extraction processes. The rate of decrease in these types is less, indicating that the enzymatic processes in-

volved in the degradation of the difficultly soluble type of pectic material proceed more rapidly than those that effect the soluble type. This may be attributed to different enzymatic actions, or, to a single process, the rate of which changes with altering conditions.

Summary

Comparative quantitative data on the pectic content of many plant materials have been obtained; also, data indicating the enzyme processes involved in the degradation of pectin.

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