CARBOHYDRATE AND ACID COMPOSITION OF FINNISH BERRIES

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Abstract. The study comprised six wild and seven cultivated berries grown in Finland, one imported berry and the rhubarb. The samples were analysed for sugars, starch, hemicel ulose polysaccharides, cellulose, crude lignin, titratable and total acidity and organic salts, crude protein, crude fat and ash. Five berry species were furthermore analysed for the amount and composition of seeds. The sugar content of the berries is some 35—55 per cent of the dry matter, hemicellulose plus cellulose is 10—20 per cent, and crude lignin 3—10 per cent. A considerable proportion of the last two groups occurs in the seeds. The total amount of plant acids varies within a range of 10—20 per cent, and 10—30 per cent of the acids is in the form of salts. Titratable acid amounts to some 70—90 per cent of the total acid content. Seed content and the composition of seeds varies greatly. In some berries seeds account for one-quarter of the dry matter, and seeds may have a fat content that is nearly 30 per cent of the dry matter.

The main components in the dry matter of berries are carbohydrates, primarily sugars, and non-volatile organic acid, i.e. plant acids. There is, however, little published information on the composition of berries. Money and Christian (1950) quated analytical data of fruits, including many berry fruits. These data include total sugars and titratable acidity. Similar information is provided in Osborn's (1964) table. Kuusi (1969) has published certain parameters of Finnish berries though no carbohydrate values. Like the above authors, she expresses the acidity as a simple titration result, the so-called titratable acidity. Certain textbooks and tables of foodstuffs (e.g. Souci et al. 1962, Drews 1968) contain similar data on some berries. Whiting (1958) has studied the non-volatile acids of some berries, determining both the titratable acid and total acid content.

The objective of the present study was to investigate the main composition of Finnish berries. The samples were analysed for sugars, starch, hemicellulose, cellulose, crude lignin, titratable and total acidity, organic salts, crude protein, crude fat and ash. Five berry species were furthermore analysed for the amount and composition of seeds.

Materials and methods

Materials. The samples were obtained from Helsinki vegetable market and food stores. The berries accepted for analysis were ripe, fresh and of good quality. The only exception was the cloudberry which appeared to have been picked half-ripe and had ripened in the dish. Berries of poor appearance were discarded from the samples.

From three berry species, two different samples were analysed. The sample blueberry I represents the first ripe berries on the market, while blueberry II was picked three weeks later. Samples I and II of strawberry and raspberry were obtained at a few days interval. In addition to Finnish berries, also an imported berry, the Hungarian raspberry, was investigated. Besides berries, also rhubarb was analysed.

Preparing of samples. All berries were »tailed» before weighing, and the gooseberries also »topped». The hard berries were rinsed in water and dried with paper. The rhubarb was peeled and chopped. The berries were crushed in a dish and the majority of the samples was freeze-dried. Other samples were dried in a vacuum oven at 40°C. No difference was noted between the two drying methods in the analysis, and the method is therefore not indicated in the tables. The dried samples were ground with an IKA analysis mill. A sieve mill is not suitable for this type of material.

A seed sample was prepared from five berry species, and the proportion of seed in the dry matter was determined. Seeds were separated using a Top Drive macerater, sieves and water.

Methods. The carbohydrates were determined by Salo's (1965a) method. The hemicellulose determination was, however, carried out directly on ethanol-extracted residue. No starch was traced in the berries, and the occurence of fructosan was considered so unlikely that it was not tested.

Titratable acidity, total acidity and organic salts were determined by the methods of Salo and Kotilainen (1969). The only exception was that the cation determination was carried out with flame spectrophotometry on a number of the samples, and with atomic absorption spectrophotometry on the rest. The latter determination is faster since cations can be determined directly from aqueous extraction.

Crude protein was determined by the Kjeldahl method. Crude fat was determined by the conventional ether extraction method. The dry matter was determined by drying at 100°C and the ash by incineration at 700°C.

Results and discussion

Carbohydrates. Table 1 presents the carbohydrate contents of the berries. Like all other analysis results of the present paper they are expressed as a percentage of dry matter.

The results reveal, firstly, that sugars form the biggest dry matter group in berries. The amount of sugars, monosaccharides and sucrose together, usually varies within the range of 35—55 per cent. The bulk of the sugars is in the form of monosaccharides (glucose and fructose). The fact that cloudberry has a lower sugar content than the other berries was probably due to the sample having ripened in the dish. No starch was found in the berries, not even in their seeds.

Berries have a relatively high content of hemicellulose, cellulose and lignin. A comparison of the figures of Tables 4 and 5 shows that a considerable proportion of these cell-wall substances derives from the seeds. Especially xylans and mannans belong to the seeds. Seed plants usually have mannans only in traces (Salo 1965b), whereas mannose was

Table 1. Carbohydrate and lignin contents of berries, percentages of dry matter

	Mono-sacha-rides	Sucrose	Hemicellulose sugar anhydr.	Hemicellulose uronic anhydr.	Cellu-lose	Crude lignin	Percentile distribution of hemicellulose sugars galac-tose	glu-cose	man-nose	arabi-nose	xylose
Wild berries											
Strawberry	24.9	14.6	4.6	6.8	4.9	6.0	20	10	+	30	40
Blueberry I	43.2	0.0	6.3	5.5	5.6	4.9	20	10	+	20	50
» II	46.6	3.7	4.7	5.0	4.0	5.1					
Raspberry	35.2	2.1	5.5	5.4	7.8	8.0	15	15	+	20	50
Cloudberry	23.0	0.0	9.2	9.4	13.9	10.2	10	10	+	10	70
Lingonberry	48.7	2.1	3.4	4.7	3.6	3.8	20	10	+	50	20
Cranberry	36.0	0.0	4.1	5.4	4.8	8.1	25	10	+	45	20
Cultivated berries											
Strawberry »Ydun»	37.9	14.7	3.5	5.7	4.8	4.9	25	10	+	35	30
» »Senga Sengana» I	44.7	9.7	3.0	6.6	3.6	2.9	20	5	+	50	25
» » » II	38,3	20.1	2.5	7.4	2.7	2.8					
Raspberry, Finnish »Preussen»	26.5	6.4	5.9	6.5	8.0	9.2	20	10	—	20	50
» Hungarian I	43.3	5.4	5.0	5.3	6.9	7.3	20	10	—	20	50
» » II	37.9	8.4	5.2	5 2	7.4	7.2					
Black currant »Bröd-torp»	36.1	4.7	4.7	6.5	2.8	7.2	15	15	30	20	20
Red » »Punain. hollantil.»	34.2	1.7	8.4	5.9	4.5	10.2	15	10	35	20	20
Gooseberry »Lepaan punain.»	36.6	13.9	6.1	5.0	3.1	5.8	20	5	35	35	5
» »Houghton»	37.6	11.2	5.3	5.6	2.8	7.2					
Rhubarb	9.8	3.5	5.7	7.0	10.3	3.8	50	10	—	15	25

found to form about two-thirds of the hemicellulose sugar units in the seeds of currants and gooseberries. In the seeds of other berries mannose is replaced by xylose. The high content of uronic acid, galactose and arabinose indicates that the hemicellulose of the seedless part of berries principally belongs to the pectin group. Crude lignin is surprisingly abundant in many berries.

Rhubarb differs from berries on many points; as regards carbohydrates the most essential difference is the low sugar content.

The papers mentioned in the introduction have assembled figures on total sugars, indicating the mean, maximum and minimum values calculated on fresh weight. Comparison is difficult because also the dry matter contents are mean values of several samples. The only conclusion that can be drawn is that the sugar contents of the present study are well within the variation ranges of the data quoted in the literature. No comparable figures were found in the literature for carbohydrate groups other than the sugars.

Plant acids and organic salts. Table 2 supplies data on the acid content of berries. The first column gives the so-called titratable acidity, i.e. the simple

Table 2. Free and combined acids of berries per 1 g dry matter.

	Acidity mequiv.		Correc- tions[1]) mequiv.	Corrected total acidity		Water-sol. cations, mequiv.					Plant acids, mequiv.		Free acids % of total	Titrat. acidity % of total
	titra- table	total		mequiv.	as citric acid %	K^+	Na^+	Ca^{++}	Mg^{++}	total	free	salts		
Wild berries														
Strawberry	1.44	1.94	0.04	1.90	12.2	0.31	0.00	0.11	0.12	0.54	1.40	0.50	74	74
Blueberry I	1.00	1.38	0.02	1.36	8.7	0.17	0.00	0.07	0.06	0.30	1.08	0.28	79	72
,, II	1.18	1.42	0.03	1.39	8.9	0.19	0.00	0.06	0.04	0.29	1.13	0.26	81	83
Raspberry	1.46	1.77	0.06	1.71	10.9	0.29	0.00	0.06	0.10	0.45	1.32	0.39	77	82
Cloudberry	1.02	1.41	0.04	1.37	8.8	0.28	0.01	0.07	0.11	0.47	0.94	0.43	69	72
Lingonberry	1.64	1.86	0.02	1.84	11.8	0.13	0.01	0.09	0.04	0.27	1.59	0.25	86	88
Cranberry	2.88	3.13	0.01	3.12	20.0	0.14	0.00	0.09	0.04	0.27	2.86	0.26	92	92
Cultivated berries														
Strawberry »Ydun»	1.78	2.30	0.10	2.20	14.1	0.45	0.01	0.07	0.10	0.63	1.67	0.53	76	77
,, »Senga S.» I	1.53	2.16	0.08	2.08	13.3	0.50	0.01	0.07	0.14	0.72	1.44	0.64	69	71
,, ,, II	1.51	2.06	0.05	2.01	12.9	0.50	0.01	0.07	0.09	0.69	1.39	0.62	69	73
Raspberry, Finnish	2.29	2.71	0.06	2.65	17.0	0.36	0.00	0.07	0.14	0.57	2.14	0.51	81	85
,, Hungarian I	1.14	1.42	0.08	1.34	8.6	0.24	0.01	0.08	0.09	0.42	1.00	0.34	75	80
,, ,, II	1.23	1.52	0.08	1.44	9.2	0.16	0.01	0.06	0.07	0.30	1.22	0.22	85	81
Black currant	2.56	3.05	0.09	2.96	18.9	0.40	0.01	0.10	0.09	0.60	2.45	0.51	83	84
Red ,,	2.11	1.64	0.11	2.53	16.2	0.45	0.01	0.08	0.07	0.61	2.03	0.50	80	80
Gooseberry »L.p.»	2.00	2.34	0.05	2.29	14.6	0.34	0.01	0.04	0.03	0.42	1.92	0.37	76	85
,, »H.»	2.38	2.73	0.04	2.69	17.2	0.28	0.01	0.08	0.06	0.43	2.30	0.39	86	87
Rhubarb	4.82	6.40	0.38	6.02	38.5	1.23	0.01	0.03	0.10	1.37	5.03	0.99	84	75

[1]) See text

titration result of water extract. Column 2 shows the total acidity, i.e. the acid result after salts had been converted into acid form by cation exchanger. The cation exchanger also changes the possible inorganic salts into corresponding acids, and column 3 gives the sum of the phosphate, chloride and nitrate corrections, mainly composed of phosphates. The corrected total acidity is shown in the table both as equivalents and calculated as citric acid. Berries, like plant materials in general, contain many organic acids. In berries citric acid is found to predominate (Whiting 1958, Kushman & Ballinger 1968), whereas malic acid predominates in rhubarb. Also oxalic acids occurs in rhubarb, but forms only 10—30 per cent of the total acid quantity. Furthermore, almost half of it is not soluble in water (Blundstone & Dickinson 1964, Allison 1966).

Table 2 also shows the amounts of four water soluble cations, and the organic salt quantities calculated on the basis of the sum of cations. The percentages reveal that the majority of the acids in berries (some 70—90 per cent) is in free form. Furthermore it can be seen that this figure is in agreement with the titratable acidity obtained by simple alkaline titration. The titratable acidity suffices, therefore, for a relatively precise determination of the free acid quantity in berries. In vegetables and feeds the share of free acid in total acid is much lower and less uniform (about 10—50 per cent) (Salo & Kotilainen 1969). For this reason also their titratable acidity/total acidity ratio varies within wide limits.

Table 3. Dry matter content and the main groups of dry matter of berries

	Dry matter %	Percentages of dry matter									Ratio sugar/acid
		Sugars	Other carbohydrates	Crude lignin	Plant acids	Crude protein	Crude fat	Ash	Total determined	Seeds	
Wild berries											
Strawberry	15.5	39.5	16.3	6.0	12.2	8.1	5.2	4.0	91.3		3.2
Blueberry I	16.3	43.2	17.4	4.9	8.7	6.2	7.3	1.7	89.4		5.0
„ II	16.1	50.3	13.7	5.1	8.9	5.2	6.4	1.8	91.4		5.7
Raspberry		37.3	18.7	8.0	10.9	7.7	8.4	2.9	93.9		3.4
Cloudberry	16.5	23.0	32.5	10.2	8.8	10.5	7.0	2.9	94.9		2.6
Lingonberry	16.5	50.8	11.7	3.8	11.8	3.7	4.6	1.3	87.7		4.3
Cranberry	13.8	36.0	14.3	8.1	20.0	4.0	5.5	1.4	89.3		1.8
Cultivated barries											
Strawberry »Y.»	11.0	52.6	14.0	4.9	14.1	6.8	2.6	4.0	99.0		3.7
„ »S.S.» I	11.3	54.4	13.2	2.9	13.3	8.1	2.4	4.4	98.7	7.2	4.1
„ „ II	10.2	58.4	12.6	2.8	12.9	6.9	2.4	4.2	100.2		4.5
Raspberry, Finnish	15.7	32.9	20.4	9.2	17.0	8.1	5.5	3.3	96.4		1.9
„ , Hungarian I	16.4	48.7	17.2	7.3	8.6	8.3	3.8	2.4	96.3		5.5
„ , „ II	16.3	46.3	17.8	7.2	9.2	8.6	3.9	2.2	95.2	23.9	5.0
Black Currant	19.8	40.8	14.0	7.2	18.9	8.0	4.0	4.1	97.0	13.3	2.2
Red „	16.8	35.9	18.8	10.2	16.2	7.1	6.9	4.1	99.2	23.0	2.2
Gooseberry »L.p.»	17.1	50.5	14.2	5.8	14.6	5.5	2.5	2.9	96.0	10.0	3.5
„ »H.»	19.0	43.8	13.7	7.2	17.2	4.1	2.4	2.5	95.9		2.8
Rhubarb	5.7	13.3	23.0	3.8	38.5	12.5	2.4	10.5	104.0		0.3

The acid content of most berries is of the order of 10—20 per cent of the dry matter. Cranberry, currants, gooseberry and raspberry represent the highest acid content, cloudberry and blueberry the lowest. The only sample of foreign berries in the table, the Hungarian raspberry, differs essentially from the Finnish: its acid content is about half that of the Finnish, while it has more sugar than the Finnish raspberry. The same finding was recorded in a comparison of Finnish and imported apples (Salo & Korhonen 1972).

It is difficult to compare the reports in the literature with the present results for the reason already indicated for sugars. If a comparison of titratable acidity of fresh weight is carried out, the mean values for the same berry species in Kuusi's (1969) tables are of the same magnitude as those now reported, excepting the lingonberry and cranberry for which Kuusi quotes a higher acid content. In the tables of Money and Christian (1950) and of Osborn (1964) the titratable acidity values are somewhat lower than the present values. The same is true of rhubarb (Blundstone & Dickinson 1964, Allison 1966). Whiting (1958) determined both total acids and titratable acids for some of the berry species included in the present study. His figures, on the whole, were also slightly lower than the present values; the acid content of raspberry, however, was closer to the Finnish than the Hungarian. The share of titratable acidity in total acidity was close to that recorded in the present study.

General information on the composition of berries. Table 3 presents general information on the composition of berries.

The differences in cell-wall carbohydrates, lignin and protein contents are partly due to differences in the seed content, as can be seen from Tables 4 and 5, and partly

Table 4. Composition of berry seeds

	Seeds % of dry matter	Composition of seeds % of dry matter								
		Sugars	Hemicellulose sugar anhydr.	Hemicellulose uronic anhydr.	Cellulose	Crude-lignin	Plant acids	Crude protein	Crude fat	Ash
Black currant	13.3	4.7	19.7	5.0	7.4	20.1	1.5	25.6	28.9	4.6
Red currant	23.0	6.5	25.5	3.4	7.9	10.7	1.5	19.0	24.9	3.2
Gooseberry »Lepaan pun.»	10.0	4.9	24.5	4.7	7.6	18.2	1.6	21.8	24.9	3.6
Raspberry, Hungarian	23.9	1.1	14.1	5.5	24.2	25.5	1.3	7.7	8.2	2.0
Strawberry »Senga S.»	7.2	1.5	10.9	—	11.7	24.0	—	19.4	—	2.4

Table 5. Composition of the seedless part of berries, percentages of dry matter

	Seedless part %	Sugars	Hemicellulose sugar anhydr.	Hemicellulose uronic anhydr.	Cellulose	Crude lignin	Plant acids	Crude protein	Ash
Black currant	86.7	46.4	2.4	6.7	2.1	5.2	21.6	5.3	5.1
Red currant	77.0	44.7	3.2	6.6	3.5	10.0	20.6	3.5	4.4
Gooseberry	90.0	55.6	4.0	5.0	2.6	4.4	16.0	3.7	2.8
Raspberry, Hungarian	76.1	63.8	2.1	5.2	1.4	1.5	10.9	8.5	2.5
Strawberry »Senga S.»	92.8	58.5	2.4	—	3.0	1.3	—	7.2	4.6

to the structural differences of the berry species. The analysis results suggest that the seed content is highest in cloudberry which, however, was not examined for seeds.

The differences in crude fat content are due to differences both in the seed content of various berries and in the fat contents of the seeds (cf. Table 4). The fat values are inaccurate, because e.g. citric and malic acid are dissolved in ether.

The last column shows the sugar/acid ratio. This figure reveals clearly the difference between the Finnish and Hungarian raspberry. It also reveals the difference between the berries and rhubarb.

It can furthermore be seen that the difference in composition between different samples (I and II) of the same species are not great. The riper berries seem to contain some more sugar and less protein than the less ripe ones, whereas no difference can be seen in the acid contents.

The seeds. When berries are eaten a large quantity of seeds, up to a quarter of the dry matter, is also eaten. In the human body the berry seeds escape digestion. Owing to the high seed content the physiological calorie value of berries is lower than might be expected from the chemical composition of the berries.

The seed content and composition of seeds was determined for five berry samples. The dry matter content of seeds was about 60—65 per cent. Table 4 shows the seed content and their composition calculated on dry matter. A low content of sugar and acid is the characteristic common to the seeds of all five species. Otherwise the composition of seeds varies a great deal from one species to another. The currants and gooseberries are alike: the main component of the hemicellulose is mannan, in the other species it is xylan. No starch occurs in seeds; the energy reserve consists of fat which in currant and gooseberry seeds amounts to 25—30 per cent of dry matter. The seed residue obtained from currants in the berry processing industry would make valuable animal feed owing to its high fat and protein content, if drying and grinding the residue were an economic proposition.

Table 5 shows the composition of the seedless part of berries, calculated by subtraction. The sugar and acid contents are naturally higher compared with the whole-berry sample, while the proportion of cell-wall components and mostly also that of protein has fallen. In currants and gooseberries, the »tops» of the berries apparently raise the cell-wall contstituent percentage of the seedless part. The crude fat content is not calculated because the ether extract partly consists of substances other than lipids.

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SELOSTUS

SUOMALAISTEN MARJOJEN HIILIHYDRAATTI- JA HAPPOPITOISUUDESTA

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Tutkimuksessa määritettiin kuudesta suomalaisesta luonnonmarjasta ja seitsemästä puutarhamarjasta, yhdestä tuontimarjasta sekä raparperista sokerit, hemiselluloosahiilihydraatit, selluloosa, raakaligniini, vapaana ja suolamuodossa esiintyvät kasvihapot, raakaproteiini, raakarasva ja tuhka. Viidestä marjalajista määritettiin lisäksi siementen osuus ja siementen koostumus. Analyysitulokset käyvät ilmi taulukoista.

Yleispiirteenä mainittakoon, että marjoissa on sokeria noin 35—55 % kuiva-aineesta, kettoainehiilihydraatteja 10—20 % ja raakaligniiniä 3—10 %. Huomattava osa kahdesta viimeksimainitusta ryhmästä kuuluu siemeniin. Kasvihappojen kokonaismäärä liikkuu rajoissa 10—20 %. Hapoista 10—30 % on suolamuodossa.

Tavanomainen raakarasvamääritys antaa liioitellun kuvan marjojen kaloriarvosta, sillä raakarasva koostuu siementen lipideistä ja malto-osan orgaanisista hapoista.

Siemenpitoisuus ja siementen koostumus vaihtelee suuresti. Eräissä marjoissa siemeniä on neljäsosa kuiva-aineesta. Siemenet saattavat sisältää rasvaa 30 % kuiva-aineesta.