DISTRIBUTION OF CERTAIN SUGARS IN BOSC PEARS

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(WITH TWO FIGURES)

Introduction

Since an investigation of the various sugars present in winter pears was in progress at this station, it was thought desirable to determine in a preliminary way the variation in the sugar content of the various portions of the fruit, and from this information to decide as to the best method of taking samples of the pear. The effort was made to divide the fruit into natural regions on the basis of anatomical characteristics rather than on the basis of some arbitrary geometric differentiation.

KELHOFER (**6**) has noted that in the Siebenmannsbienen pear sugar and acid were higher in the central fleshy portion of the fruit than in the core or peel. Tannin was observed in greatest concentration in the peel while small amounts were noted in the core region. Analyses of blossom end, central portion, and stem end showed slightly more sugar and acid in the blossom end than in the central portion, and still smaller amounts in the stem end of the fruit.

ALLEN (**1**) in reporting on the electrical conductivity of pear tissue showed that there were quite marked differences in the specific resistance of the flesh of the cortical and pith regions of Bartlett pears, and noted that the resistance of the flesh of these regions changed as the fruit ripened after harvest.

While a number of workers have investigated the amounts of sucrose, dextrose, and levulose in pears both during the growing season (**5, 14**) and during storage (**4**), none have reported the concentration of these sugars in the several regions of the fruit.

SMITH (**13**) has recently published a comprehensive report dealing with the course of stone cell formation in pear fruits and has shown the changes in total sugars, starch, hemicellulose, pectins, and other constituents during growth and subsequent storage. He has pointed out the importance of expressing the results of analyses of growing fruits in terms of the actual amounts of the various constituents per fruit rather than in terms of concentration, and has suggested that sampling which included the whole fruit would be more representative in sugar content than that taken only from the midsection if it were established that marked differences in sugar concentration existed in the various parts of the fruit.

CRIST and BATJER (**3**) have reported on the nature and occurrence of "grit cells" in pear fruits and have discussed their probable function as well as that of the stony sheath of these cells surrounding the core of the fruit.

Since no complete investigation of the morphology of the pear has been reported as yet it was thought desirable to make a brief study of longitudinal and transverse sections of the pear in an effort to determine the general anatomy of the fruit. Longitudinal sections were prepared by cutting 4-mm. sections of the fruit with a bread knife, then soaking these overnight in 5 per cent. chloral hydrate, and finally clearing for one week in 2 per cent. potassium hydroxide. Transverse sections were made by imbedding a pear in a block of paraffin and sectioning in a meat slicer in one of the local butcher shops. By use of this method transverse sections 1 mm. thick from the calyx to the stem end of the fruit were rapidly and easily cut. These sections were partially dehydrated without curling by keeping in 70 per cent. alcohol 24 hours and then clearing in 95 per cent. alcohol for one week. By these methods both longitudinal and transverse sections were prepared which photographed clearly. The nomenclature used by KRAUS (7, 8) in his studies of the morphology of the apple has been adopted to designate and describe the various regions of the pear.

After a study of the longitudinal and transverse sections of the pear (figs. 1 and 2) it became evident that the fruit might logically be divided into four regions on the basis of marked differences in the anatomy of the fruit itself. The most obvious of these regions were the skin and core portions of the fruit, but it was also noticed that the remaining flesh was made up of two distinct areas differing markedly in their structure. The outer portion of

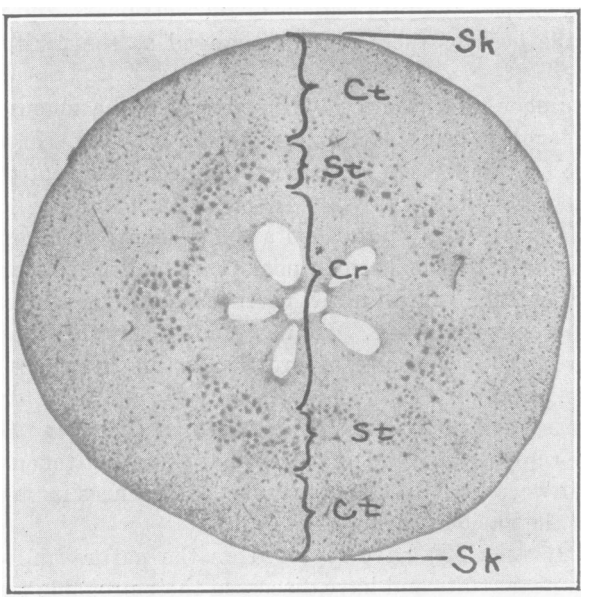

FIG. 1. Transverse section of pear through carpels.

the flesh contained a network of fine anastomosing vascular bundles and comparatively few small stone cells, while the inner portion was practically devoid of fine anastomosing bundles and contained many large stone cells which formed a rather dense sheath about the core. These two portions of the fruit were separated at the median section through the carpels (fig. 1) by the ten primary vascular bundles, but no definite core line was observed as in the apple.

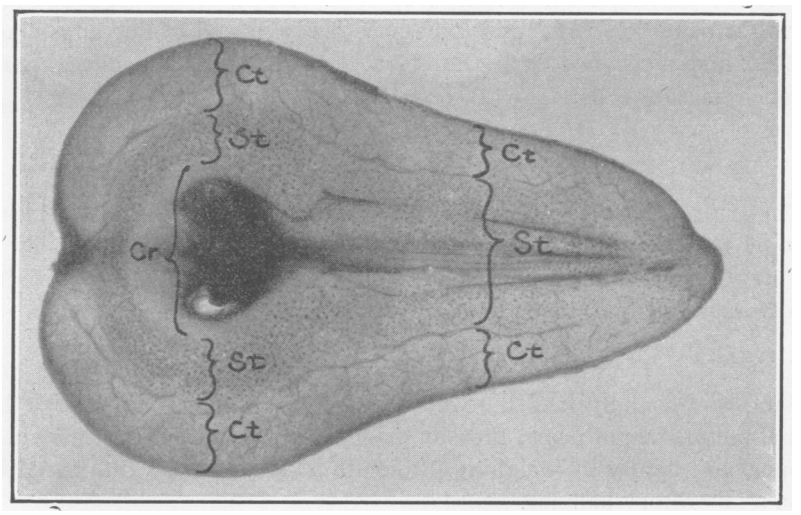

FIG. 2. Longitudinal section of pear along axis and through carpels.
Sk—Skin region
Ct—Cortical region
St—Stone cell region
Cr—Core region

Using these observations as a basis the fruit was divided into the following four regions: (a) The innermost portion of the fruit was designated as the *core region* and was made up of the seeds, carpels, and the surrounding parenchyma which extended outward to the dense stony layer mentioned above and shown in figures 1 and 2. (b) The outermost portion of the fruit was designated as the *skin region* and included the cuticle, epidermis, and such portions of the cortex as might be removed in careful peeling. The cuticle and epidermis had been ruptured in much of the skin during the natural process of russeting and a number of layers of corky tissue had been formed from a cork cambium in the outer portion of the cortex. These corky tissues were likewise included in the skin region. (c) The outer portion of the remaining flesh containing the secondary vascular bundles and their fine anastomosing branches extended inward as far as the outer cycle of primary vascular bundles and appeared to correspond to the cortex of the apple. It

was therefore designated as the *cortical region.* (d) The remaining portion of the fruit was designated as the *stone cell region.* In the calyx end of the fruit and at the section through the carpels (fig. 1) this region lay inside of the ten primary vascular bundles, but toward the stem end it was apparently traversed by the dorsal and ventral carpellary bundles as well as by the inner cycle of primary vascular bundles. From the material at hand it was not possible to determine whether the tissue of this region belonged morphologically to the pith or to the cortex or to both. In all of the sections studied, however, this region was found to be practically devoid of fine anastomosing bundles, and contained large numbers of stone cells or aggregations of sclerenchymatous cells.

Materials and methods

Source of materials

The fruit used in this investigation was obtained from a single tree of a block of full-bearing Bosc trees in the upper Rogue River Valley near Phoenix, Oregon. The fruit was picked on August 26, 1934, and withdrawn from storage for analysis on January 20, 1935.

Methods of sampling

Samples for analysis of the whole fruit were prepared by cutting longitudinal sectors of ten pears, then by grinding these through a Russwin food chopper, and finally by weighing duplicate 50-gm. samples into tared beakers on a laboratory balance.

In the preparation of samples of tissue from the four regions which have been described above, ten additional sectors were cut from the opposite sides of the same ten pears. These ten sectors were then divided by means of a small narrow-bladed scalpel into portions from the skin, cortical, stone cell, and core regions. The portions from each region were placed in tared beakers and the fresh weight of tissue from each region was recorded. Seven additional pears were sampled in the same fashion except that two opposite sectors were cut from each fruit. Enough additional skin was pared and core material cut from the remaining portions of the fruit so that sufficient material was at hand to prepare duplicate 25-gm. samples of the core material and duplicate 50-gm. samples of tissue from each of the other regions. All samples were preserved by boiling 2 to 3 min. in sufficient ethyl alcohol so that the final concentration was above 80 per cent.

Methods of chemical analysis

The material was extracted with 95 per cent. ethyl alcohol in a Soxhlet apparatus, the alcohol then evaporated at 40 to 45° C. under a 26 to 28-in. vacuum, and the aqueous extract finally clarified by the addition of neutral lead acetate and deleaded with a slight excess of potassium oxalate.

Reducing sugars before and after inversion were determined by the method of LANE and EYNON (9). Sucrose was then calculated from the difference in reducing sugars before and after inversion. The inversion was carried out by the following procedure: 10 ml. HCl (sp. gr. 1.1029) were added to 100 ml. of solution and the mixture heated one hour in a hot water oven at 70° C. Dextrose and levulose were determined by the method of LOTHROP and HOLMES (11) with the following modifications. (a) Owing to the low sugar content of the extracts to be analyzed it was found desirable to reduce by half the amounts of the reagents to react with a given amount of sugar solution. (b) Owing to lack of facilities it was necessary to carry out the oxidation at room temperature (20–25° C.) instead of at 20° C. Total sugars were computed as the numerical sum of sucrose, dextrose, and levulose. The alcohol insoluble residue was determined as the dry weight of the material remaining in the tared thimbles after extraction.

Presentation and discussion of results

The amounts and proportions of the fresh tissue found to be present in the various regions, as determined by the weights of the component parts of the longitudinal sectors, are listed in table I. It is to be noted that the cortical region contained over half of the total tissue of the pear, the stone cell region a little over a quarter, while successively smaller amounts were found in the skin and core regions.

TABLE I

REGIONAL DISTRIBUTION OF PEAR TISSUE

REGION	10 SECTORS FROM 10 PEARS		14 SECTORS FROM 7 PEARS		AVERAGE PERCENTAGE OF FRESH WEIGHT
	WEIGHT OF TISSUE	PERCENTAGE OF FRESH WEIGHT	WEIGHT OF TISSUE	PERCENTAGE OF FRESH WEIGHT	
	gm.	%	*gm.*	%	%
Skin	23	11.92	24	10.39	11.08
Cortical	104	53.88	126	54.55	54.25
Stone cell	53	27.46	64	27.70	27.60
Core	13	6.74	17	7.36	7.07
Total weight	193	100.00	231	100.00	100.00

The results of the sugar analyses of the material from each of the four regions of the fruit as well as those of the undivided sectors are shown in table II.

It is apparent from table II that the total sugar content was greatest in the cortical and core regions, while it was somewhat less in the stone cell region and markedly smaller in the skin.

TABLE II

VARIATION IN SUGAR CONTENT OF THE SEVERAL REGIONS OF THE PEAR EXPRESSED AS PERCENTAGES OF FRESH WEIGHT

REGION	ALC. INS. RESIDUE	SUCROSE	LEVULOSE	DEXTROSE	REDUCING SUGARS	TOTAL SUGARS
	%	%	%	%	%	%
Skin	5.82	1.91	3.27	3.72	6.99	8.90
Cortical	2.80	2.72	6.00	2.32	8.32	11.04
Stone cell	4.85	3.60	4.55	2.00	6.55	10.15
Core	5.52	2.25	5.80	2.67	8.47	10.72
Undivided sectors	3.98	3.18	5.22	2.39	7.61	10.79

More significant variations, however, were observed in the concentrations of the individual sugars. Sucrose was present in far greater amounts in the stone cell region than in any other part of the fruit. Both levulose and reducing sugars were present in largest amounts in the core and cortical regions.

The fact that both levulose and reducing sugars were high in the core and cortical regions is of especial interest since these portions of the fruit appear to be the terminal regions of the vascular bundles through which carbohydrates pass into the fruit. Similarly the facts that sucrose was high and that reducing sugars were low in the stone cell region are significant since this region appeared to be very nearly devoid of fine anastomosing bundles although it was traversed and bordered by the larger vascular bundles.

While dextrose was observed to be present in the highest concentration in the skin there is a possibility that some interfering substance may have been present. The glucoside arbutin, reported in pear bark by LINCOLN (**10**) and in pear leaves and in the skin of the pear by BOURQUELOT and FICHTENHOLZ (**2**), may have affected the observed proportions of levulose and dextrose if present in appreciable amounts. Tests with pure arbutin, added to pear extracts, showed that its presence would not have affected the values of reducing sugars or sucrose which were determined by copper reduction methods, but would have materially affected the iodometric determination of dextrose as carried out by the method of LOTHROP and HOLMES (**11**), and consequently would have caused error in the observed proportions of dextrose and levulose. Unfortunately no work was done in this preliminary investigation to determine the actual extent to which arbutin or other interfering substances were present in the fruit.

The composition of the undivided sectors, as shown in table II, differed considerably from that of tissue from the other regions studied. This was to be expected, however, since the undivided sectors were made up of unequal

amounts of material from each of these four regions of the fruit. It may be well to point out, in addition, that the sectors dissected to provide regional material were in no cases taken adjacent to the undivided sectors, and in over half of the material were taken from a different set of pears.

A comparison of the composition of the undivided sectors with the corresponding compositions of the tissues of the four regions was made in order to test the method of using longitudinal sectors as a source of representative material in sampling. These sectors taken along the longitudinal axis, should have contained material from the various regions of the fruit in proportion to the total amounts of material present in each region in the whole fruit. The composition of the undivided sectors should have been a weighted average of the individual compositions of the four designated regions.

To test this it was assumed from the data in table I that in 100 gm. of representative material, 11.08 gm. was derived from the skin region, 54.25 gm. from the cortical region, 27.58 gm. from the stone cell region, and 7.07 gm. from the core region. By multiplying each of these weights by the percentages of the several sugars listed in table II for the appropriate region, data were obtained showing the amount and source of the sugars observed in 100 gm. of representative tissue. These amounts are listed in table III.

TABLE III

DISTRIBUTION OF SUGARS IN 100 GRAMS OF REPRESENTATIVE TISSUE EXPRESSED IN GRAMS OF SUGAR

REGION	ALC. INS. RESIDUE	SUCROSE	LEVULOSE	DEXTROSE	REDUCING SUGARS	TOTAL SUGARS
Skin	0.643	0.211	0.361	0.411	0.772	0.983
Cortical	1.519	1.476	3.255	1.258	4.513	5.989
Stone cell	1.338	0.994	1.256	0.552	1.808	2.802
Core	0.390	0.159	0.410	0.189	0.599	0.758
Sum of the sugars in all regions	3.89	2.84	5.282	2.410	7.692	10.532
Composition of undivided sectors	3.98	3.18	5.22	2.39	7.61	10.79

Ideally the sum of the amounts of each sugar found in the four regions should have equalled the amount of the same sugar as determined by the analysis of the undivided longitudinal sectors. A comparison of these two sets of values is given in table III and it may be noted that these values are in most cases nearly equal. It appears then that the analysis of longitudinal sectors yields results very nearly equal to the sum of the same constituents as determined by the analysis of the component regions of the fruit.

If further investigation bears out the observed differences in sugar con-

tent noted in the several regions of the fruit, it would seem essential in taking samples for chemical analysis that each region make up the same proportion of the sample as of the total tissue of the fruit. Similarly it may be pointed out that the removal of the skin and core in sampling may affect the results of subsequent analyses, while the use of flesh of the fruit derived only from the midsection may yield samples which are not truly representative of the fruit as a whole.

Summary

1. As a result of a study of sections of the fruit, the pear was divided for chemical analysis into the following four regions on the basis of anatomical differences in structure.

(a) The *skin region* included the cuticle, epidermis, and several layers of corky tissues together with such additional portions of the cortex as might be removed in careful peeling.

(b) The *cortical region* included the bulk of the cortex and was located between the skin region and the outer cycle of primary vascular bundles and contained large numbers of fine anastomosing vascular bundles.

(c) The *stone cell region* included the tissues lying between the cortical region and the pith parenchyma about the carpels, and was so named because of the large numbers of stone cells occurring in that portion of the fruit.

(d) The *core region* included the carpels, seeds, and the pith parenchyma extending from the carpels outward to the dense stony sheath marking the inner boundary of the stone cell region.

2. The observed amounts of material found in these regions constituted far different percentages of the pear, 54 per cent. of the fresh weight being found in the cortical region, 28 per cent. in the stone cell region, 11 per cent. in the skin region, and 7 per cent. in the core region.

3. While noticeable differences in the total sugar concentration were observed in the four regions, far more significant differences were noted in the concentrations of the individual sugars, dextrose, levulose, and sucrose, in these regions.

4. Levulose was found to be the predominant sugar in all parts of the fruit except the skin, and the highest concentrations were noted in the cortical and core regions.

5. Sucrose was observed in largest amounts in the stone cell region with lessening amounts in the cortical, core, and skin regions.

6. Dextrose was present in largest amounts in the skin while the amounts found in the other regions differed but slightly.

7. On the basis of these preliminary observations, it appears highly desirable in taking samples of Bosc pears for chemical analysis that the amounts of material from each of the four regions of the fruit be present in proportion

to the total amounts of tissue of each of these regions actually present in the fruit if a truly representative sample is to be obtained.

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