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SOME CARBOHYDRATE CHANGES IN SHELLED GREEN PEAS

Z. I. Kertesz

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BULLETIN No. 622

SOME CARBOHYDRATE CHANGES IN SHELLED GREEN PEAS

Z. I. KERTESZ

ABSTRACT

An attempt has been made to trace the origin of the long-standing fallacy that sugars change to starch when shelled green peas are held before canning. New experimental evidence is advanced to prove the incorrectness of this assumption, and the practical relations of the results are pointed out.

When changes in the composition of shelled green peas are expressed as percentages of fresh or dry weights at the time the samples are taken, they give no indication of the changes in absolute quantities of the various constituents, which alter the weight of a unit. Thus the samples include varying numbers of units and the composition expressed in percentage of the fresh or dry weight is often misleading.

INTRODUCTION

Chemical changes in shelled green peas have assumed considerable commercial importance in recent years. With an over-production from the standpoint of the individual producer in practically all lines of agriculture and with considerable surplus at hand, the importance of the quality of agricultural products assumes the ascendancy over high yields and mass production. The regulatory work of state and federal authorities which sets standards and gives definitions to different quality grades imposes an additional severe penalty on the producer of low-grade products by requiring the labeling of all sub-standard goods. This means that manufactured products must be of at least standard quality to have a fair chance to be marketed and to make a return to the manufacturer and grower.

Delays in the regular progress of shelled peas to the can are sometimes unavoidable. The rapid deterioration of shelled green peas in such cases often results in canned products of inferior quality even after relatively short periods of holding. Studies have
been made of changes occurring in shelled peas in an effort to find methods of holding shelled green peas before canning. In these studies the disappearance of sugars from the peas could always be demonstrated, but contrary to the general belief no increase in the percentage and absolute amount of starch was found.

At the present time there are three official methods for the determination of starch in different products, but not enough care has been exercised by various workers in evaluating the limitations of these methods. One often finds in the literature reports of the starch content of vegetables based on determinations made by the direct acid-hydrolysis method which was adapted by the Association of Official Agricultural Chemists for the determination of starch in raw starch, potatoes, etc. This method gives data which include pentosans and other acid-hydrolyzable higher carbohydrates as starch. Still the results obtained by this method on vegetables are often referred to as starch. This is obviously incorrect since other higher carbohydrates were also present. This fact often led to faulty conclusions concerning the fate of carbohydrates in stored vegetables.

IMPORTANT OF PROPER SAMPLING TECHNIC

The accurate sampling of respiring plant material is a very difficult matter, altho the difficulties are generally overlooked. The usual expression of the analytical data on the fresh and dry matter basis may be misleading in this regard. When decreasing moisture content is accompanied by losses in dry matter caused by respiration, a 100-gram sample from stored plant material may include in successive samples more and more units of the original material, because the simultaneous decrease in moisture and dry matter content causes a diminution in the weight of a single unit. Consequently, the samples taken later include a larger proportion of the unchanged constituents. This can be illustrated by Fig. 1, where the chemical composition of a 100-gram sample is shown graphically.

A represents the original 100-gram sample. Suppose that during a 6-hour storage period the water content decreases by 20 per cent and the sugar content by 50 per cent, the composition of the sample may be represented by B and C. When the results are calculated on the actual weight of the sample after 6 hours, there is an
apparent increase in fractions 3 and 4 which represent starch and constituents other than water and sugars. Obviously, this is not true, and the results can be correctly expressed only on the basis of the original 100-gram sample, as has been done in C where it is shown that the starch content has not changed. An apparent increase in unchanged constituents occurs as a result of the incorrect method of calculation.

Fig. 1.—The apparent increase in the unchanged constituents of respiring plant material as the result of expressing the chemical analysis on a percentage basis.

A, original 100 grams of peas. B, the same 100 gram sample after 6 hours of storage. The composition is calculated on the basis of the actual weight after 6 hours. Note the apparent increase in fractions 3 and 4. C, the same as B, but with the results of the chemical determinations calculated on the basis of the original 100-gram sample.

Two methods which have been used to avoid this error may be applied to any case when the results of chemical analyses made on successive samples from plant material are calculated. One of these methods should be used not only with respiring material, but in all cases where the weight of a single unit is changed by washing, cooking, etc.
The two methods are as follows: 1. The use of a certain number of units, such as a definite number of fruits, peas, etc. This method can be applied only in cases where units of regular sizes can be obtained, or where the size of a unit is small enough to obtain a significantly representative number of the units in a certain weight.

2. The use of a certain weight of material with all samples weighed at the beginning of the experiment. In this case the difference between the weight of the original sample and the sample taken after a certain period represents the losses in moisture and also in other constituents.

Studying the changes which occur in peas during storage and under other conditions, the first method is the better one. It is called the "single pea basis" and it represents in the samples graded for sizes the absolute weight of a constituent in a single pea of given size, or in the case of ungraded samples the absolute weight of the constituent in an average pea.

EVALUATION OF PREVIOUS WORK

Brown, in 1928, reported experiments on the effect of paper wrappers on the keeping of shelled green peas (Telephone variety) at different temperatures. He recorded the loss of sugars from stored peas and the accumulation of starch at the same time. His results, or rather their interpretation, are based on the fresh material or dry matter basis, without taking into consideration the simultaneous decrease of water and total solids. However, he recorded the weight lost by the different samples during certain periods. These data make it possible to recalculate his figures for the original 100 grams of peas. Table 1 presents the results on the check samples, which were not wrapped in paper, as given by Brown, and the recalculated values.

No chemical data on the fresh peas entering the storage are given, and for this reason these figures cannot be evaluated from the standpoint of progressive changes in the stored peas. On the other hand, they represent the usual way of expressing analytical results obtained on vegetables. Comparing the two columns as given by Brown and recalculated for the original 100 grams of fresh peas, it is obvious that the method of presentation makes a variation of several hundred

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### Table 1 — Brown's Results Recalculated for Original 100 Grams of Fresh Peas

<table>
<thead>
<tr>
<th>No. of experiment</th>
<th>Storage at °C</th>
<th>Days</th>
<th>Loss of weight, per cent</th>
<th>Sugars, per cent</th>
<th>Starch, per cent</th>
<th>Dry matter, per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>3.8</td>
<td>2.94</td>
<td>1.24</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>26.7</td>
<td>0.22</td>
<td>3.72</td>
<td>2.77</td>
<td>0.74</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>7</td>
<td>0.98</td>
<td>20.00</td>
<td>20.28</td>
<td>9.26</td>
</tr>
</tbody>
</table>

Recalculated Brown

Recalculated
per cent. Brown found that "the starch content increased 400 per cent" in the wrapped samples stored at high temperatures for 7 days. According to his figures, the checks showed an increase of 480 per cent in starch, while the same sample contained when calculated on the original 100-gram basis only 81 per cent more starch than the 3-day-old sample. Obviously, Brown's results and conclusions were sufficient and fit to draw conclusions as regards the effect of paper wrappers on final composition and quality; nevertheless, his way of presenting the analytical figures was such that conclusions as to changes in absolute quantities were fallacious.

Jones and Bisson\(^2\) studied the changes occurring in garden peas after harvest. These authors sampled the stored peas in the usual way, \textit{viz.}, without recording the changes in the weight per pea. Their samples taken after various intervals obviously contained different numbers of peas since they observed a constant percentage of dry matter during a 24-hour storage period of shelled peas, but found a large decrease (53 per cent) in the sucrose content of the peas. The constant dry matter content reported by them must have been the result of an approximately uniform and simultaneous evaporation of water and the consumption of solid materials by respiration. Since neither the rate of loss of weight nor the number of peas contained in the samples is given, their results cannot be recalculated. It is believed, however, that the recorded increase in starch is due to the method of presenting the results.

**EXPERIMENTAL RESULTS**

Before presenting the experimental results obtained at this Station, it should be mentioned that the starch determinations were always performed by treatment with taka diastase\(^3\) instead of malt diastase, followed by acid hydrolysis. The sugars were extracted by hot 80 per cent alcohol and determined by Bertrand's method\(^4\) and calculated by the use of the recalculated tables.\(^5\) In all experiments only small amounts


\(^5\) Kertesz, Z. I. Recalculated tables for the determination of reducing sugars by Bertrand's method. \textit{Budapest}, 1930.
of reducing sugars have been found in peas. For this reason, in the following tables, only the amount of total sugars found are indicated.

The author presented a paper in 1930 on the chemical changes in shelled green peas. The results of these experiments were presented on the fresh material basis, but a sufficient number of samples and notes were taken at the time to extend later the analytical work on these samples and to calculate the results on the single pea basis. The results of these determinations are presented in Table 2.

These samples were stored in flat glass dishes and consequently they dried out much more rapidly than peas would under commercial storage conditions. In the young peas the starch content was constant within the limits of fluctuation caused by sampling and experimental error. In the older peas the starch content decreased appreciably during storage. There was some increase in both cases in the fraction designated as "other acid-hydrolyzable higher carbohydrates," but this was immaterial as compared with the large losses in the sugars. The "total analyzed carbohydrates" decreased rapidly during storage. A very definite increase was found in the fraction insoluble in hot 80 per cent alcohol including higher carbohydrates, most proteins, etc. This shows that during storage some compounds included in this fraction are formed which are not starch and other acid-hydrolyzable higher carbohydrates. It is believed, that the desiccation of some colloids of the peas is at least partly responsible for the production of these materials.

Kerteszt and Green reported experiments on the holding of canneries peas before canning on a commercial scale. Peas were kept in cold storage for several days without serious deterioration when they were chilled in ice water before entering the storage. Other lots were given the regular hot water blanch used in canneries (5 minutes at 82°C) before cooling, and the loss in quality was slower following this treatment than where the blanch was omitted. Samples from both lots were taken regularly for chemical analyses and the results calculated on the single pea basis. Table 3 presents some of the results obtained.


Table 2.—Carbohydrate Changes in Stored Peas in 1929, Expressed in mg. per Pea.

<table>
<thead>
<tr>
<th>No. of Test</th>
<th>Storage at 25° C</th>
<th>Fresh weight, mg.</th>
<th>Alcohol-insoluble residue, mg.</th>
<th>Total sugars, mg.</th>
<th>Starch, mg.</th>
<th>Other acid-hydrolyzable higher carbohydrates, mg.</th>
<th>Total analyzed higher carbohydrates, mg.</th>
<th>Total analyzed carbohydrates, mg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>211</td>
<td>15.13</td>
<td>15.9</td>
<td>1.90</td>
<td>3.25</td>
<td>5.15</td>
<td>21.05</td>
</tr>
<tr>
<td>2</td>
<td>6 hours</td>
<td>200</td>
<td>18.71</td>
<td>9.0</td>
<td>1.52</td>
<td>3.61</td>
<td>5.13</td>
<td>14.13</td>
</tr>
<tr>
<td>3</td>
<td>24 hours</td>
<td>177</td>
<td>22.92</td>
<td>5.9</td>
<td>1.98</td>
<td>4.05</td>
<td>6.03</td>
<td>11.93</td>
</tr>
<tr>
<td>4</td>
<td>7 days</td>
<td>34</td>
<td>23.09</td>
<td>4.2</td>
<td>0.61</td>
<td>4.64</td>
<td>5.25</td>
<td>9.45</td>
</tr>
<tr>
<td>5</td>
<td>50 days</td>
<td>31</td>
<td>23.50</td>
<td>2.7</td>
<td>1.54</td>
<td>4.55</td>
<td>6.09</td>
<td>8.79</td>
</tr>
</tbody>
</table>

6 Days from Blooming*

| 6 | None | 293 | 28.35 | 22.5 | 4.72 | 3.38 | 8.10 | 30.60 |
| 7 | 6 hours | 274 | 30.30 | 14.3 | 2.94 | 4.28 | 7.22 | 21.52 |
| 8 | 24 hours | 228 | 34.61 | 10.7 | 2.82 | 7.35 | 10.17 | 20.87 |
| 9 | 48 hours | 162 | 34.80 | 5.2  | 3.02 | 7.76 | 10.78 | 15.98 |
| 10 | 56 hours | 100 | 34.17 | 6.0  | 1.91 | 6.86 | 8.80 | 14.80 |

10 Days from Blooming†

*Dry weight, 32.8 mg.
†Dry weight, 57.8 mg.
It is obvious again that the starch content per pea did not increase. There was some loss in sugars in the unblanched peas, while there was no significant change in these constituents in the blanched samples. This fact is undoubtedly due to the partial inactivation of the respiratory enzyme system by the heat of blanching. It has been shown by the author\textsuperscript{8} that a 5-minute treatment at 82°C reduces respiration as measured by the amount of carbon dioxide produced by about 90 per cent. The variation in the sugar content of the blanched samples is within the experimental and sampling error. No significant change in the crude fiber content could be observed.

### Table 3.—Carbohydrate Changes in Stored Peas in 1931, Expressed in mg. per Pea.

<table>
<thead>
<tr>
<th>No. of test</th>
<th>Storage, hours</th>
<th>Fresh weight, mg.</th>
<th>Dry weight, mg.</th>
<th>Alcohol-insoluble residue, mg.</th>
<th>Total sugars, mg.</th>
<th>Starch, mg.</th>
<th>Crude fiber, mg.</th>
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<tbody>
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<td>1</td>
<td>None</td>
<td>406</td>
<td>94.1</td>
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<td>15.8</td>
<td>12.7</td>
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<tr>
<td>2</td>
<td>20</td>
<td>430</td>
<td>98.2</td>
<td>66.5</td>
<td>11.3</td>
<td>11.2</td>
<td>8.1</td>
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<td>48</td>
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<td>11.4</td>
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<td>6</td>
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<td>92.0</td>
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<table>
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</table>

In 1932, an extensive study of this question was made with machine-shelled size 4 Perfection peas. Lots of the same peas were treated in several different ways and stored at 3° and 25°C for different periods. These peas were stored in wire baskets containing 5 pounds of peas and for this reason the drying out proceeded slowly. Since the weight of a single pea changed during storage, the results have been calculated on the single pea basis. These figures are to be found in Table 4.

<table>
<thead>
<tr>
<th>No. of test</th>
<th>Storage Temperature, °C</th>
<th>Storage Period, hours</th>
<th>Fresh weight, mg.</th>
<th>Dry weight, mg.</th>
<th>Alcohol insoluble residue, mg.</th>
<th>Total sugars, mg.</th>
<th>Starch, mg.</th>
<th>Acid-hydrolyzable higher carbohydrates, mg.</th>
<th>Total analyzed carbohydrates, mg.</th>
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<td>1</td>
<td>-</td>
<td>-</td>
<td>363</td>
<td>69.1</td>
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<td>15.8</td>
<td>4.60</td>
<td>9.82</td>
<td>30.22</td>
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<td>3.57</td>
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<td>15.3</td>
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<td>3.54</td>
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The blanching always extracted considerable amounts of material, especially carbohydrates, from the peas, a fact noted before by Strassburger. The dry matter per pea decreased in the untreated samples during storage. The decrease in the treated samples was much less and more irregular. The total sugars per pea decreased in the untreated samples and in the sample blanched for 5 minutes at 82°C, and there was some decrease in the peas heated for 15 seconds at 100°C. The total sugars were almost constant in the samples heated for 1 minute at 100°C. The respiration in these peas was reduced by about 98 per cent, according to data reported by the author, thus giving the least diminution in sugars during storage. Again no increase in the starch could be found in any of the samples. The fraction designated as "other acid-hydrolyzable higher carbohydrates" showed some increase during storage of the untreated samples, but because of the fluctuation of these figures little consideration should be given to this finding. The treated samples also showed some variation in this fraction, but without any regular trend. The total analyzed carbohydrates show a decrease in the case of the untreated samples, but there is practically no change in them in the blanched samples.

PRACTICAL RELATIONS OF THE PROBLEM

Altho the assumption that the sugars in peas are transformed into starch during storage could not be verified, there is a practical relation of this problem worth considering.

When 100 pounds of shelled peas are weighed and canned after storage, there may actually be less sugar and more starch in the 100 pounds than when the peas are weighed immediately after harvest. This increase in starch, however, is by no means the product of transformation of sugars into starch, as has been generally believed, but is due to the disappearance of other constituents, leaving a large proportion of the unchanged products. The canner's task is to process all the raw material without delay, if possible, but where delays are unavoidable precautions should be taken to prevent or to delay the chemical changes which lower the quality of the product. It has been shown that losses in sugars in peas can

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*Strassburger, L. V. Blanching of peas. The Canner, 74, No. 20, 13. 1932.

*Loc. cit.*
be avoided by the inactivation of the respiratory enzymes by blanching the peas and by using storage temperatures near the freezing point.

CONCLUSIONS

The literature contains relatively little information on the chemistry of vegetables, considering their enormous economic importance. Many suppositions have come to be regarded as true, despite the fact that they have never been proved. One of these is the assumption that sugars are transformed into starch in shelled green cannery peas.

In the present paper it has been emphasized that the methods of sampling and calculation are mostly responsible for the few data in the literature which seem to prove this supposition. When these results are recalculated on a basis which is regarded as the only one giving reliable results, the fallacy of the conclusions can be proved.

The fate of the sugars in stored green peas is not entirely clarified by the experimental results presented. Obviously, the majority of them are consumed in respiration and in the production of carbon dioxide. There are other products besides carbohydrates which increase the solid content of peas during storage. It seems that this is especially true, or can best be traced, in the experiments presented in Table 2 where the peas were stored in flat glass dishes in a thin layer.

No evidence of transformation of sugars into starch during storage could be found. Some increase was found in other acid-hydrolyzable higher carbohydrates and in the fraction insoluble in 80 per cent hot alcohol. These results cannot be explained on the basis of our present knowledge.