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ON THE NATURE OF THE SUGARS FOUND IN THE TUBERS OF ARROWHEAD.

By

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慈姑中の糖の性質に就きて

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The present paper embodies the result of our study on the nature of the sugars found in the arrowhead tubers (*Sagittaria sagittifolia forma sinensis*), and forms a part of the investigation of sugars contained in the underground reserve organs of plants, now being conducted in our laboratory.

In the reserve organs of plants, the substances must be kept in a highly condensed form in order that they may be stored up in as small a space as possible, since the nutrition of the young shoots in early spring necessarily depends on the materials stored up in these organs. In fact, such a substance as a starch, which is a highly condensed form of glucose, is generally abundantly stored in the underground organs of many plants. From this reason, it may be inferred that the sugars in these organs will also take the higher condensed forms rather than ordinary monosaccharide.

Investigations of the sugars in the underground reserve organs, up to the present time, have revealed the presence of the following:—maltose (in sugar beet¹⁾), raffinose (in *Beta vulgaris*²⁾), gentianose (in the rhizome of *Gentiana*

1) Stoklasa,-Zs. f. Zuckerind. in Böhmen, Bd. 24, P. 560 (1899).

2) Boivin & Leiseau,- Compt. rend., Tome 60, P. 164 (1865); Loiseau,- Journ. de fabr. de sucre. Bd. 24, P. 52; Bd. 26, P. 23; La sucrerie indigene, Bd. 23, P. 96; Compt. rend., Tome 82, P. 1058 (1876); Zs. d. Vereins d. d. Zuckerind., Bd. 35, P. 1108 (1885); Lippman,- Chem. Ztg., Bd. 8, P. 386 (1884); Zs. d. Vereins d. d. Zuckerind., Bd. 35, P. 257 (1885); Bd. 41, P. 519 (1891); Tollens,- Ber. D. chem. Ges., Bd. 18, P. 26 (1885); Zs. d. Vereins d. d. Zuckerind., Bd. 35, P. 31 (1885); Bd. 36, P. 212 (1886); Scheibler,- Ber. D. chem. Ges., Bd. 18, P. 1779 (1885); Zs. d. Vereins d. d. Zuckerind., Bd., 35, P. 844 (1885); Leblay,- Bull. de l'Assoc. des chimistes, Bd. 3, P. 166 (1886); Pellet & Biard,- La sucrerie indigene, Bd. 25, P. 505 (1888); Bodenbänder,-Zs. d. Vereins d. d. Zuckerind., Bd. 38, P. 597 (1888) etc.

*lutea*¹⁾), cyclamose (in the tuber of *Cyclamen europaeum*²⁾), stachyose (in the rhizome of *Stachys tuberifera*³⁾), *Lansium altius*⁴⁾) and other Labiaceæ⁵⁾ and verbascose (in mullein root⁶⁾). These sugars are all of di-, tri- or tetrasaccharide, except sucrose which is widely distributed in the vegetable kingdom. It will be then of great interest to study in detail these organs in many plants in this connection. The arrowhead tuber or Kuwai was selected as the first material to be studied.

A search of the literature on *Sagittaria sagittifolia forma sinensis* failed to show the result of special investigations on the composition of its tubers, beyond a brief article by Kellner⁷⁾ on their general composition. His analysis is as follows :

	Original material %	Water-free substance %
Water	66.86	—
Ash	1.43	4.31
Protein	7.05	21.26
Fat	0.55	1.65
Crude fiber	1.18	3.56
Nitrogen-free extracts	22.93	69.21

Consequently, at the beginning of this investigation we have undertaken to test the carbohydrates of the arrowhead tubers and have obtained the following result.

Water	78.16%
in water-free substance	
Starch	55.32%
Dextrin	1.75%
Reducing sugars	0.67% (as glucose).
Non-reducing sugars	5.54% (as sucrose).

1) Meyer,- Zs. Physiol. Chem., Bd. 6, P. 135 (1882); Ber. D. chem. Ges., Bd. 15, P. 530 (1882); Bourquelot & Nardin,- Compt. rend., Tome 126, P. 280 (1898).

2) Michaud,- Journ. de Pharm. et de Chim., (5), 16, P. 84 (1887).

3) Planta,- Landw. Versuchsstat., Bd. 25, P. 473 (1877); Schulze & Planta,- Ber. D. chem. Ges., Bd. 23, P. 1692 (1890); Bd. 24, P. 2705 (1891); Landw. Versuchsstat., Bd. 40, P. 277 (1892); Bd. 41, P. 123 (1893); Strohmer & Stift,- Oesterr-ungar. Zs. f. Zuckerind. u. Landw., Bd. 20, P. 895 (1891); Hanauser,- Chem. Centralbl., Bd. I, P. 518 (1894); Tanret,- Compt. rend., Tome 134, P. 1586 (1902); Tome 136, P. 1569 (1903); Bull. de la Soc. chim., (3), 27, P. 947 (1902); 29, P. 888 (1903).

4) Piault,- Journ. de Pharm. et de Chim., (6), 29, P. 236 (1903); Chem. Centralbl., Bd. I, P. 1168 (1909).

5) Piault,- Journ. de Pharm. et de Chim., (7), 1, P. 248 (1910); Chem. Ztg., Bd. 34, P. 186 (1910).

6) Bourquelot & Bridel,- Compt. rend., Tome 151, PP. 760-762 (1910); Chem. Abs., Vol. 5, P. 1263 (1911).

7) König,-Chemie der menschlichen Nahrungs u. Genussmittel., Berlin, Bd. I, P. 705 (1903).

Mucic acid producing substance by oxidation..	1.43% (as galactose).
Insoluble in 95% alcohol	0.60% („).
Soluble in 95% alcohol	0.74% („).
Pentosane (including methyl pentosane)	1.83%

As has been shown in the above table, of the carbohydrate constituents, starch is a prominent substance, its amount attaining 55.32% of the dry matter. Sugars are also present in no slight quantity, reaching the amount of 6.21% of the dry matter, and they constitute an important part of the carbohydrate constituents.

To determine the exact nature of the sugars of the arrowhead tubers, the following investigation was undertaken according to plan herein described.

1. *Preparation of the syrup.*

The arrowhead tubers were peeled of their rind and finely chopped. The chooped parts were allowed to dry in the air, requiring about two weeks for drying to such a state that they could be ground easily and finely pulverized.

The preparation of the syrup was begun by extracting 100 grams of the finely pulverized material in a Soxhlet apparatus with ether. The residue so obtained, which was freed from oil, after evaporating ether, was placed in 750 cc. flask fitted with inverted condenser and treated daily with 300 cc. of 95% alcohol heated in a boiling water bath. The extract was at first of a deep yellow colour, but it gradually became lighter from day to day. It had a sweetish taste and was nearly neutral to litmus during the entire time of extraction. One week was required to remove the last traces of sugars. The combined extracts were filtered to remove the sediment which was formed in standing, and the filtrate was evaporated to a small volume in a partial vacuum. The concentrated liquor was again extracted many times with a small quantity of absolute alcohol, until, after the evaporation of the alcohol, no more residue was produced. The residue (I) here obtained was preserved in a desiccator as material for the later investigation. The extracts were concentrated to a syrupy condition in a partial vacuum and allowed to dry over sulphuric acid.

Above method of the preparation was repeated about ten times to get a sufficient quantity of the materials for investigation.

2. *Experiment with the syrup.*

a. Qualitative tests.

The syrup obtained above, gave the following qualitative reactions:—

- 1) It had a very sweet taste.
- 2) It reduced Fehling's solution weakly; after inversion with hydrochloric acid, the reducing power was very much enhanced, showing that the non-reducing sugars were present in abundance.
- 3) Molish-Udransky's reaction was positive.
- 4) It gave characteristic blood red colour by heating with picric acid and a few drops of caustic soda solution (Reaction of Braun on glycoses).
- 5) It gave Seliwanoff's reaction very distinctly.
- 6) It gave Pinoff's reaction of free fructose with ammonium molybdate and acetic acid.
- 7) It gave characteristic red colour by heating in a boiling water bath for exactly one minute with resorcin and alcohol-sulphuric acid mixture according to Pinoff.
- 8) It did not show any pentose reaction by the phloroglucin method.
- 9) Mucic acid was produced upon oxidation with nitric acid of 1.15 sp. gr., as in the usual manner.
- 10) Saccharic acid was detected as acid potassium salt in the oxidized solution separated from the crystals of mucic acid by the usual method.
- 11) It rotated the plane of polarization toward the right; after inversion it was almost inactive.
- 12) It produced no characteristic mannose phenylhydrazone with phenylhydrazine. When the mixture was warmed in a boiling water bath with acetic acid, the yellowish crystalline osazone was clearly produced. Even after inversion mannose phenylhydrazone was not produced.
- 13) Two drops of the syrup were placed on an object glass and were seeded respectively with a crystal of glucose, fructose, galactose, maltose, sucrose and raffinose. After twenty four hours, the drop which had been seeded with sucrose showed the formation of new crystals, while the others remained unchanged.

From the above qualitative reactions it is safe to conclude that the syrup contains both reducing and non-reducing sugars and that the presence of glucose, fructose, galactose molecule and sucrose is highly probable. Moreover, it is probable that fructose in a free form is present, because the reaction 6, according to Pinoff, is only produced by free fructose while other sugars which contain fructose molecule in combination as sucrose does not show the same colour reaction. It is still more evident that the presence of pentose and mannose, even in combined forms, is excluded, since no characteristic pentose phloroglucin

reaction and mannose phenylhydrazone could be formed as above mentioned.

b. Isolation of sucrose.

When the syrup was left untouched nearly twenty four hours, it was found thickly laden with fine crystals. A small amount of 95% alcohol was added to the syrup, mixed, filtered with suction, and washed with absolute alcohol and ether. The sugar thus obtained was slightly yellowish in colour, but upon recrystallization from alcohol it became perfectly white and left no ash on ignition. After drying over sulphuric acid in a vacuum, its melting point was determined and found to be 159°C.

0.5 gram of the dried sugar was dissolved in water and made up into 25 cc., and polarized in 200 mm. tube in Schmidt and Haensch half shadow polariscope. The rotation was found to be 7.7 on the scale toward the right. The specific rotatory power of this sugar is

$$(\alpha)D = \frac{7.7 \times 0.346 \times 25}{0.5 \times 2} = +66.6 \text{ (at } 20^\circ)$$

The melting point and specific rotatory power indicates that the sugar at hand is no other than sucrose.

c. Osazone tests.

The mother-liquor filtered off from the crystals of sucrose was evaporated again into a syrup. After standing for about two days, a small amount of sucrose crystals was again formed in it. The crystals were removed as in the above experiment, and the filtrate was concentrated once more to a syrup. It did not show any sign of forming new crystals even after one week standing. An attempt was then made to separate and detect the sugars as osazone.

1. 1 gram of the syrup, 2 grams of phenylhydrazinhydrochloride, 3 grams of sodium acetate and 20 cc. of water were mixed and heated in a boiling water bath. After 15 minutes yellowish crystals had been produced. At the end of one hour and a half, the heat was removed, and the crystals were examined under a microscope. None of the other forms, besides the stellate form of the yellow needle shaped crystals, which coincides with that of phenylglucosazone, were observed. When cooled, it was filtered and washed with a little water. The yellow crystals thus obtained were recrystallized from 60% alcohol and dried over sulphuric acid in a vacuum. The melting point was determined and found to be 204°, which coincides with that of phenylglucosazone. Consequently, the osazone under question is phenylglucosazone.

The filtrate from the crystals of phenylglucosazone was heated and concentrated again in a boiling water bath. This produced second very fine crystals of brownish yellow colour, and their form was quite identical with that of phenylgalactosazone prepared from pure galactose in our laboratory. After heating for about 1 hour, it was filtered and washed with a little water. The crystals were recrystallized and dried over sulphuric acid in a vacuum. The melting point was determined and found to be 193–194°. The crystalline form and melting point indicate that the osazone at hand is no other than phenylgalactosazone.

2. 1 gram of the syrup was dissolved in 20 cc. of water and inverted with hydrochloric acid in a boiling water bath for about 30 minutes. After it was neutralized with sodium carbonate, 2 grams of phenylhydrazine hydrochloride and 3 grams of sodium acetate were added and heated in a boiling water bath, exactly in the same manner as described above. In this case, none of the other osazones, aside from a considerable quantity of both gluco- and galactosazone, were obtained.

The osazone tests, which were made to separate and detect the sugars in the syrup, failed to obtain a more favorable result than that of the qualitative reactions as already mentioned. But, as the result of this experiment, maltose can hardly be expected to exist, because maltosazone can easily be distinguished from the glucosazone in its crystalline form, though its melting point will be almost similar to that of the latter. The formation of galactosazone from the original syrup in this case is apparently striking, since the presence of free galactose in nature, up to the present time, had not been reported except in the paper by Lippman¹⁾ who proved its presence in the hoar frost like coating of berry ivy after a sudden night frost in autumn. As to whether or not the formation of galactosazone from the original syrup is due to the presence of free galactose or a slight inversion of some non-reducing sugar containing galactose molecule as one of the constitutional units, we have not sufficient data to decide; and the question remains to be solved in future.

In the experiments with the syrup, the question concerning the nature of galactose containing sugar still remains to be solved.

3. *Experiment with the residue (I).*

a. Qualitative tests.

The residue (I) gave the following qualitative reactions:—

1) E. O. van Lippmann, Ber. D. chem. Ges., Bd. 43, PP. 3611–3612 (1910).

1. It had a sweetish taste.
2. It did not reduce the Fehling's solution directly; after inversion with hydrochloric acid, it reduced very strongly showing the presence of non-reducing sugars.
3. It did not give the characteristic reaction of pentose with phloroglucin and hydrochloric acid.
4. Molish- Udransky's reaction was positive.
5. It did not give the characteristic colour reaction of Braun with picric acid and caustic soda.
6. It gave the characteristic fire red colour of ketose with resorcin and hydrochloric acid (Seliwanoff's reaction).
7. It did not give the characteristic colour reaction of free fructose with ammonium molybdate and acetic acid.
8. Upon oxidation with nitric acid of 1.15 sp. gr., mucic acid was produced.
9. From the filtrate of the mucic acid crystals, saccharic acid was separated and detected as acid potassium saccharate by the usual method.
10. It did not produce any crystals with phenylhydrazine hydrochloride and sodium acetate. When the mixture was warmed in a boiling water bath for about 30 minutes, a few crystals of the yellowish crystalline glucosazone were produced. After inversion, the gluco- and galactosazone were formed in abundant quantity by heating for about 15 minutes.
11. It rotated the plane of polarization toward the right both before and after inversion; though in the latter case its power was smaller than in the former case.

From the above qualitative tests, it will be clear that the residue (I) under examination contains some non-reducing sugars which are constituted from three groups of glucose, galactose and fructose or two of these hexoses.

b. Isolation of sucrose.

The residue (I) was dissolved with 95% alcohol and evaporated to a syrup. It did not show any sign of forming crystals of its own accord, even after one week's standing. An attempt was then made to purify the syrup by means of basic lead acetate. The syrup was diluted with a sufficient quantity of water, to which a favorable quantity of basic lead acetate solution was added and the mixture well shaken. The fluid soon became turbid and after standing for a little while, a small amount of flocculent precipitates was formed. After separating the precipitates by filtration, a further quantity of basic lead acetate and ammonia

was added to the filtrate, when a flocculent substance of quite white colour was abundantly produced. The insoluble lead compound thus resulted was collected on a "Nutsch" filter with suction, well washed with water, suspended in water and decomposed by hydrogen sulphide. After the decomposition was complete, it was filtered, and well washed with water, and then the filtrate was evaporated to a small volume in a partial vacuum. The syrup was then extracted with boiling 95% alcohol and separated into two parts of soluble and insoluble, the former being predominate in quantity. The insoluble part of a slightly dark colour was designated as the residue (II) and preserved in a desiccator as the material for the later investigation. The soluble part was again concentrated to a syrup.

The purified syrup did not produce any marked crystals even after standing for about one week. Hence, an attempt was made once more to clarify the syrup by means of absolute alcohol, i.e. the syrup was extracted many times with a small quantity of absolute alcohol until, after evaporation of alcohol, no more residue was produced, and it was thus separated into two parts, soluble and insoluble, in absolute alcohol. The extracts were united and concentrated again into a small bulk. The insoluble substance of quite white colour had a sweetish taste and was preserved in a desiccator as the material for a further study, designated as the residue (III).

When the twice purified syrup was left untouched for about twenty-four hours, it was found thickly laden with fine crystals. A small amount of 95% alcohol was then added to the syrup, mixed, filtered with suction and washed with absolute alcohol and ether. The sugar thus obtained was perfectly white in colour and left no ash on ignition. After drying over sulphuric acid in a vacuum, its specific rotatory power was determined and found to be $+66.53^\circ$.

For the determination of specific rotatory power, 0.4551 gram of the sugar was dissolved in 25 cc. of water and polarized in a tube of 200 mm. length. A dextro-rotation of 7.0 on the scale of Schmidt and Haensch half shadow polariscope was observed. The specific rotatory power is

$$(\alpha)D = \frac{7.0 \times 0.346 \times 25}{0.4551 \times 2} = +66.53 \text{ (at } 20^\circ\text{)}.$$

The melting point was also determined and observed to be 160° . The specific rotatory power and melting point indicates that the sugar at hand is no other than sucrose.

4. *Experiment with the residue (III).*

On the qualitative tests, the residue (III) has shown almost the same reactions as those of the residue (I). A trial was then made to separate and detect the sugar which contains the galactose group. First, we examined, how much mucic acid would be produced from the residue by oxidation and the following result was obtained.

0.2 gram of the residue was put in a small beaker, to which nitric acid of sp. gr. 1.15 was added and oxidized in a boiling water bath as in the usual manner. The mucic acid produced was collected on the filter and weighed 0.0065 gram corresponding to 3.25%.

Next, we tried to determine its specific rotatory power and the result obtained was as follows:

0.1163 gram of the residue was dissolved in water and made up into 10 cc. and polarized in 100 mm. tube. The rotation was observed to be 2.8 on the scale toward the right. The specific rotatory power is

$$(\alpha)D = \frac{2.8 \times 0.346 \times 10}{0.1163 \times 1} = +83.35 \text{ (at } 20^\circ\text{)}.$$

If the sugar under question be raffinose, the amount of this sugar corresponding to 0.0064 gram of mucic acid would be 0.087 gram according to Creydt¹⁾. If we assume that sucrose be formed besides raffinose, the quantitative ratio of sucrose and raffinose in the residue (III) would be 1.3:1. Upon this ratio, if we calculate the specific rotatory power of the sample, we will then find the following value which well coincides with that of actually observed facts, i.e.

$$\frac{(66.803^2) \times 1.3 + (104.^3) \times 1}{2.3} = +82.98$$

Methyl alcohol, which was recommended for raffinose, was found to be a good solvent for the extraction of the sugar under examination. Hence, a small amount of methyl alcohol was added to the total residue (III), well mixed and decanted. This operation was repeated until the bulk of the residue insoluble in methyl alcohol was reduced to about half of its original volume. The combined extracts were evaporated to a syrup. The syrup did not show any sign of forming

1) Creydt.- Zs. d. Ver. d. D. Zuckerind., Bd. 37, P. 153; Lippmann,- Chemie d. Zuckerarten, Braunschweig, Bd. II. P. 1652, (1904).

2) Specific rotatory power of sucrose according to Tollens.

3) Specific rotatory power of raffinose according to Tollens.

crystals even after standing for 7 days. Absolute alcohol was then added to the syrup to remove matters soluble in the alcohol, well mixed and decanted. The insoluble residue in absolute alcohol was dried in vacuum over sulphuric acid, and its specific rotatory power determined. The following result was found:

$$(a)D = \frac{0.4 \times 0.346 \times 10}{0.015 \times 1} = +92.27 \text{ (at } 20^\circ\text{)}.$$

The residue was again treated with methyl- and absolute alcohol to remove the accompanying matter, in exactly the same manner as above described. The substance here obtained was almost tasteless. The specific rotatory power was determined and found to be +103.8.

$$(a)D = \frac{0.45 \times 0.346 \times 10}{0.015 \times 1} = +103.8^\circ \text{ (at } 20^\circ\text{)}.$$

The residue was once more purified in the same manner as in the above cases. The specific rotatory power was determined and found to be identical with that of the above case.

$$(a)D = \frac{0.3 \times 0.346 \times 10}{0.01 \times 1} = +103.8^\circ \text{ (at } 20^\circ\text{)}.$$

Next, we determined the quantity of mucic acid which is produced from the residue by oxidation. 0.0834 gram of the residue and nitric acid of sp. gr. 1.15 were mixed in a small beaker and oxidized in a boiling water bath according to the usual method. The mucic acid produced was collected on a filter and weighed 0.0065 gram corresponding to 7.79%.

According to Tollens¹⁾, the specific rotatory power of raffinose is +103.0° or +104.0° while Lippmann²⁾ found it to be +105.0° and +104.95°. The production of mucic acid from 0.1 and 0.075 gram raffinose according to Creydt³⁾ is 0.009 and 0.0056 gram corresponding to 9.0% and 7.5% respectively.

Consequently, the residue under examination would probably be raffinose.

5. Experiment with residue (II).

The residue, insoluble in boiling 95% alcohol, was slightly dark coloured and had a slightly sweet taste. Upon qualitative tests, the residue gave reactions almost similar to those of residue (III).

1) Tollens,- Zs. d. Ver. d. D. Zuckerind., Bd. 35, P. 31 and 591; Lippmann,- Chemie d. Zuckerarten, Braunschweig, Bd. II, P. 1636 (1904).

2) Lippmann,- ibid., Bd. 35, P. 257; Bd. 38, P. 1232; Lippmann,- ibid., PP. 1636- 1637.

3) Creydt,- I.c.

The residue was extracted with methyl alcohol, and the extract was concentrated to a syrup. The syrup did not form any crystals even after standing for 7 days. The syrup was then treated with absolute alcohol to remove such substances, which are soluble in this alcohol. On this treatment, slightly yellow coloured powder was obtained. It did not give a sweet taste. We determined its specific rotatory power, and obtained the following result.

0.05 gram of this dried powder was dissolved in water and made up into 10 cc. and polarized in 100 mm. tube. Bi-rotation was not observed. The rotation was 1.5 on the scale toward the right. The specific rotatory power is

$$(\alpha)D = \frac{1.5 \times 0.346 \times 10}{0.05 \times 1} = +103.5 \text{ (at } 20^\circ\text{)}.$$

The powder was once more treated with methyl and absolute alcohol respectively as above mentioned and determined its specific rotatory power and found it to be as follows:

$$(\alpha)D = \frac{1.1 \times 0.346 \times 10}{0.0367 \times 1} = +103.7^\circ \text{ (at } 20^\circ\text{)}.$$

We then tried to determine how much mucic acid is produced from the powder upon oxidation, and the following result was obtained.

0.06 gram of the powder was dissolved in a small beaker with nitric acid of sp. gr. 1.15 and oxidized in a boiling water bath in the usual manner. The mucic acid produced was collected on a filter, washed and dried. The weight of the crystals thus obtained was 0.0036 gram corresponding to 6% of the powder.

According to Creydt¹⁾, the quantity of mucic acid produced from 0.05 and 0.075 gram of raffinose is 0.0024 and 0.0056 gram in weight which correspond to 4.8% and 7.5% respectively.

Consequently, it may be concluded that the powder under examination is probably raffinose.

6. Summary.

- a. The reducing sugars of the arrowhead tubers consist of both glucose and fructose. As to whether or not the galactose is present as such or only in combination with other hexoses, we have not sufficient data to decide, and the question remains to be solved in future.

1) Creydt, l.c.

- b. The non-reducing sugars consist of sucrose and a sugar which seems to be raffinose.
- c. The presence of maltose, pentose and mannose is excluded. Even in combination, the presence of the latter two sugars is also excluded.

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摘 要

本論文は慈姑中に含有せらるゝ糖の性質に就きての研究結果にして且つ植物地下貯藏機關中に存する糖の性質に関する研究の第一報なりとす。

元來植物の貯藏機關たるや嫩芽の生長資料たるべき多量の營養物質の蓄積を要するが爲めに其の物質たるや高級縮合化合物にして其の分子量大且つ滲透壓の低きものならざる可らず否らずんば多量の物質の蓄積をなす能はざればなり、同化作用の生産物質として生成せられたる糖類の澱粉に變成するが如き以上の理に由るものにして實に吾人は貯藏物質として澱粉類の廣く植物界に存するを知るものなり、同理に依り吾人は亦地下貯藏機關に於ける糖類は之れを單糖類に比し孰れも高級縮合形態をなさざる可らざることを推量し得べし。

今日迄地下貯藏機關中に存する複糖類としては一般に廣く且つ多量に存する甘蔗糖以外に麥芽糖 (Beet根中に) ラフネース (Beet根中に) ゲンチアノース (*Gentiana lutea* の地下莖中に) シクラモース (*Cyclamen europaeum* の塊根中に) スタキオース (*Stachys tubrifera*, *Lansium altuus* 並に他の唇形科植物の地下莖中に) 及びフルバスコース (*Mullein* 根中に) の六糖發見報告せられたるのみ、従うて此の方面に於ける研究は植物生理化學上極めて趣味多く且つ將來の探究を要すること

大なりと云ふべし、是に於てか吾人は研究材料として。第一に慈姑を撰擇し其の糖の性質を精査し以て次の結果を得たり。

第一、慈姑中に含有せらるゝ還元糖は葡萄糖及び果糖より成立するものゝ如し、慈姑酒精浸出液中よりガラクトオサゾンと分離し得たりと雖も游離ガラクトースの存在は疑しく此の點に就ては尙ほ將來の研究を要す。

第二、慈姑中に含有せらるゝ非還元糖は甘蔗糖並にラフキノースと認むべき復糖より成立す。

第三、慈姑中には麥芽糖、マンノース及びヘントース存在せず、化合狀態に於ても後の兩者は存在することなし。
