

terminations owing to a portion of the graphite being oxidized merely to carbon monoxide.

[CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF THE U. S. DEPARTMENT OF AGRICULTURE, NO. 30.]

COMPARISON OF THE STANDARD METHODS FOR THE ESTIMATION OF STARCH.¹

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Received February 15, 1898.

THE study of the nature of the carbohydrate bodies which exist in foods has been vigorously prosecuted by chemists in different parts of the world during the past few years. The result of these studies has been to arouse new interest in the standard methods of starch determination. The numbers which are secured by different workers for starches vary so greatly as to lead to the belief that the estimation of starch is not such an easy matter as is generally supposed; in fact, long experience has convinced us that there are few operations in agricultural analytical chemistry which require greater skill, or are attended with greater difficulties than the estimation of starch in the presence of the other carbohydrate bodies.

At a recent meeting of chemists in England, it was stated in one of the papers that the methods of starch determination are now so easy of application and so accurate that there is no longer any excuse for being ignorant of the exact content of starch in any body. Stone, in Bulletin No. 34 of the Office of Experiment Stations, described a method which was easily seen to be erroneous, yielding only about half as much starch as was really contained in the samples examined. A cursory glance at the methods of analysis employed by him convinced us that the fault was insufficient saccharification, due to the weakness of the acid and the shortness of the time of heating.

In a subsequent article² Stone called attention to the error of his previous statements, and proposed a modification of his first published method, which, as is seen below, gives very much better results. Having to estimate, annually, the starches in many hundreds of substances, we were led to make a compara-

¹ Read before the American Chemical Society and Section C of the American Association for the Advancement of Science, at Detroit, August 12, 1897.

² This Journal, 19, 347.

tive study of the standard methods which have been used for starch determination, and of some modifications which seemed to us worthy of trial. The standard methods which we employed were those described in "Principles and Practice of Agricultural Analysis," 3, 196-222, and 300-302. The materials which we used in our investigations were starches of commerce, the ordinary cereal grains, and a sample of the wheat which was the subject of the investigations of Stone, and which was kindly furnished us by Professor Stone. We give below a brief résumé of the work we have done.

The sample of spring wheat No. 1, which we received from Professor Stone, was examined for all of its principal constituents, according to the official and standard methods of analysis, and the data obtained by him and by us are given below. The moisture stated in the second column of the appended table was determined by drying for five hours in a high vacuum at 100°.

PRELIMINARY GENERAL ANALYSIS.

Spring wheat No. 1.	Data obtained by	
	Stone. Per cent.	Wiley and Krug. Per cent.
Moisture	8.55	10.65
Ether extract.....	2.00	2.24
Ash	1.43	1.77
Fiber.....	2.77	2.56
Albuminoids	14.22	14.44
Pentosans	4.54	5.17
Starch and undetermined.....	66.49	63.17

Before determining the starch it seemed of interest to take the sample in the state in which it was sent, as we assumed that it had thus been analyzed by Professor Stone. It also seemed to us that the digestion with malt extract prescribed by him was not long enough to insure the complete conversion of the starch into maltose and dextrins. To determine this, one set of samples was digested one hour at 60°, and another set two and one-half hours at 50°, since Lintner states that diastase is most active at this latter temperature. The results obtained show that our surmise was correct.

	Stone method. Per cent. of starch.	Wiley and Krug method. Per cent. of starch.
Spring wheat No. 1.		
<i>a</i>	56.27	57.39
<i>b</i>	57.00	58.73
<i>c</i>	58.65	59.88
	<hr/>	<hr/>
Means.....	57.31	58.66

The residues from the diastase digestion were all thoroughly washed with hot water and then examined with iodine under the microscope. In every case a large number of cells was found which contained undigested starch, showing that the sample had not been ground to a sufficient degree of fineness. This is, therefore, another source of error in Professor Stone's work. The sample was then reground and the starch determined by three methods; *viz.*, first, the Reinke lactic acid method, second, a method which differs from this by the use of five-tenths gram of salicylic acid instead of lactic acid, and third, the diastase method. The residues were again examined and in every case found free from starch, showing that the conversion had been complete.

The following results were obtained :

	Reinke method. Per cent. of starch.	Salicylic acid method. Per cent. of starch.	Diastase method. Per cent. of starch.
Spring wheat No. 1.			
<i>a</i>	62.22	63.25	62.66
<i>b</i>	62.41	63.09	62.25
<i>c</i> .....	....	62.94	....
	<hr/>	<hr/>	<hr/>
Means	62.32	63.09	62.46

As is subsequently shown, the result obtained by the last method is more probably correct. The number for starch thus obtained, added to our per cents. of the other constituents gives us a total of 99.28. The separate determination of the sucrose, galactan, invert sugar, and dextrin, originally present, was omitted, and these bodies are included with the starch.

This work led us to undertake an investigation of other methods for the determination of starch which have been proposed from time to time, our desire being to avoid, if possible, the use of diastase and to shorten the time of procedure.

It seemed that this might be accomplished by polarizing the

products of hydrolysis and thus avoiding the labor incident to the gravimetric method of determining copper. To this end, several methods were tried. These methods depend either on the complete conversion of the starch into dextrose or on the formation of soluble starch, maltose, and dextrins.

THE GUICHARD METHOD.

Guichard¹ proposes to boil four grams of the material for one hour with 100 cc. of ten per cent. nitric acid (ten cc. strong acid (sp. gr. 1.42) to ninety cc. water) in a flask provided with a return condenser. The solution is cooled, filtered, and polarized. The starch is found by the formula

$$A = \frac{av \times 25 \times 0.016}{2 \times 52.8},$$

where a = rotation in angular degrees, v = volume of liquid, and A = starch transformed. As our polarizations were made with a Schmidt and Haensch instrument, the dextrose was determined by the formula

$$(a)_D = \frac{a \times 100}{c \times l},$$

where a = rotation, c = weight of dextrose, l = length of tube in dm., and $(a)_D = 52.8^\circ$.

THE PRESSURE METHOD.

Three grams of substance are heated in a flask with eighty to ninety cc. of water until pasty, and the starch rendered soluble by heating from three to five hours in an autoclave, at from two to three atmospheres. The volume is completed to 100 cc. and the solution polarized. The gyrodynat of soluble starch prepared in this way varies from $(a)_D = 196.5^\circ$ to 197° .

THE BAUDRY METHOD.

To 2.883 grams of the substance (for Schmidt and Haensch instrument) add from eighty to ninety cc. of water and five-tenths gram salicylic acid. Boil twenty minutes, dilute to about 190 cc., add one cc. ammonia, cool, dilute to 200 cc., filter, and polarize in a 400 mm. tube. Multiply the result by three. Baudry determined the gyrodynat of soluble starch to be $(a)_D =$

¹ This and the following polarimetric methods are described in detail in Vol. III of "Principles and Practice of Agricultural Analysis."

202.66° at 15°–18° C., when sucrose = 67.3° (Girard and de Lugnes), and 200.25° when sucrose = 66.5° (Tollens). As the normal weight for sugar is 26.048 grams ($(a)_D = 66.5^\circ$) the normal weight for starch will be $\frac{26.048 \times 66.5^\circ}{200.25^\circ} = 8.650$ grams.

We furthermore tried to apply polarization to the solution obtained by the Reinke method. Three grams of the material were heated two and one-half hours in the autoclave with thirty cc. of one per cent. lactic acid and 25 cc. of water at three and one-half atmospheres, diluted to about eighty cc. and inverted two and one-half hours with five cc. hydrochloric acid of 1.20 specific gravity. The volume of the solution was then completed to 100 cc., filtered, and polarized. The results show that the polarizing power of the solution was too high and that too little acid had been used, and another series was made in which the quantity of acid was doubled. In this case, the results were too low. The solutions were always highly colored, and we were unable to polarize them without previous treatment with bone-black. In the following table are given the results obtained by the polarimetric methods above described.

Nos. 1 and 2 are samples of commercial corn starches, Nos. 3 and 4 specimens of wheat obtained at the Columbian Exposition.

COMPARISON OF POLARIMETRIC METHODS ON STARCH AND
WHEAT.

	Guichard method. Per cent. starch.	Pressure method. Per cent. starch.	Baudry method. Per cent. starch.	Reinke method. Five cc. acid. Per cent. starch.	Reinke method. Ten cc. acid. Per cent. starch.
1. Starch	81.9	....	67.8	100.16	76.33
	80.04	....	....	101.26	76.33
	80.90	....	....	....	....
Means..	80.97	....	....	100.71	76.33
2. Starch	83.72	....	80.4	101.81	79.73
	84.18	....	....	102.90	76.33
Means..	83.95	....	....	102.36	78.03
3. Wheat	55.43	36.45	28.89	83.45	50.35
	55.94	41.66	....	82.26	49.86
Means..	55.69	39.06	....	82.66	50.11
4. Wheat	53.59	36.45	36.00	96.56	49.62
	53.13	36.45	35.46	92.99	49.34
Means..	53.36	36.45	35.73	94.78	49.48

This table shows that there is much variation between the results obtained by the different methods. The Guichard method gives promise of being applicable to pure starches, but does not give good results with wheat. When the nitric acid is added to the cereal the oxidizing action is very violent for some minutes, and the proteid matters which are brought into solution doubtless counteract, to some extent, the right-handed rotation due to the dextrose formed. It is evident also that the acid brings a large proportion of the pentosans into solution. It seems probable that a careful study of the conditions under which the Reinke method should be used may render this method available. The pressure method fails to render all the starch soluble, as was shown in the work with pure starch, where in every case the solution contained large quantities of gelatinized starch, which made filtration and polarization almost impossible.

The use of salicylic acid in the Baudry method suggested its substitution for lactic acid in the Reinke method, as it was noticed that the solutions obtained with it were very free from caramelization. It was found that this was also true of the solutions obtained with it in the autoclave. The results were proportionately higher and indicate that lactic acid in conjunction with the pressure decomposes a considerable portion of the pentosans present. Comparative estimations on the same samples gave the following results:

Material.	Lactic acid. Per cent. starch.	Salicylic acid. Per cent. starch.
1. Starch	82.93	84.27
2. Starch	82.60	84.03
3. Cornstarch.....	<i>a</i> 83.96	<i>a</i> 84.27
	<i>b</i> 83.66	<i>b</i> 84.46
	<i>c</i> 83.84	<i>c</i> 84.21
	<i>d</i> 83.72	<i>d</i> 84.24
Means.....	83.795	84.295
4. Wheat	62.25	63.17
5. Wheat	62.32	63.09

These figures show a fairly uniform increase in the amount of starch found when salicylic acid was used. It might be claimed that this increase in the case of wheat is due to the greater solubility of the pentosans present in the cereal and not to the greater solvent power of the salicylic acid on starch. In order

to determine whether this is the case, three grams of wheat were treated in the autoclave by two methods, 100 cc. of the filtrate distilled with twelve per cent. hydrochloric acid and the furfural determined. It was found that lactic acid dissolved 3.55 per cent. of pentosans and salicylic acid 3.69 per cent. in terms of the substance. It is therefore evident that both acids exert a like hydrolyzing power on the pentosans and the increased percentage of starch by salicylic acid is not due to this property. The solutions obtained with salicylic acid were never at any stage of the process darker than a straw-yellow while the final liquid obtained with the Reinke method is generally deep brown, showing that considerable caramelization has taken place. We therefore recommend the use of salicylic acid in place of lactic acid when it is necessary to determine the fermentable constituents of a cereal by the high pressure method, and also with the proper corrections for general analytical work.

METHOD OF LINDET.

Lindet¹ describes the following method for the direct determination of starch.

According to an observation of Girard, the grains of starch in the cereals are surrounded with a glutinous envelope, and the principle of the new process of Lindet is based upon the solution of this envelope by pepsin under such conditions as to prevent any hydrolysis of the starch. After the solution is complete, the starch granules are easily washed out, collected, dried, and weighed. The process is therefore one for the direct determination of starch, and gives promise of usefulness in the technical examination of cereal grains to be used for starch-making. The cereal grains are finely ground and ten grams of the flour are placed in a vessel and covered with a solution containing two per cent. of pepsin and one and one half per cent. of hydrochloric acid. The mixture is left for twelve or fourteen hours, with frequent shaking, at a temperature of from 40° to 50°. The contents of the vessel are then poured upon a fine bolting-cloth, the cloth gathered into the form of a knot and washed in a capsule of water until starch is no longer removed. The washwaters containing the starch are brought together, treated with

¹ Bulletin de l'Association des Chimistes de Sucrierie et de Distillerie, 14. 405

a little formic aldehyde or mercuric chloride to prevent bacterial action, and the starch is collected upon a weighed filter. The filtration is somewhat tedious, especially when the cereal contains large quantities of gum. It can be facilitated, to a certain degree, by adding to the filter a known quantity of calcined and washed pumice stone. The collected starch is dried at first at 50° and finally at 150°. Lindet has assured himself, by careful trial, that the presence of the hydrochloric acid in the quantity noted above prevents the action of any of the natural diastases or enzymes which the cereal may contain upon the starch, but that a hydrochloric acid of that strength exercises, at the temperature employed, no hydrolyzing effect whatever upon the starch granules.

The method appeared to be so short and easy of manipulation that we decided to try it. For this purpose four cereals were purchased and prepared; *viz.*, wheat, oats, rye, and barley. A general analysis was first made which gave these results:

	Wheat. Per cent.	Rye. Per cent.	Oats. Per cent.	Barley. Per cent.
Moisture.....	11.33	11.71	9.26	12.20
Ether extract	2.00	1.63	4.72	0.92
Fiber	2.15	2.36	12.81	0.80
Ash	1.69	2.31	3.78	0.93
Proteids.....	12.19	11.69	9.63	10.44
Pentosans	5.80	8.10	13.65	6.50
(a) Starch ¹ (salicylic acid method).....	64.41	62.64	46.78	68.38
(b) Starch ¹ (diastase method).....	63.17	61.55	45.05	67.56
Total (including starch a)	99.57	100.44	100.63	100.17
Total (including starch b)	98.33	99.35	98.90	99.35

The starch was determined both by the use of salicylic acid as described above and by the means of diastase. The increase due to the hydrolyzing action of the acid is clearly shown by the data and proves that its use as well as that of other organic acids is warranted only when analytical data are desired in connection with the technical use of high pressure in commercial operations, or when the final data are corrected as hereinafter described.

¹ Including sugar, galactan, dextrin, etc.

In our application of the Lindet method to these cereals we reduced the amount taken to three grams, as it seemed desirable to estimate the starch not only by direct weighing but also after conversion into dextrose, and this quantity was found very convenient to handle on the bolting-cloth. The starch was also determined in the residue left on the cloth, and the starch which was washed through was dried and weighed, then gelatinized, treated with malt extract, and determined as usual. It was then found that in most cases some fiber had gone through the cloth and rendered the results too high.

LINDET METHOD.

Cereal.	Direct weight.			Determination after conversion into dextrose.			
	Starch. Per cent.	Residue. Per cent.	Total. Per cent.	Starch. Per cent.	Residue. Per cent.	Total. Per cent.	Fiber in starch. Per cent.
Oats	44.19	0.14	44.33	44.27	0.14	44.41	....
	44.31	0.00	44.31	43.73	0.00	43.73	0.58
	43.81	0.33	44.14	43.47	0.32	43.80	0.34
Barley ...	71.41	0.97	72.38	66.47	0.97	67.44	4.94
	72.72	0.00	72.72	67.47	0.00	67.47	5.25
	71.66	0.98	72.64	66.51	0.98	67.49	5.15
Rye.....	61.24	0.79	62.03	58.18	0.79	58.97	3.06
	60.83	1.21	62.04	57.94	1.21	59.15	2.89
	59.83	2.41	62.24	57.68	2.41	60.09	2.15
Wheat ...	67.35	0.00	67.35	60.18	0.00	60.18	7.17
	66.05	0.60	66.65	60.11	0.60	60.71	5.94
	66.55	0.00	66.55	60.26	0.00	60.26	6.29

This table shows that not quite all the starch was removed by the washing in every case, and that some material which is not starch is counted as such. It required almost a week to filter the liquid containing the starch and this was no doubt due to the pepsin present. It was also quite impossible to keep some of the starch granules from running through the filter. The method is therefore more tedious than the common processes and not nearly so accurate.

One of the main sources of error in the estimation of starch in a cereal is the difficulty of converting it all into soluble products. This is due to the fact that the starch granules are imbedded in proteid matters and are thereby partially protected from the action of the solvent. We have therefore combined the use of pepsin to dissolve this protein with the salicylic acid method

described above. Three grams of the cereal were digested fourteen hours at 45° C. with thirty cc. of pepsin solution, the hydrochloric acid carefully neutralized with sodium carbonate, five-tenths gram salicylic acid added, and the material heated two and one-half hours in the autoclave to three and one-half atmospheres. The neutralization of the hydrochloric acid is necessary, since it would dissolve additional quantities of the pentosans present. Some curious color-reactions took place during the process. The neutralization with sodium carbonate turned the solution light green. On removal from the autoclave it was found to be a straw-yellow, but after neutralizing the hydrochloric acid used in the final inversion the liquid again became deep green. This is probably due to the products formed by the action of the pepsin on the proteids. The results obtained follow :

	Starch.			Means. Per cent.
	Per cent.	Per cent.	Per cent.	
Wheat	64.50	64.51	64.44	64.48
Rye.....	62.41	62.14	62.50	62.35
Oats	47.29	47.42	47.08	47.26

A comparison of these results with those obtained by the salicylic acid method alone shows a close concordance. The use of pepsin is, however, a safeguard which it is well always to apply as it insures the thorough solution of the starch. The pepsin must be free from material which exercises a reducing action on the copper solution. We have also tried the combination of the pepsin and diastase digestions, but reserve the report on this method for further study.

We also have thought it advisable to apply taka-diastase instead of malt extract for dissolving the starch, since it can easily be obtained in a dry form and retains its activity for a considerable length of time. We were not able to study its action thoroughly on account of lack of time, but found that five-tenths gram of taka-diastase required twelve hours to completely dissolve the starch in three grams of wheat. The experiment was made at 50°. It was found that the taka-diastase contained no reducing substances, which is an advantage over malt extract. The solutions obtained with it had commenced to decompose at

the end of twelve hours and it was therefore deemed inadvisable to estimate the starch in them.

We have also tried quite extensively the pancreatic diastase prepared by Frederick Stearns & Co., of Detroit, and found it exceedingly active and free of any reducing matter. The indications are that it may prove to be the most desirable form of hydrolyzer yet used. The data obtained by us with this reagent will be increased and made the subject of another communication.

Following are the conclusions which are drawn from the vast amount of analytical data which has been accumulated.¹

1. All the heretofore described methods for determining the percentage of starch by polarization, whether with the soluble starch or with dextrose made therefrom, are liable to grave errors and none of them can be relied upon to give accurate results. The only advantage which can be claimed for such methods is in the saving of time. The sources of error, however, are so great as to nullify the advantage of time-saving.

2. The methods depending upon hydrolysis in an atmosphere of steam under pressure are obnoxious to the danger of caramelization. This seems to be entirely prevented by the addition of a very small quantity of an organic acid. Of the organic acids suggested tartaric is excluded on account of its optical properties. Of lactic and salicylic acid the latter is to be preferred. In all cases where dilute organic acids are employed the pentosans of the cereal and its products are hydrolyzed to a considerable extent. The presence of the sugars produced by the hydrolysis of the pentosans increases the quantity of metallic copper obtained and thus raises the apparent percentage of starch. In these cases, a correction must be made by determining the quantity of pentose sugar present and diminishing the percentage of starch obtained in proportion to the quantity of pentose sugar found.

In this instance, a difficulty arises from the uncertainty concerning the quantity of pentosan corresponding to a given amount of sugar produced therefrom reckoned as dextrose. We have seen

¹ More than 500 gravimetric determinations have been made by Mr. W. H. Krug in prosecuting this research. In each case the reduced cuprous oxide was dissolved and the metallic copper precipitated electrolytically.

that salicylic acid, in the autoclave, under the conditions specified above, dissolved 3.69 per cent. of pentosans calculated on the weight of the ground cereal employed. We have shown in another paper that diastase dissolves very little pentosan from cereals. It is therefore easy to make a determination of the copper reducing power of the dissolved pentosans reckoned in terms of dextrose. In a preceding table, we have shown the excess of reducing sugar, obtained by the salicylic acid under pressure, over the amount secured by the diastase method without pressure. In the case of wheat this excess was 1.24 per cent., in rye 1.09 per cent., in oats 1.73 per cent., and in barley 0.82 per cent.

The mean excess for the four cereals examined was 1.23 per cent. In the case of wheat, therefore, it is seen that 3.69 per cent. of dissolved pentosans yielded an amount of reducing sugar equivalent to only 1.24 per cent. of dextrose. We therefore propose, in the case of wheat, when the salicylic acid method is used with pressure in the autoclave, to diminish the apparent per cent. of starch by 1.25. Where greater exactitude is required the pentosans should be determined and the per cent. found divided by three. The quotient will be the figure to be subtracted from the apparent percentage of starch obtained.

3. The direct weighing of the starch, according to the method of Lindet, after solution of the protein by means of pepsin, has many advantages for practical work, especially in starch factories. Small particles of other matters, however, of no greater size than the starch grains themselves, pass through the bolting-cloths and are reckoned as starch in the final weighings. This error is partly compensated for by a portion of the starch remaining attached to the filter and the final result by the Lindet method is in some cases approximately correct.

4. The combination of the Lindet method, in so far as the solution of the protein is concerned, with the diastase method as practiced by us, has given most encouraging results and it is probable that a satisfactory method of starch estimation can be worked out in this line.

5. The diastase method without pressure gives satisfactory results when the diastase is freshly prepared and used in proper quantities and at an appropriate temperature. The diastase

exerts only a small solvent action on the pentosans and the final hydrolytic products obtained are not contaminated with any appreciable amounts of pentose sugars. The use of taka-dias-tase is worthy of further investigation since it can be easily prepared uncontaminated with any reducing sugars. The sample we employed, however, was not very active, requiring several hours more time for a complete solution of the starch than diastase recently prepared from malt. The materials on which the diastase acts should be ground to the finest possible powder and should be previously extracted with ether to prevent the retarding action of fat on the ferment. The treatment with diastase should always be repeated after boiling and cooling to about 50°. The residue must not show any starch granules when stained under the microscope with iodine.

6. The time at our disposal did not permit us to make a comparative trial of saliva as a solvent for the starch. This part of the problem remains to be worked out, and it is hoped that saliva will be found to exert a minimum solvent action on the pentosans and celluloses present in cereals.

7. The summation of the several per cents., obtained in the analysis of a cereal or cereal product by the methods employed by us, does not in all cases approximate closely to 100. The variations are somewhat greater than in ordinary mineral analysis. They are, however, not of such a magnitude as to warrant the assumption of the existence in cereals of a class of bodies of unknown properties and different in any marked degree from those already known to exist. In this connection, it should not be forgotten that in the estimation of the ash by the official method there is danger of loss of chlorine, sulphur, and phosphorus, especially of the former and latter, the organic phosphorus escaping combination with the already saturated bases present. In some recent experiments we have found the loss to be more than one per cent. of the total weight of the cereal employed. When this fact is taken into consideration, it is evident that there is practically no constituent unaccounted for in the analytical data. The small quantity of matter unaccounted for in the cereal grains is doubtless of a carbohydrate nature, belonging to that complex class, pentosan-ligno-celluloses, whose chemical and physical properties are so nearly alike as to make

their exact separation and determination extremely difficult. The quantity of these undetermined bodies in cereal grains is very minute. In stalks and straw, and other bodies containing a large excess of ligno-cellulose compounds, this quantity is doubtless much larger.

[CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF THE U. S. DEPARTMENT OF AGRICULTURE, NO. 31.]

THE SOLUBILITY OF THE PENTOSANS IN THE REAGENTS EMPLOYED IN THE ESTIMATION OF STARCH.

BY W. H. KRUG AND H. W. WILEY.¹

Received February 15, 1898.

THE methods which have been generally adopted for the quantitative determination of starch in a cereal or fodder are based on one or two principles; *viz.*, the application of high pressure in contact with water containing some organic acid, to prevent the decomposition of the sugars formed during the hydrolysis, or the conversion of the starch by means of diastase. The results obtained by the former methods are always a little too high and do not represent the actual starch content of the material under examination. In analytical work where it is desired to obtain the exact percentage of starch, diastase must be used and the application of any acid avoided until those bodies which may be acted upon by it have been removed by filtration, or else a correction must be applied as described in our preceding paper. The increased amount of starch found by the use of high pressure methods is due to the action of the organic acid on the pentosans and hemicelluloses present which results in the formation of reducing substances.

We have determined the amount of pentosans dissolved in the application of these methods with the following results:

1. Solubility of the pentosans by digesting for two and one-half hours at three and one-half atmospheres with thirty cc. of water and twenty-five cc. of one per cent. lactic acid:

Substance.	Per cent. of pentosans in substance.	Pentosans dissolved.	
		In per cent. of substance.	In per cent. of pentosans.
Wheat No. 1	5.80	4.63	79.83
Wheat No. 2	5.17	4.66	90.13

¹ Read before the American Chemical Society and Section C of the American Association for the Advancement of Science, at Detroit, August 12, 1897.