change with the *p*-nitro-phenol is as rapid and as sharp as with the other in the mixtures titrated. It is evident, therefore, that in using this indicator, we are able to measure not only the free mineral acids, but the acid combined with casein also.

In the titration of the casein itself, considered as an acid, the range of the phenolphthalein is wider than that of the *p*-nitro-phenol, as illustrated by the results in the acetic acid experiments. This difference is possibly due to the fact that we have to deal with some decomposition products of casein in small amount, and the acid strength of some of these may not be sufficient to show with the *p*-nitro-phenol. This indicator may have practical value in differentiating between just such mixtures, but as yet its full importance cannot be assigned.

Conclusions.

These experiments show that the basic behavior of casein toward acid is as marked and definite as the acid behavior toward alkalies. At the ordinary temperature one gram of dry casein combines with nearly 7 cc. of N/10 hydrochloric, hydrobromic, hydriodic, sulphuric and acetic acids, and also with tartaric, phosphoric, oxalic and other acids for which numerical values could not be found. The base fixing-power is somewhat greater, as one gram combines with 9 cc. of N/10 sodium, potassium, lithium or ammonium hydroxide or carbonate.

With application of heat, as in the evaporation of weak acid solutions with casein, the combining power becomes much greater. For hydrochloric acid about four times as much acid appears to combine at the higher temperature as was found in the cold titration. For hydrobromic and hydriodic acids the combining rates at high temperature are relatively greater. This may be due to the simple effect of the heat in favoring the union with additional amino groups of the casein, but it is undoubtedly due, in part at least, to the formation of and combination with the products of hydrolysis.

My thanks are due to Mr. Frank Gephart, who rendered me much assistance in carrying out many of the above experiments.

NORTHWESTERN UNIVERSITY MEDICAL
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STUDIES OF THE NITROGEN CONTENT OF WHEAT AND ITS DISTRIBUTION TO DIFFERENT PARTS OF AN INDIVIDUAL PLANT.

BY R. W. THATCHER AND H. R. WATKINS.

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The following article is a brief report of the results of a study of the distribution of nitrogen in the several parts of the different heads of wheat which grow from a single seed, and hence form a single individual wheat plant. The object of the study was two-fold; first, what might be termed an anatomical study to show how the plant distributes its nitrogenous matter in the production and ripening of its seed; and second, to establish, if possible, a suitable basis for the selection of individuals of desirable characteristics to be used as seed in breeding up improved strains of wheat. The data obtained seem to afford conclusive evidence along both of these lines of investigation and are presented with these ideas in view. The studies involved a determination of the average weight of the kernels and their nitrogen content on about 350 single spikes (or heads) or parts of spikes of wheat. The full details of the results of all these determinations are to be published in a bulletin of this Station, and may be consulted there by any one who is interested in the matter. They are much too voluminous to be inserted in this brief article, and the analytical tables herewith presented contain only such averages and other individual data as are necessary to demonstrate the points in question.

In determining upon the proper basis of selection of desirable seed grain, the first point to be settled is as to which is the proper unit in such selection; the single kernel, the spike (or single head), or the whole plant (or "stool," as it is commonly called) which grows from a single individual seed grain. In the case of the single kernel, it is not possible, by any means yet devised, to measure accurately its chemical composition or the percentage of any desired constituent, such as nitrogen for example, without destroying the kernel, thereby rendering it unavailable for seed purposes. A great deal of investigation has been carried on with a view of definitely connecting the nitrogen content with some physical property of the kernel, such as size, weight, specific gravity, hardness, etc., etc. The results of these studies are discussed very comprehensively by Lyon in his historical summary of the investigations of the conditions affecting the composition and yield of wheat.[1] More recent investigations have been made by Snyder[2], Harper and Peter[3], and Soule and Vanatter.[4] The results of most of these investigations indicate that some idea of the relative nitrogen content of wheat kernels may be obtained from a measurement of some physical property and that a basis for selection of seed grain rich in nitrogen might be thus established. But unfortunately most of these investigations have resulted in associating high nitrogen content with some otherwise undesirable quality in seed grain. Furthermore, this method of selection does not permit one to judge as to whether the variations in nitrogen content between different kernels are likely to be due to hereditary influence or to environmental conditions during their growth, and hence

[1] "Improving the Quality of Wheat." Bulletin No. 78, B. P. I., U. S. D. A.

[2] Minn. Exp. Sta. Bull. No. 85 and No. 90.

[3] Ky. Exp. Sta. Bull. No. 113.

[4] Tenn. Exp. Sta. Bull. Vol. XVI., No. 4.

leaves the question of their probable transmission to succeeding generations wholly undeterminable, except by actual experiment. Hence it has seemed to us that the selection of the individual kernels, while perhaps capable of giving some very valuable practical results, is not of sufficient accuracy to serve as the best basis for careful breeding for improvement in chemical composition. This leaves to be determined the question as to whether the spike or the whole plant is the proper unit. Several facts bearing on this point are demonstrated by the investigations recorded below, and are pointed out in the discussions of the several phases of the work.

The following lines of work were undertaken: (*a*) studies of the whole plant, including relation of nitrogen content to total weight of grain produced and to average weight of kernel; relation of composition of individual spikes to the length of straw; and the selection of a suitable sample for analysis to represent the remainder of the plant; and (*b*) studies of the distribution of nitrogen to kernels in different parts of individual spikes, including analyses of opposite rows of spikelets, of kernels from lower, middle and upper spikelets, and of grain from the outer and middle rows of kernels within the spikelets. It should be noted that all the plants used in this investigation were grown in rows and at equal distances apart in order to avoid as far as possible any differences due to unequal nutrition during growth.

Relation of Nitrogen Content to Weight of Kernel.

Lyon[1] has reached the conclusion that the percentage of proteid nitrogen in a wheat spike decreases as the average weight of the kernel, the average weight of proteid nitrogen in each kernel, and the total weight of nitrogen in the spike increases. Or in other words, that the spikes which show a high percentage of nitrogen contain lighter kernels and less actual weight of nitrogen. This conclusion was derived from the study of spikes of a single variety of wheat grown in a single field. It seemed to us to be desirable to determine whether the same rule should apply to other varieties of wheat and to wheats grown under different conditions, and whether the same law applies also to all the grain of a plant as well as to a single spike. For this purpose we selected thirty-seven different plants of wheat bearing a total of 212 spikes, representing five different varieties and grown at three different localities in this State, namely, the experiment station farm at Pullman, and two sub-stations at Ritzville and Quincy. Each individual spike was threshed separately and the number and weight of kernels, and their total nitrogen content determined. The data thus accumulated is far too voluminous to present in this article, but it may be stated that with only very infrequent exceptions (such as might be expected from unusual environmental con-

[1] Bureau of Plant Industry. Bull. 78, p. 57.

ditions or experimental errors), the spikes showed the same phenomena observed by Lyon, namely, that high percentage of nitrogen in kernel is accompanied by low average weight of kernel and low total weight of nitrogen in the spike. The data concerning all the spikes of each plant were then assembled and averaged to give the information concerning the plants as a whole. These averages are presented in Table 1, which is given in full as it furnishes what are, so far as we are aware, the only analytical data of this kind which have yet been accumulated.

TABLE I.

RELATION OF WEIGHT OF KERNEL AND NITROGEN CONTENT OF ALL THE SPIKES OF DIFFERENT PLANTS.

Variety	Grown at	Plant No.	Number of Heads.	Average Composition of Spikes.				
				Number of Kernels.	Total Weight of Kernels. gms.	Average Weight of Kernels. gms.	Nitrogen in Kernels. mgms.	Nitrogen in Kernels. %
Bluestem	Ritzville	G	7	30	0.711	0.0225	20.84	3.009
"	"	F	6	29	0.750	0.0253	20.90	2.783
"	"	D	4	34	0.861	0.0254	22.85	2.656
"	"	E	6	41	1.100	0.0264	28.52	2.633
"	"	C	5	39	1.257	0.0314	30.80	2.474
"	"	B	5	36	1.160	0.0320	28.78	2.497
"	"	A	7	38	1.294	0.0340	29.14	2.254
Turkey Red	Pullman	B	20	27	0.554	0.0185	15.10	2.926
"	"	A	7	26	0.680	0.0230	18.49	2.830
"	Ritzville	C	4	30	0.430	0.0147	10.96	2.518
"	"	A	5	25	0.465	0.0185	11.74	2.517
"	"	B	5	30	0.749	0.0240	18.36	2.350
"	Quincy	C	5	25	0.740	0.0284	13.92	2.418
"	"	B	5	25	0.809	0.0316	16.79	2.089
"	"	D	5	22	0.685	0.0318	14.66	2.361
"	"	A	6	23	0.779	0.0343	15.82	2.046
Fife	Pullman	A	9	42	1.095	0.0253	29.90	2.858
"	Ritzville	C	5	49	1.398	0.0284	32.75	2.325
"	"	B	5	49	1.460	0.0294	33.72	2.313
"	"	D	5	56	1.690	0.0297	38.24	2.252
"	"	A	5	52	1.608	0.0304	38.13	2.417
"	Quincy	A	3	44	1.259	0.0277	25.59	2.113
"	"	C	6	47	1.699	0.0363	35.05	2.083
"	"	B	3	37	1.406	0.0366	31.32	2.261
Little Club	Ritzville	B	6	53	1.269	0.0233	38.02	3.010
"	"	A	7	54	1.414	0.0239	42.26	2.983
"	"	C	6	55	1.426	0.0254	42.30	2.982
"	"	D	6	53	1.512	0.0274	43.66	2.897
"	Pullman	B	9	43	0.938	0.0190	23.59	2.858
"	"	A	8	39	0.808	0.0196	21.95	2.900
"	"	C	5	47	1.098	0.0228	29.95	2.812
"	Quincy	C	4	41	1.277	0.0307	30.05	2.362
"	"	B	4	47	1.488	0.0310	23.69	2.301
"	"	A	4	46	1.494	0.0327	27.42	1.912
Forty-fold	Quincy	A	3	22	0.891	0.0399	18.25	2.095
"	"	B	4	26	1.168	0.0435	24.08	2.063
"	"	C	3	22	1.063	0.0474	18.46	1.756

An inspection of this table, in which the plants of each variety and from the same locality are arranged in the order of the average weight of kernel, shows at once that the same law which has been found to hold for individual spikes applies as well to whole plants. The very obvious conclusion is that wheat plants which show by analysis a high percentage of nitrogen are those which bear a smaller total weight of grains, whose kernels are lighter in weight and whose total weight of nitrogen is less. It would seem, therefore, that the breeding of wheat of increased percentage of nitrogen is likely to involve a deterioration in other desirable qualities. Whether this be true, or whether the nitrogen percentage is a more strongly hereditary trait than the other properties, remains to be proved by experimental tests, which we are now inaugurating.

Composition of Opposite Rows of Spikelets of the Whole Plant.

As is well known by every one who has seen a wheat head, the spike is composed of two separate and distinct rows of spikelets growing on opposite sides of the stem. Lyon[1] having suggested as a result of his studies on a single variety of wheat that the analysis of one of these rows of spikelets from each of these spikes of the plant would serve as a measure of the nitrogen contents of the other half of the kernels, we desired to confirm the general applicability of this method of selection.

TABLE II.

COMPARISON OF OPPOSITE ROWS OF SPIKELETS (HALVES) OF ALL THE SPIKES OF A PLANT.

Variety	Number of Plants	Average Number of Heads per Plant	Half	Average Composition of Each Half: Number of Kernels	Total Weight of Kernels gms.	Average Weight of Kernels gms.	Nitrogen in Kernels gms.	
Turkey Red	4	10	First	126	2.863	0.0238	0.0837	3.007
			Second	131	2.916	0.0231	0.0835	2.957
Fife.......	2	16	First	311	7.558	0.0240	0.2173	2.886
			Second	328	7.916	0.0238	0.2267	2.872
Little Club	5	12	First	251	5.638	0.0219	0.1536	2.752
			Second	250	5.650	0.0222	0.1536	2.748

The results of our work are presented in Table II, and show that the composition of one-half of all the heads of a plant is sufficiently accurate counterpart of the other half of the heads to serve as a basis of selection.

Relation of Composition of Individual Spikes to the Length of the Stem on Which They Grow.

A considerable variation in composition of different individual spikes of a plant having been often observed, we wished to ascertain what causes these differences. Individual heads usually grow upon stems of different lengths, the longest stem being presumably the one which started first and which received the most favorable nutrition during the growth of the

[1] Loc. cit. pp. 76-78.

plant. We, therefore, selected several plants which showed straw (or stems) of quite variable lengths and separated and analyzed their spikes separately. The results from a few typical plants are presented in Table III. The other plants which were analyzed show the same general relationships, but the results of their analyses are omitted in order to shorten the table of analytical data.

TABLE III.

RELATION OF COMPOSITION OF DIFFERENT SPIKES OF A PLANT TO THE LENGTH OF STRAW.

Variety	Head No.	Length of Straw	Composition of the Spike: Number of Kernels	Total Weight of Kernels gms.	Average Weight of Kernels gms.	Nitrogen in Kernels gms.	%
Turkey Red	1	18″	12	0.134	0.0112	4.493	3.353
	2	25″	21	0.369	0.0176	11.092	3.006
	3	30″	27	0.718	0.0266	20.217	2.815
	4	30″	28	0.720	0.0259	20.076	2.788
	5	33″	34	0.882	0.0271	23.868	2.706
	6	36″	34	0.864	0.0254	23.026	2.665
	7	39″	39	1.075	0.0276	26.676	2.481
Little Club	1	27″	18	0.192	0.0107	7.301	3.808
	2	27″	23	0.278	0.0121	9.266	3.333
	3	35″	32	0.576	0.0180	16.848	2.925
	4	35″	38	0.704	0.0185	19.936	2.832
	5	38″	42	0.994	0.0237	26.114	2.627
	6	39″	50	1.133	0.0266	28.781	2.540
	7	40″	57	1.362	0.0239	35.800	2.628
	8	41″	52	1.226	0.0240	31.590	2.578
Fife	1	24″	44	0.909	0.0206	28.220	3.104
	2	25″	28	0.446	0.0159	15.584	3.494
	3	31″	45	1.145	0.0254	30.888	2.955
	4	33″	35	0.784	0.0224	23.868	3.044
	5	34″	30	0.741	0.0247	21.902	2.955
	6	38″	42	1.262	0.0300	33.556	2.659
	7	40″	40	1.091	0.0273	27.518	2.522
	8	44″	66	1.963	0.0297	50.544	2.574
	9	44″	48	1.514	0.0315	36.083	2.383

These results clearly show that as the length of straw increases there is a quite regular increase in the number of kernels in the spike, the total and average weight of kernels and the total weight of nitrogen stored up in the spike, and an equally regular decrease in the percentage of nitrogen. This indicates that the differences between different spikes of the plant are chiefly due to differences in nutrition and other environmental conditions during growth and are not in any sense hereditary. This apparently eliminates the head or spike as a unit for selection for plant breeding purposes. It is further apparent from these results that those spikes which are richest in percentage of nitrogen are otherwise very poorly qualified to serve as seed for a new generation of plants.

Another fact which appears in this table is that all the spikes of a plant which are of equal height have about the same composition, and that if we eliminate the abnormally short and abnormally tall stalks, the remaining spikes are fairly similar in composition. This would seem to be the true hereditary composition of the plant and a means of selection for plant breeding purposes.

Selection of One Spike to Represent Composition of Whole Plant.

The facts pointed out in the preceding paragraph made it appear possible that, since all the heads of the same plant of average normal height are fairly similar in character, one head might be selected and analyzed to give a knowledge of the other heads of the plant. Obviously this would be impossible in plants which contain many stalks of very irregular heights, but with plants in which the heads were all of similar growth it seemed very probable that such a system of sampling for analysis would be sufficiently accurate for purposes of selection. To test this several plants, of three different varieties, were taken and from each of these a single sample spike was selected and analyzed separately and the remaining spikes analyzed as a whole with the results as recorded in Table IV.

TABLE IV.

SELECTION OF ONE HEAD TO REPRESENT COMPOSITION OF PLANT.

Variety	Plant No.	Number of Heads.	Composition of Heads. Number of Kernels.	Total Weight of Kernels. gms.	Average Weight of Kernels. gm.	Nitrogen in Kernels. gm.	Nitrogen in Kernels. Per cent.
Turkey Red	G	One head	28	0.745	0.0266	0.0189	2.544
		Four "	132	3.644	0.0276	0.0918	2.521
Fife	B	One head	45	1.057	0.0235	0.0309	2.922
		Four "	161	3.653	0.0228	0.1031	2.821
"	E	One head	52	1.430	0.0275	0.0383	2.673
		Ten "	517	13.865	0.0269	0.3595	2.593
Little Club	I	One head	40	0.830	0.0208	0.0218	2.622
		Seven "	303	6.732	0.0221	0.1757	2.610
"	J	One head	41	1.140	0.0278	0.0296	2.600
		Four "	160	4.757	0.0297	0.1167	2.454
"	K	One head	41	0.915	0.0223	0.0263	2.870
		Seven "	271	5.710	0.0210	0.1678	2.939
"	L	One head	52	1.100	0.0212	0.0312	2.833
		Seven "	357	6.983	0.0190	0.2096	3.001

These results appear to show that such a method of sampling is quite satisfactory for purposes of selection. In most cases the agreement between the results on the two portions of each plant is as close as is usually expected of duplicate determinations. In one or two cases where the stalks were of quite irregular height the error is somewhat larger than might be quite desirable, but even in these cases no error in the selective rank of the plant is caused by the slight inaccuracy of representation of the plant by the sample head selected. We believe that this method of sampling for analysis for seed selection is preferable to that of Dr. Lyon (analysis of half of all the heads) in that it emphasizes the necessity for elimination of abnormal heads, and that it gives a means of selection which destroys a much smaller proportion of the kernels of the plant and leaves a correspondingly larger proportion to serve for purposes of propagation. We propose to use this method in practical experiments in breeding wheats both of high total nitrogen in the plant and of high percentages of nitrogen in the grain.

Distribution of Nitrogen to Different Parts of the Same Spike.

Having ascertained the laws governing the distribution of nitrogenous matter to the different spikes of the plant it seems desirable to discover whether there might be any regular variation in the distribution of the nitrogen to various parts of each individual spike. We first compared the composition of the kernels of the opposite rows of spikelets on several spikes from each of four different varieties of wheat. The full details of the results are omitted in order to economize space, but the maximum, minimum, and average variation in composition between the opposite rows of spikelets are presented in Table V.

TABLE V.

COMPARISON OF COMPOSITION OF OPPOSITE ROWS OF SPIKELETS ON THE SAME SPIKE.

		Differences Between Composition of Opposite Rows of Spikelets.					
		In Average Weight of Kernels.			In Per cent. of Nitrogen.		
Variety	Number of Spikes Examined.	Maximum. gm.	Minimum. gm.	Average. gm.	Maximum. Per cent.	Minimum. Per cent.	Average Per cent.
Bluestem	7	0.0016	.0003	.0007	0.171	0.009	0.072
Fife	7	0.0013	.0002	.0005	0.173	0.023	0.081
Turkey Red	3	0.0009	.0002	.0003	0.066	0.035	0.050
Little Club	4	0.0022	.0001	.0009	0.151	0.027	0.069

These results show that the composition of the opposite rows of spikelets, or longitudinal halves, of a spike of wheat is practically identical. In most cases the differences found are not greater than might be expected from ordinary analytical errors. It is probable that even these differences might have been considerably reduced in some cases by rejecting the terminal spikelet, which does not properly belong to either row and which is very sensibly different in composition from other spikelets—as indicated in the following results. This latter fact was not discovered, however, until after the work on the composition of the opposite rows of spikelets was completed.

We next studied the variations in the composition of the grain from the upper and lower spikelets. A part of the sample spikes were divided into two sections, the upper and lower halves, while others were separated into three divisions, the upper, middle, and lower. The results of all the spikes of the same variety were averaged and are included in Table VI.

TABLE VI.

COMPOSITION OF KERNELS IN SPIKELETS OF DIFFERENT PARTS OF THE SAME SPIKE.

Variety.	Number of Spikes Examined.	Average Weight of Kernel. Upper Spike-lets. gm.	Middle Spike-lets. gm.	Lower Spike-lets. gm.	Composition of Kernels. Average Weight of Nitrogen in 1 Kernel. Upper Spike-lets. mgm.	Middle Spike-lets. mgms.	Lower Spike-lets. mgm.	Average Per cent. of Nitrogen in Kernel. Upper Spike-lets. per cent.	Middle Spike-lets. per cent.	Lower Spike-lets. per cent.
Bluestem	3	.0281	——	.0281	.697	——	.712	2.483	——	2.541
Fife	3	.0263	——	.0251	.674	——	.668	2.697	——	2.919
Little Club	3	.0208	——	.0220	.554	——	.623	2.538	——	2.683
Bluestem	4	.0358	.0365	.0364	.914	1.056	.998	2.568	2.762	2.720
Fife	2	.0252	.0272	.0255	.632	.736	.688	2.517	2.695	2.794
Forty-fold	2	.0368	.0397	.0359	.942	1.079	.999	2.542	2.744	2.812

These results show that the average weight of kernel is about the same in the upper and lower spikelets but somewhat higher in the middle spikelets of the same head. The kernels of the middle spikelets always contain the greater weight of nitrogen per kernel; and this was true not only the averages for each variety but of each single spike which we tested. The percentage of nitrogen shows a quite regular increase from the tip of the spike downward, every individual spike showing grain with the lowest percentage of nitrogen in the tips, and in all but three of the fourteen spikes, the highest percentage of nitrogen in the kernels from the lower division, the differences between the lower and middle spikelets being not so great, however, as between the middle and upper ones. From this it appears that the best kernels from the standpoint of composition are those growing in the middle of the spike.[1]

Finally, we separated the outer kernels from the middle kernels of each spikelet and analyzed separately all the grain from the outer and from the inner rows of kernels. The averages of the results on all the spikes of each variety are presented in Table VII.

TABLE VII.

COMPOSITION OF KERNELS FROM OUTER AND INNER ROWS IN THE SAME SPIKE.

Variety	Number of Spikes Examined.	Average Weight. of Kernel. Outer gm.	Inner gm.	Composition of Kernels. Average Weight of Nitrogen in 1 Kernel. Outer mgm.	Inner mgm.	Average Per cent of Nitrogen. Outer per cent.	Inner per cent.
Little Club	4	0.0275	0.0223	0.767	0.667	2.653	2.848
Fife	3	0 0274	0.0245	0.744	0.639	2.684	2.618
Bluestem	4	0.0371	0.0318	0.987	0.841	2.732	2.538
Forty-fold	3	0.0303	0.0266	0.878	0.728	2.925	2.877

These results show clearly that the heaviest kernels containing the highest weight of nitrogen are invariably from the outer rows. Not only was this true in the average of each variety, but in every single spike which was tested. In general, the increase in nitrogen in the outer ker-

[1] Harper and Peter of the Kentucky Experiment Station found the same phenomenon in the case of a single head of Pootung wheat of which they analyzed each pair of spikelets separately. (See Ky. Sta. Bull. No. 113, p. 11).

nels is greater than the increase in the weight of the kernels, resulting in a higher percentage of nitrogen, also, in the outer kernels, but there were frequent exceptions to this. It is apparent from these results that the kernels of the most desirable qualities came from the outer rows.

Briefly summarized, the results of our studies of the composition of the grain from different parts of a single head show that the best grains from the standpoint of weight of kernel, and nitrogen content, came from the outer grains of the spikelets in the middle of the spike. Whether these properties are capable of transmission to the succeeding generations can be determined only by experimental trial, which we are inaugurating.

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THE EFFECT OF COLORING MATTERS ON SOME OF THE DIGESTIVE ENZYMES[1].

By H. W. HOUGHTON.

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The following investigation was conducted under the supervision of the Department of Chemistry of The George Washington University. I wish to express my indebtedness to Drs. C. E. Monroe and T. M. Price for their suggestions and assistance.

A search through the literature indicates that there has been but little work done in the study of the effect of coloring matters on the digestive enzymes. However, that which has been accomplished by H. A. Weber[2], Edward Gudeman[3], A. J. Winogradow[4], and others has given results which are exceedingly interesting and important.

In the article by H. A. Weber, it is shown that oroline yellow effects the peptic digestion of fibrin, while saffoline, magenta and methyl orange effect the pancreatic digestion of this body.

Gudeman found that ultramarine, burnt sienna, chrome yellow and ponceau effected the artificial peptic digestion of egg albumen when used in such quantities as one part, or less, of the color to 400 parts of the food.

In the investigation conducted by A. J. Winogradow, he found that Safranine, Ponceau R. R., Azofuchsine, G., Orange II, Coeruline S., Phoxine, R. B. N., Iodeosine, Chrysaniline, Magdala red, Azoflavine,

[1] Presented before the meeting of the American Chemical Society at Toronto, Ontario, June 27-29, 1907; being a thesis submitted to The George Washington University for the Degree of Master of Science.

[2] On the Behavior of Coal-tar Color toward the Process of Digestion, by H. A. Weber, Am. Ch. J., 1896, XVIII, 1092-1096.

[3] Artificial Digestion Experiments, by Edward Gudeman, J. Am. Chem. Soc. 1905.

[4] The Influence of certain Coal-tar Dyes on the Digestion, by A. J. Winogradow. Z. Nahr. Genussm., 1903, VI, 589-592.