

of uric acid was mainly determined by the quantities of meat products consumed.

In the case of well-trained professional athletes, very severe and prolonged muscular exertion had little influence upon the formation and elimination of uric acid, except indirectly, by inducing an appetite for stimulating foods such as meat extracts.

Marked loss of sleep had no apparent influence upon the amount of uric acid eliminated.

The writer desires to express his indebtedness to Professor W. O. Atwater, of Wesleyan University, in whose laboratory a large part of the work, here described, was performed.

NEW YORK CITY,
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[CONTRIBUTIONS FROM THE UNIVERSITY OF ILLINOIS, AGRICULTURAL
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THE CHEMICAL COMPOSITION OF DIFFERENT PARTS OF THE CORN¹ KERNEL.²

BY C. G. HOPKINS, L. H. SMITH, AND E. M. EAST.

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THE possibility of selecting seed corn for improved chemical composition by a simple mechanical examination of sections of kernels has been clearly established by experiments previously reported;³ and the practical value of this method of selecting seed corn for high protein, high oil, and other desirable qualities, has been fully confirmed by subsequent investigations.⁴

A considerable amount of additional data relating to this matter has been accumulating with the progress of our experiments in corn-breeding, and because of the very great importance of this subject to agriculture, and also because of the marked interest which is manifested both by progressive, practical agriculturists and by scientific investigators, it has seemed advisable to publish, in somewhat greater detail, the results of our investigations along this line.

¹ "Corn" is, of course, used with the American meaning of Indian corn or maize.

² From advance sheets of Bulletin No. 87 of the University of Illinois Agricultural Experiment Station.

³ This Journal 21, 1039 (1899); Univ. of Ill. Agr. Expt. Station Bulletin 55 (1899).

⁴ Univ. of Ill. Agr. Expt. Station Bulletin 82 (1902); U. S. Dept. of Agr., Office of Expt. Stations, Bulletin 123, 91 (1903); West Indian Bulletin 4, 9 (1903).

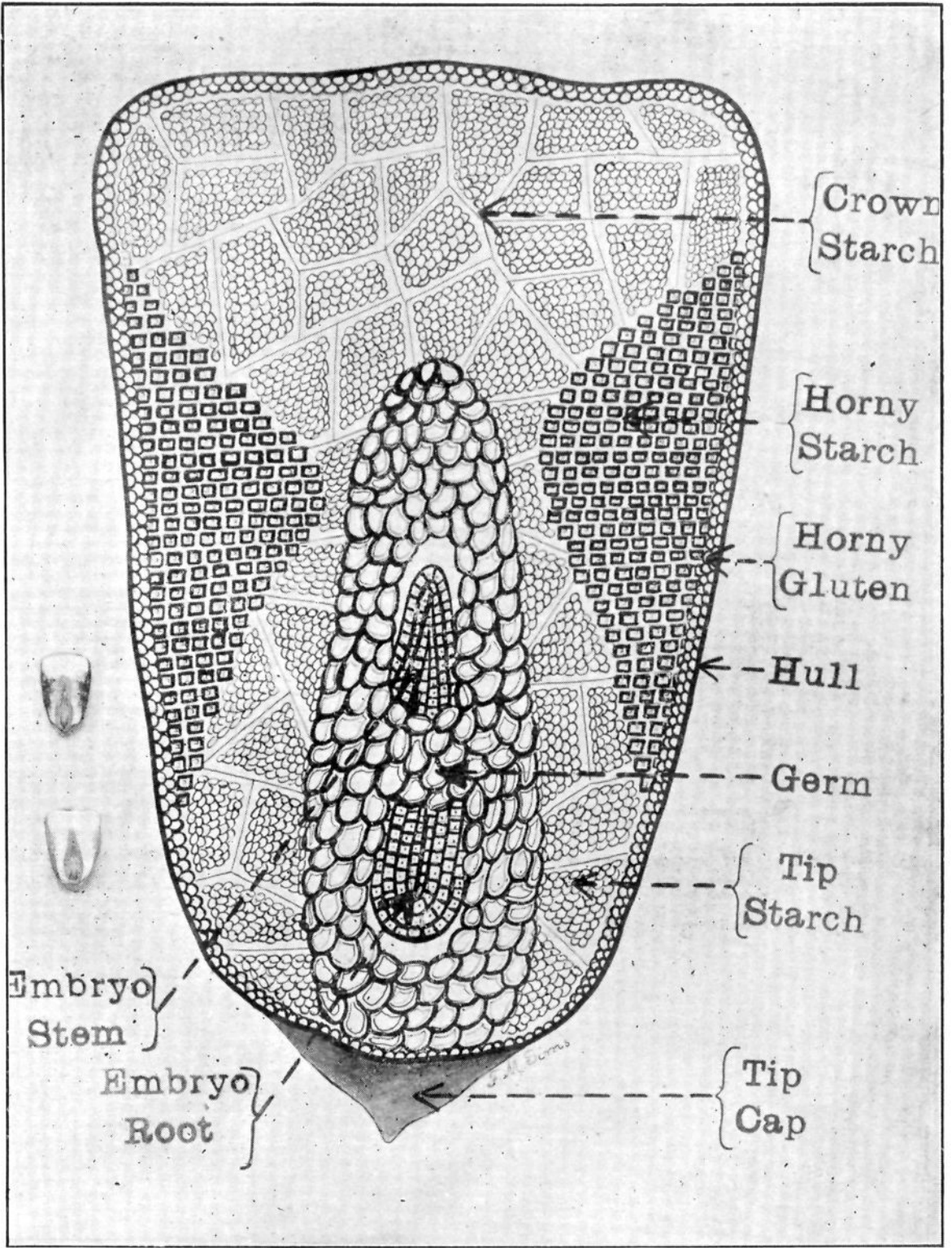


Plate I.—Low-protein corn kernel from drawing (small kernels from photograph).

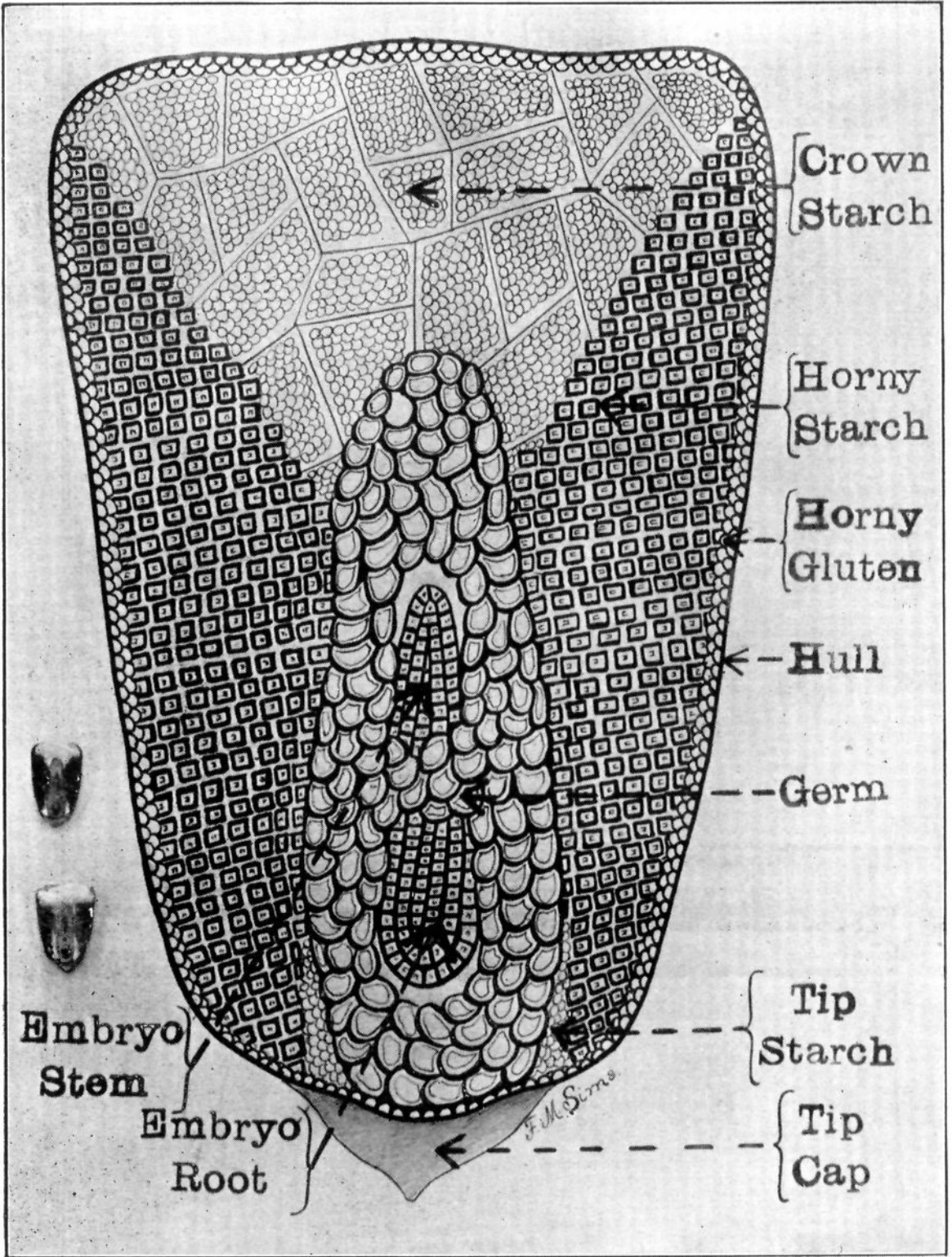


Plate II.—High-protein corn kernel from drawing (small kernels from photograph).

PARTS OF THE CORN KERNEL.

There are six distinctly different parts in a kernel of corn, as will be readily seen by the reference to Plates¹ I and II.

(1) *Tip Cap*.—This is a small cap, covering the tip end of the kernel, and serves as a protection to the end of the germ. It consists of material somewhat resembling the cob, and occasionally, in shelling corn, the tip cap remains attached to the cob, leaving the tip end of the germ uncovered, but nearly always it remains on the kernel.

(2) *Hull*.—This is the very thin outer covering of the kernel. It consists largely of carbohydrates, especially fiber or cellulose, although it also contains a small percentage of other constituents.

(3) *Horny Glutinous Part*.—This part is the aleurone layer which lies immediately underneath the hull. It constitutes a second covering of the kernel, usually much thicker than the hull. For short, it is called *horny gluten*, although it is, of course, not pure gluten. However, it is the richest in protein of any part of the corn kernel, as has been stated in bulletins published by this station and previously by Dr. Voorhees, director of the New Jersey Experiment Station.

(4) *Horny Starchy Part*.—This part lies next to the horny gluten, on the back and sides of the kernel. For short, it is called *horny starch*, although it is not pure starch, as it contains considerable amounts of other constituents, especially of protein. In an examination of the kernel with the unaided eye, the horny glutinous part and the horny starchy part are not readily distinguished from each other, the line between them being somewhat indefinite and indistinct. Considered both together, these two parts constitute the horny part of the kernel.

(5) *White Starchy Part*.—This part occupies the crown end of the kernel above the germ and it also nearly surrounds the germ toward the tip end of the kernel. For convenience, this material is called *white starch*, although it is not pure starch. In some kernels the horny starch extends nearly or quite to the germ (near the middle of the kernel) and thus separates more or less completely the white starch into two parts which we call *crown starch* and *tip starch*.

¹ It should be understood that these drawings are intended to show merely the location and relative amounts of the various parts of the kernel, not the exact cell structure.

(6) *Germ*.—The germ occupies the center of the front of the kernel toward the tip end and usually extends about one-half or two-thirds of the length of the kernel. Within the body of the germ are the embryonic stem pointing upward toward the crown end and the embryonic root pointing downward toward the tip of the kernel, both of which are, of course, parts of the germ. These embryonic parts within the germ may be easily seen by any one who will carefully shave off the front side of the germ from a kernel of corn (see small photographic reproduction of sections of kernels of high- and low-protein corn in Plates I and II).

MECHANICAL SEPARATION OF THE DIFFERENT PARTS.

It is not a difficult matter to obtain very pure samples of each of the above-named parts of the corn kernel, although in making the separations there is, of necessity, some waste material consisting of a mixture of three different parts; namely, horny gluten, horny starch, and white starch.

By the use of a small, sharp knife, any one can make the following separations: (1) Tip cap; (2) hull; (3) horny gluten; (4) horny starch;¹ (5a) crown starch: (5b) tip starch: (6) germ; (7) waste (mixed material). In making these separations the kernels are first soaked in hot water for fifteen or twenty minutes.

The tip cap is then very easily and perfectly separated by simply cutting under one edge and then pulling it off. The hull is separated without difficulty by peeling it off in strips. It is only necessary to use the knife to start the peeling at the tip end where the hull has been broken by removing the tip cap. With some care the hull can be completely peeled out of the dent in the corn. The aleurone layer is more easily distinguished after the hull is removed. It covers the entire kernel, excepting the germ.² The aleurone layer is removed by carefully shaving it off with a sharp knife. Adhering particles of starch can be more easily separated from this horny gluten after the shavings have been allowed to dry for some time. In scraping off these particles of horny starch or white starch adhering to the shavings, more or less horny gluten will also be scraped off, so that, while we are thus able to obtain a pure, clean sample of the aleurone layer, we

¹ As used in this article the term "starch" is employed in a technical or commercial sense, and not as the name of a definite chemical compound.

² This layer does not occur between the germ and the tip cap as indicated in the drawings.

also obtain some waste material, consisting of particles of horny gluten, horny starch, and white starch.

The germ is next removed, and with care this can be done very perfectly. If any particles of starch adhere to the germ they can easily be completely removed. After the tip cap, hull, aleurone layer, and germ have been removed, the remainder of the kernel, consisting of the horny starch and white starch only, is allowed to dry, and the kernel is broken in two lengthwise.

The crown starch is dug out with the knife as completely as possible without taking any of the horny starch. The tip starch is next removed in the same manner as the crown starch. The horny starch from each side usually remains in a solid piece. This is now carefully scraped to remove all adhering particles of white starch or horny gluten, the scrapings being carefully saved and added to the waste material.

By this method of separation we obtain eight different products, including the waste material, and seven of these products are pure samples of distinctly different parts of the corn kernel, excepting the crown starch and tip starch, both of which, of course, belong to the white starch; they are kept separate, however, because they are found in different places, frequently being entirely separated in the kernel, although more commonly there is some white starch continuous from crown to tip.

COMPOSITION OF THE DIFFERENT PARTS.

Table I shows the percentage of these eight different products, or parts, and the percentage composition of each part, also the percentage composition of the whole corn, for each of three different ears of corn. Ear No. 1 is corn of comparatively low¹ protein content. Ear No. 2 has about the usual protein content of ordinary corn. Ear No. 3 is high¹ protein corn. About 200 grams (nearly one-half pound) of kernels from each ear were separated into the different parts, and each part was then weighed and

¹ It should be understood that ear No. 1 (9.28 per cent. protein) and ear No. 3 (12.85 per cent. protein) do not represent extremes in protein content; indeed, in our breeding of corn for low protein we have produced good ears containing less than 6.50 per cent. of protein, and in our high-protein field we have produced corn containing over 16 per cent. of protein. In extremely low-protein corn the percentage of horny part is very much less than in ear No. 1, and in extremely high protein corn the tip white starch is frequently almost entirely wanting and the crown white starch very greatly reduced, both being replaced by the horny part, as shown in the drawings and also in the actual photographs of sections of kernels shown beside the drawings in Plates I and II.

analyzed separately, another sample of the corn from each ear being analyzed to give the composition of the whole corn. (All results are given on the water-free basis.)

TABLE I.—PERCENTAGE OF DIFFERENT PARTS AND PERCENTAGE COMPOSITION OF EACH PART.

Names of parts.	Per cent. of whole.	Composition of parts.			
		Protein. Per cent.	Oil Per cent.	Ash. Per cent.	Carbohydrates. Per cent.
Ear No. 1 (low in protein).					
Tip caps	1.20	7.36	1.16	0.91	90.57
Hulls	5.47	4.97	0.92	0.82	93.29
Horny gluten	7.75	19.21	4.00	0.92	75.87
Horny starch	29.58	8.12	0.16	0.18	91.54
Crown starch	16.94	7.22	0.19	0.32	92.27
Tip starch	10.03	6.10	0.29	0.29	93.31
Germis	9.59	19.91	36.54	10.48	33.07
Mixed waste	18.53	9.90	1.06	0.61	88.43
Whole corn .....	....	9.28	4.20	1.41	85.11
Ear No. 2 (medium in protein).					
Tip caps	1.46	8.83	2.30	1.11	87.76
Hulls	5.93	3.96	0.89	0.79	94.36
Horny gluten	5.12	22.50	6.99	1.72	69.09
Horny starch	32.80	10.20	0.24	0.24	89.32
Crown starch	11.85	7.92	0.17	0.24	91.67
Tip starch	5.91	7.68	0.39	0.31	91.62
Germis	11.53	19.80	34.84	9.90	35.46
Mixed waste	25.40	11.10	1.23	0.57	87.10
Whole corn .....	....	10.95	4.33	1.55	83.17
Ear No. 3 (high in protein).					
Tip caps	1.62	4.64	1.99	1.87	91.50
Hulls	6.09	3.84	0.76	1.10	94.30
Horny gluten	9.86	24.58	4.61	1.74	69.07
Horny starch	33.79	10.99	0.22	0.21	88.58
Crown starch	10.45	8.61	0.52	0.37	90.50
Tip starch	6.23	7.29	1.36	0.60	90.75
Germis	11.93	19.56	33.71	10.00	36.73
Mixed waste	20.03	12.53	1.15	0.61	85.71
Whole corn .....	....	12.85	5.36	1.67	80.12

A careful study of Table I reveals some very interesting and useful facts regarding the structure of the corn kernel and the composition of the different parts. It is exceedingly useful to be able, by a mechanical examination of corn, not only to pick out high-protein corn or high-oil corn as one may desire, but even to separate the several distinctly different parts from one another

by purely mechanical means—to separate, for example, the aleurone layer, containing (in the high-protein ear) nearly 25 per cent. of protein, and then the white starchy parts, with only 7 or 8 per cent. of protein; or the germs containing about 35 per cent. of oil and 10 per cent. of ash, and then the horny starchy part containing less than 0.25 per cent. of either oil or ash.

The hulls contain about 4 per cent. of protein and are clearly the poorest in protein of any part of the kernel, the next poorest being the tip caps and white starchy parts, containing about 7 or 8 per cent., the tip starch being slightly poorer than the crown starch. The horny starch is richer in protein than the white starch, especially in the medium and high protein corn where the difference amounts to more than 2 per cent., the horny starchy part containing from 10 to 11 per cent. of protein. The protein content of the germs is very uniform in the different ears, although the poorest germs are found in the high-protein corn, and the richest in the low-protein corn, the variation being from 19.56 to 19.91 per cent. The aleurone layer is the richest in protein of any part of the kernel in both ordinary and high-protein corn, as was pointed out several years ago by Dr. Voorhees,¹ director of the New Jersey Experiment Station, and as we have quoted in previous publications of the Illinois Experiment Station. In the high-protein corn the protein content of the aleurone layer amounts to 24.58 per cent. In the low-protein corn it is slightly less than that of the germ.

It is plainly seen that the oil in corn is very largely in the germ, although the aleurone layer also contains a considerable percentage, the germ containing about 35 per cent. of oil and the aleurone layer about 5 per cent. Both the horny starch and the white starch are exceedingly poor in oil, averaging about 0.25 per cent., if we disregard the tip starch in ear No. 3, which appears to have absorbed some oil directly from the germ which it adjoins and partially surrounds. The hulls contain slightly less than 1 per cent. of oil and the tip caps slightly more than 1 per cent., and it is quite possible that this oil may have been obtained, in part at least, by absorption from the aleurone layer and germ. Indeed, it seems highly probable that practically all of the true oil in the corn kernel is originally deposited in the germ and aleurone layer.

¹ New Jersey Agricultural Experiment Station Bulletin 105 (1894).

and that the small percentage or mere trace, which is found in the other parts, is largely obtained by absorption. That such absorption actually does occur is definitely proved by the fact that the percentage of oil in hominy and hominy products increases with the age of the corn used in the milling. (Hominy consists largely of the horny starch with more or less adhering white starch.)

It may be of interest to state in this connection that in 1866 Haberlandt¹ discovered, with the microscope, that the germ of the corn kernel contains a large amount of oil. He observed no oil in the remaining portions of the kernel. By chemical analysis, Lenz¹ found, however, that after the germs were removed the remaining portion of the kernel contained 1.57 per cent. of oil. These results were fully confirmed by Dr. Atwater,² who found 1.63 per cent. of oil in the corn after removing the germs and adjoining material, although neither Lenz nor Atwater appear to have ascertained that the horny gluten (the aleurone layer) contains the chief percentage of oil outside of the germ.

By further reference to Table I, it will be observed (1) that the germ contains about 10 per cent. of ash or mineral matter; (2) that this is about ten times the average percentage of ash contained in the other parts; and (3) that the percentage of ash in the different parts varies with the percentage of oil, to quite a noticeable degree. Of course, the percentage of carbohydrates (starch, cellulose, pentosans, etc.) varies inversely as the sum of the other constituents, being about 35 per cent. in the germ, 70 per cent. in the horny gluten, and from 90 to 95 per cent. in the other principal parts.

The marked degree of uniformity in the entire percentage composition of the germs from each of these three ears, whether low-protein, medium-protein, or high-protein, seems especially noteworthy. The percentage of protein varies only from 19.56 to 19.91; the oil from 33.71 to 36.54; the ash from 9.90 to 10.48; and the carbohydrates from 33.07 to 36.73. It will also be noted that the percentages of both protein and oil are lower in the germs from high-protein corn than in those from the low-protein corn, although the differences are not marked.

¹ *Allgemeine land- und forstwirtschaftliche Zeitung*, 1866, p. 257; *Jahresbericht (Hofmann) über die Agricultur-Chemie*, 9, 106 (1866).

² Thesis, Yale College (1869); *Am. J. Sci. and Arts* (2), 48, 332 (1869).

MATHEMATICAL DISTRIBUTION OF WASTE.

It will be borne in mind that in making the mechanical separations, in order to obtain each of the seven different parts in pure condition, unmixed with any other part, there was necessarily some waste product. This waste substance amounted to about 20 per cent. of the whole. As has already been explained, this mixed waste material consists of only three distinctly different parts—horny gluten, horny starch, and white starch (from crown and tip), the other three parts—tip caps, hulls, and germs—being easily separated completely and in pure form.

By a simple computation the mixed waste material can be distributed among the respective parts of which it is composed, provided we may be allowed to make the assumption (which is approximately the truth) that the horny starch and white starch are present in the waste material in the same proportions as they are in the pure separated portions. Any error which might be introduced by following this assumption would have but little effect because the composition of the horny starch and white starch are not very markedly different (the protein differs by 2 to 3 per cent.); and also because the total amount of waste material to be distributed is only from one-third to one-half the sum of the separated horny starch and white starch.

It will be observed (see Table I) that the mixed waste is always richer in protein than the horny starch, thus showing that, besides horny starch and white starch, it also contains more or less horny gluten, which, of course, we know to be the fact.

If in 100 grams of corn we let x equal the number of grams of tip starch, Bx the number of grams of crown starch, Cx the number of grams of horny starch, y the number of grams of horny gluten, and S the sum of these four parts, then

$$x + Bx + Cx + y = S. \quad (1)$$

Now if we let a equal the per cent. of protein in the tip starch, b the per cent. of protein in the crown starch, c the per cent. of protein in the horny starch, d the per cent. of protein in the horny gluten, and s the number of grams of protein in all of these four parts, then

$$ax + bBx + cCx + dy = s. \quad (2)$$

Thus we have two equations with which to solve for x and y , which are the only unknown quantities, B and C being factors

which can be obtained by dividing the per cent. of separated crown starch and horny starch, respectively, by that of tip starch, and S being the sum of the separated tip starch, crown starch, horny starch, horny gluten and mixed waste, as given in Table I, and a, b, c, d being the respective percentages of protein in the four separated materials, tip starch, crown starch, horny starch, and horny gluten, and s being the total number of grams of protein contained in these four separated parts and in the mixed waste, all of which data are also given in Table I.

PHYSICAL COMPOSITION OF THE CORN KERNEL.

From the above computations we obtain the results given in Table II, which gives the total percentages of each of the seven different parts contained in the corn kernel (counting crown starch and tip starch as two parts), and with no waste material.

TABLE II.—TOTAL PERCENTAGES OF THE DIFFERENT PARTS OF THE CORN KERNEL.

Name of parts.	Ear No. 1 (low- protein).	Ear No. 2 (medium- protein).	Ear No. 3 (high- protein).
Tip caps	1.20	1.46	1.62
Hulls	5.47	5.63	6.09
Horny gluten.....	11.61	8.51	13.32
Horny starch.....	37.15	47.08	44.89
Crown starch.....	21.26	17.01	13.88
Tip starch.....	13.71	8.48	6.28
Germs	9.59	11.53	11.93
Total.....	99.99	100.00	100.01

It will be observed that the percentages of horny gluten, horny starch, and germs are noticeably higher in the high-protein corn than in the low-protein corn, while the opposite is true with the white starch, the percentages of crown starch and tip starch being markedly higher in the low-protein corn than they are in the high-protein corn. It is noteworthy that the horny gluten in high-protein corn not only contains a higher percentage of protein than the germs, but that the proportion of horny gluten in the kernel equals or exceeds that of the germs. The only discrepancies appearing in Table II are the low percentage of horny gluten and the high percentage of horny starch in ear No. 2. Otherwise the percentages of parts in the medium-protein ear are always intermediate between those in the other two ears, as would be expected. Even these discrepancies disappear if the two

horny parts be added together and considered as one part, as is done in the practical work of selecting seed corn for higher protein content by mechanical examination, as will be seen by referring to Table III.

TABLE III.—PERCENTAGES OF THE DIFFERENT PARTS OF THE CORN KERNEL AS COMMONLY OBSERVED IN MECHANICAL EXAMINATION FOR SEED CORN SELECTION.

Name of parts.	Ear No. 1 (low- protein).	Ear No. 2 (medium- protein).	Ear No. 3 (high- protein).	Average Per cent.
Tip caps.....	1.20	1.46	1.62	1.43
Hulls.....	5.47	5.93	6.09	5.83
Horny part.....	48.76	55.59	58.21	54.19
White starch.....	34.97	25.49	22.16	27.54
Germs.....	9.59	11.53	11.93	11.02
Total.....	99.99	100.00	100.01	100.00

In this table the crown starch and tip starch are also added together and the sum recorded as white starch. The increase in the amount of horny part (from 48.76 to 58.21 per cent.) and the decrease in white starch (from 34.96 to 22.16 per cent.) as we pass from the low-protein to the high-protein corn, is plainly apparent.

DISTRIBUTION OF CHEMICAL CONSTITUENTS.

Table IV shows the location or complete distribution of the chemical constituents among the seven different physical parts of the corn kernel. In other words, this table represents the separation of 100 grams (or 100 pounds) of corn into seven different structural or physical parts, and the subsequent division of each of these parts into four chemical constituents, protein, oil, ash, and carbohydrates.

TABLE IV.—PHYSICAL AND CHEMICAL DISTRIBUTION OF 100 GRAMS (OR 100 POUNDS) OF CORN.

Names of parts.	Physical distribution (grams or pounds).	Chemical distribution.			
		Protein (grams or pounds).	Oil (grams or pounds).	Ash (grams or pounds).	Carbohydrates (grams or pounds).
Tip caps.....	1.20	0.09	0.01	0.01	1.09
Hulls.....	5.47	0.27	0.05	0.04	5.10
Horny gluten.....	11.61	2.23	0.46	0.11	8.81
Horny starch.....	37.15	3.02	0.06	0.07	34.01
Crown starch.....	21.26	1.53	0.04	0.07	19.62
Tip starch.....	13.71	0.84	0.04	0.04	12.79
Germs.....	9.59	1.91	3.50	1.01	3.17
Total.....	99.99	9.89	4.16	1.35	84.89
Whole corn.....	.....	9.28	4.20	1.41	85.11

Names of parts.	Physical distribution (grams or pounds).	Chemical composition.			
		Protein (grams or pounds).	Oil (grams or pounds).	Ash (grams or pounds).	Carbohydrates (grams or pounds).
Ear No. 2 (medium in protein).					
Tip caps	1.46	0.13	0.03	0.02	1.28
Hulls	5.93	0.23	0.05	0.05	5.60
Horny gluten	8.51	1.89	0.59	0.15	5.88
Horny starch.....	47.68	4.80	0.11	0.11	42.05
Crown starch.....	17.01	1.35	0.03	0.04	15.59
Tip starch.....	8.48	0.65	0.03	0.03	7.77
Germ8	11.53	2.28	4.02	1.14	4.09
Total	100.00	11.33	4.86	1.54	82.26
Whole corn .....	.....	10.95	4.33	1.55	83.17
Ear No. 3 (high in protein).					
Tip caps	1.62	0.08	0.03	0.03	1.48
Hulls	6.09	0.23	0.05	0.07	5.74
Horny gluten	13.32	3.27	0.61	0.23	9.20
Horny starch.....	44.89	4.93	0.10	0.09	39.76
Crown starch.....	13.88	1.20	0.07	0.05	12.56
Tip starch	8.28	0.60	0.11	0.05	7.51
Germ8	11.93	2.33	4.02	1.19	4.38
Total	100.01	12.64	4.99	1.71	80.63
Whole corn.....	.....	12.85	5.36	1.67	80.12

The agreement between the sum of the separate determinations and the direct determinations of the same constituent in the whole corn is very satisfactory, considering that these results are obtained by computation from the analyses of nine different materials, including the whole corn. The greatest difference is well within the limit of unavoidable error in sampling and analytical determinations. A careful study of this table will reveal some interesting and valuable facts. For example, it will be seen that in 100 pounds of the low-protein corn the horny gluten contains only 2.23 pounds of protein, while 3.27 pounds of protein are contained in the horny gluten in 100 pounds of the high-protein corn. Again, in 100 pounds of the low-protein corn the horny starch contains only 3.02 pounds of protein, while 4.93 pounds of protein are contained in the horny starch in 100 pounds of the high-protein corn.

On the other hand, in 100 pounds of the low-protein corn, the crown starch and tip starch contain 1.53 and 0.84 pounds of protein, respectively, while 1.20 and 0.60 are the respective amounts contained in the corresponding parts of the high-protein corn.

If we add together the horny parts and then add together the crown starch and tip starch, as is done in the practical selection of seed corn by mechanical examination, we obtain the results shown in Table V.

TABLE V.—POUNDS OF PROTEIN IN 100 POUNDS OF CORN.

Name of parts.	Low-protein corn.	Medium-protein corn.	High-protein corn.
In tip caps	0.09	0.13	0.08
In hulls	0.27	0.23	0.23
In horny part.....	5.25	6.69	8.20
In white starch	2.37	2.00	1.80
In germs.....	1.91	2.28	2.33
Total.....	9.89	11.33	12.64

It will be observed that the increase in protein in high-protein corn over that in low-protein corn occurs almost entirely in the horny part of the corn kernel. There is also a slight increase in protein in the germ, although this is quite insignificant as compared with the increase in the horny part. In passing from low-protein corn to high-protein corn, there is an appreciable decrease in the amount of protein contained in the white starch. Of course, this is due to the marked decrease in the actual amount of white starch in high-protein corn. Indeed, this decrease in the quantity of white starch is even more marked than would appear from Table V, because the white starch in the high-protein corn is actually richer in protein than that in low-protein corn, as would be expected and as is shown in Table I.

The data given in Table V strongly confirm the results which we have already obtained in practical experience in corn-breeding. For example, we have been breeding both high-protein corn and low-protein corn for the past seven years. In the high-protein corn we find that the proportion of horny part has increased very markedly, while the white starchy part has markedly decreased. In the low-protein corn the opposite is true, the horny part having decreased and the white starchy part having markedly increased, in proportion.

By computation from the data given in Table IV, we have constructed Table VI, which shows the percentage distribution of the different chemical constituents among the several physical parts of the corn kernel.

TABLE VI.—PERCENTAGE DISTRIBUTION OF CHEMICAL CONSTITUENTS AMONG PHYSICAL PARTS.

Name of parts.	Ear No. 1 (low in protein).			
	Per cent. of total protein.	Per cent. of total oil.	Per cent. of total ash.	Per cent. of total carbohydrates.
In tip caps.....	0.89	0.33	0.81	1.29
In hull.....	2.75	1.21	3.34	6.03
In horny gluten.....	22.56	11.13	7.96	10.41
In horny starch.....	30.51	1.43	4.98	40.22
In crown starch.....	15.52	0.97	5.07	23.18
In tip starch.....	8.46	0.95	2.96	15.12
In germs.....	19.31	83.99	74.87	3.75
Total.....	100.00	100.01	99.99	100.00
Ear No. 2 (medium in protein).				
In tip caps.....	1.14	0.69	1.06	1.56
In hull.....	2.07	1.08	3.06	6.80
In horny gluten.....	16.67	12.21	9.56	7.15
In horny starch.....	42.36	2.32	7.38	51.12
In crown starch.....	11.88	0.59	2.67	18.96
In tip starch.....	5.75	0.68	1.72	9.45
In germs.....	20.14	82.43	74.55	4.97
Total.....	100.01	100.00	100.00	100.01
Ear No. 3 (high in protein).				
In tip caps.....	0.59	0.65	1.76	1.84
In hull.....	1.85	0.93	3.90	7.12
In horny gluten.....	25.88	12.29	13.49	11.41
In horny starch.....	39.00	1.98	5.49	49.31
In crown starch.....	9.45	1.44	2.99	15.58
In tip starch.....	4.77	2.25	2.89	9.32
In germs.....	18.45	80.46	69.46	5.43
Total.....	99.99	100.00	99.98	100.01

It will be seen that as an average about 22 per cent. of the total protein is contained in the horny gluten, nearly 40 per cent. in the horny starch, and nearly 20 per cent. in the germ; thus these three parts contain about 80 per cent. of the total protein in the kernel.

The germ contains from 80 to 84 per cent. of the oil, while all other parts combined contain only 15 to 20 per cent. of the total oil in the kernel. Based upon this fact is the method for selecting high-oil or low-oil seed corn by mechanical examination, the ears whose kernels show a large proportion of germ being high-

oil corn and those with small germs, low-oil corn. About 12 per cent. of the total oil is contained in the aleurone layer, leaving only about 5 per cent. of the oil distributed among the remaining five physical parts, and, as stated above, more or less of this small amount is undoubtedly absorbed from the contiguous germ or aleurone layer. It will be noted that the ash is closely associated with the oil, nearly 75 per cent. of the total ash being contained in the germ, and about 10 per cent. in the aleurone layer as an average.

Table VII shows, for direct comparison, the percentage distribution of the protein among the different physical parts, in each ear, the two horny parts, and also the two white starchy parts, being combined as in Table V.

TABLE VII.—DISTRIBUTION OF 100 GRAMS (OR 100 POUNDS) OF PROTEIN AMONG THE PHYSICAL PARTS AS OBSERVED IN MECHANICAL EXAMINATION.

Names of parts.	Low-protein corn.	Medium-protein corn.	High-protein corn.
In tip caps	0.89	1.14	0.59
In hulls	2.75	2.07	1.85
In horny part.....	53.07	59.03	64.88
In white starch	23.98	17.63	14.22
In germs	19.31	20.14	18.45
Total.....	100.00	100.01	99.99

Table VII illustrates very plainly the fact that, as we pass from low-protein corn to high-protein corn, the protein decreases in the white starchy part and increases in the horny part; in other words in breeding corn for high protein, we decrease the white starchy part, which is comparatively poor in protein, and increase the horny part, which averages very much richer in protein, the horny starch containing 2 to 3 per cent. more protein than the white starch, and the horny gluten (aleurone layer) being richer in protein than any other part of the kernel. As a rule, in breeding for high protein there is also a slight increase in the proportion of germ, which, being rich in protein, adds somewhat to the increase in protein.