# INVESTIGATION UPON MAIZE.*

By E. F. Ladd.

In the Spring of 1888 the writer planned and began a series of investigations upon maize, for the purpose of gaining information upon several mooted questions, particularly the following :

1. What chemical changes take place in maize as it approaches maturity?
2. In what stage of maturity is it most advisable to cut maize for ensilage?
3. What chemical changes take place in, and what loss results from the process of converting maize into ensilage?
4. What is the loss and what the nature of the chemical changes that take place in maize during the process of field and barn curing?
5. What is the digestibility of, and what the relative nutritive value of the above several products?

These experiments and investigations, begun in 1888, were continued into the Winter of 1889–90, when it became necessary to abandon all efforts at legitimate scientific research, and, while many data were secured the work of research can hardly be said to have reached any satisfactory state of completion—in fact, it is hardly begun as originally outlined. That the writer will not have an opportunity to carry the investigation further, seems a

*The data for a part of the first of this article will be many found in the eighth annual report of the New York Agricultural Experiment Station. Some of the data relating to the digestibility of ensilage and field cured maize may be found in a paper, "Ensilage and Dry Fodder," presented to the Society for the Promotion of Agricultural Science at the Indianapolis meeting, August, 1890. The whole is here brought together in order that it may be made more accessible, and much data heretofore unpublished included.

justifiable reason for presenting these fragmentary notes to serve as landmarks to those who may be engaged in similar lines of research.

The first year little more was accomplished than to inaugurate the work and to go carefully over the ground to see what was needed; besides, the maize grown, a Southern variety (Burrill and Whitman) could not possibly mature in Central New York, and this proved an obstacle to our work. The field under experiment contained a little less than two acres; one-half was cut September 11, the remainder September 29. At the first date the maize varied from silking to watery stage of kernel, and the last from watery to milky stage. The yield per acre was as follows:

| | Sept. 11. Lbs. | Sept. 29. Lbs. |
|---|---|---|
| Total maize per acre | 25,326 | 25,011 |
| Water | 20,322 | 19,351 |
| Dry matter | 5,004 | 5,660 |
| Ash | 215 | 237 |
| Albuminoids | 525 | 512 |
| Crude fibre | 1,443 | 1,650 |
| Nitrogen-free extract | 2,696 | 3,109 |
| Fat (ether extract) | 125 | 188 |

On further investigation we find the changes that have taken place to be mainly in the albuminoids and nitrogen-free extract, and the extent of these changes is shown by the following:

| | Sept. 11. Lbs. | Sept. 29. Lbs. |
|---|---|---|
| Total nitrogen | 84 | 81 |
| Albuminoid nitrogen | 50 | 67 |
| Amide nitrogen | 34 | 14 |
| Invert sugar | 580 | 751 |
| Sucrose | 390 | 634 |
| Starch | 908 | 1,077 |

We first note that there was no increase in total nitrogen—even an apparent loss—but that much of the nitrogen in the form of amides was transformed into albuminoids, and this transformation and translocation our experiments have invariably seemed to show to be accompanied by a loss of nitrogen, and it would seem natural that this should be so. While there was an increase of 413 pounds in nitrogen-free extract between the two periods of harvesting, the sugars and starches included in the nitrogen-free extract increased 583 pounds, showing that much which was in a transitory state had been built up to higher and more organized products—sugar and starch.

## INVESTIGATIONS IN 1889.

Without further considering these results we pass to the investigation made the second year. This season, 1889, a flint variety of maize (King Philip) that would in any favorable season mature a good stand of ears, was selected for the main experiment, although the same variety as grown the previous year was under trial. In a field of about twelve acres, one acre, representative of the whole field was selected for experimental work. This acre was divided into five equal lots to be cut at different times, representing various stages of growth and to serve as a basis for our calculations and chemical examinations. From each cutting eight samples were taken for analyses, so we have as fair an average as seemed possible to secure from a product so difficult to sample. The dates of cutting and stage of growth were as follows:

| Date of Cutting. | Stage of Growth. |
|---|---|
| July 30 | Full tasseled. |
| August 9 | Full silked. |
| August 21 | Kernels watery to full milk. |
| September 7 | Kernels glazing. |
| September 23 | Ripe. |

The yield of maize per acre and the per cent. of water in same were as follows:

| | Pounds Per Acre. | Per Cent. Water. |
|---|---|---|
| July 30 | 18,045 | 91.05 |
| August 9 | 25,745 | 88.05 |
| August 21 | 32,000 | 85.766 |
| September 7 | 32,295 | 77.70 |
| September 23 | 28,460 | 72.18 |

### DRY MATTER HARVESTED PER ACRE.

From the data already given we may calculate the amount of dry matter actually harvested at the several stages of growth:

| | Maize, tons Per Acre. | Tons Water Per Acre. | Tons Dry Matter Per Acre. |
|---|---|---|---|
| July 30 | 9.02 | 8.21 | .81 |
| August 9 | 12.87 | 11.33 | 1.54 |
| August 21 | 16.30 | 13.97 | 2.33 |
| September 7 | 16.14 | 12.51 | 3.63 |
| September 23 | 14.23 | 10.27 | 3.96 |

The above table is suggestive and confirms what has been repeatedly asserted, that maize so planted as to come only to the tasseling or silking stage of growth, is principally water and furnishes but little nutritive matter to animals forced to eat the forage.

The chemical composition of the maize cut at the several dates in respect to dry substance is given below:

| | July 30. | Aug. 9. | Aug. 21. | Sept. 7. | Sept. 23. |
|---|---|---|---|---|---|
| Ash | 8.53 | 6.54 | 5.00 | 4.20 | 4.60 |
| Albuminoids | 14.881 | 14.19 | 10.31 | 8.94 | 8.56 |
| Crude fibre | 31.76 | 28.36 | 27.18 | 24.38 | 21.90 |
| Nitrogen-free ex't | 40.39 | 45.46 | 52.58 | 58.87 | 60.97 |
| Fat | 4.46 | 5.45 | 4.93 | 3.60 | 3.97 |
| Total nitrogen | 2.37 | 2.27 | 1.65 | 1.43 | 1.37 |
| Alb. nitrogen | 1.69 | 1.45 | 1.30 | 1.09 | 1.15 |
| Amide nitrogen | .68 | .82 | .35 | .34 | .23 |
| Invert sugar | 3.60 | 9.76 | 14.32 | 10.00 | 6.80 |
| Sucrose | .56 | 3.60 | 2.80 | 1.32 | 1.88 |
| Starch | 17.55 | 15.96 | 15.20 | 24.09 | 36.02 |

The chemical composition gives but a small idea of the real changes that have taken place; this can only be learned by considering the totals which are given in the following:

| | Tasseled July 30. lbs. | Silked Aug. 9. lbs. | Milk Aug. 21. lbs. | Glazed Sept. 7. lbs. | Ripe Sept. 23. lbs. |
|---|---|---|---|---|---|
| Yield per acre | 8,045 | 25,745 | 32,600 | 32,295 | 28,460 |
| Water per acre | 16,426 | 22,666 | 27,957 | 25,093 | 20,542 |
| Dry matter per acre | 1,619 | 3,078 | 4,643 | 7,202 | 7,918 |
| Ash | 139 | 201 | 232 | 302 | 364 |
| Albuminoids | 240 | 437 | 479 | 644 | 678 |
| Crude fibre | 514 | 873 | 1,262 | 1,756 | 1,734 |
| Nitrogen-free ex't | 654 | 1,399 | 2,441 | 4,240 | 4,828 |
| Fat | 72 | 168 | 229 | 260 | 314 |
| Total nitrogen | 38 | 70 | 77 | 103 | 108 |
| Albuminoid nitrogen | 27 | 45 | 60 | 78 | 91 |
| Amide nitrogen | 11 | 25 | 17 | 24 | 17 |
| Invert sugar | 58 | 300 | 665 | 720 | 538 |
| Sucrose | 9 | 111 | 129 | 95 | 149 |
| Starch | 122 | 491 | 707 | 735 | 2,853 |

The last table indicates several interesting features not the least of which is the seeming confirmation of a previous observation. That is that in the growth of the maize plant there are two periods of little or no increase in total nitrogen. The first is during the early formation of the ear, between the period of silking and watery stage of kernels; the other between the periods of glazing and full maturity. In fact, while I have not the necessary data to show it, yet I feel confident from observations made that there is at these times not only no material increase in the nitrogenous constituents, but that there is an actual loss of nitrogen incident to the transformation and translocation going on at this time in the plant. This would suggest the possibility of an advantage to be derived by making application of easily soluble nitrogenous fertilizers at two distinct periods in the life of the maize plant. We may also note the marked increase of starch during the latter stage of the maturation. As maize is preeminently a carbonaceous plant and as starch its most valuable constituent to be preserved, we can see the importance of allowing the plant to come as near to full maturity as is possible, and at the same time of allowing it to be utilized for the purpose designed. Observation has shown that if maize is to be grown for ensilage, maturation may proceed too far, so far that if the plant be stored in the silo it will mould, decay, and become almost or even quite worthless for feeding. It is important that we possess more definite knowledge on this particular point, and our investigation was continued with that end in view.

### MAIZE FOR THE SILO.

For furthering our work, two silos of about eleven tons' capacity each were available. Of each silo three sides were of cement and one of wood. Incidentally we may remark that the ensilage was much better preserved on those sides where the contact was with wood than on those with cement.

One of the silos was filled with the dent variety of maize (B. and W. corn) at about the milky stage of the kernel, September 5. This maize, after it was carefully weighed, was sampled for analyses as it was passed through an ensilage cutter that cut the stalk into one and one-fourth inch pieces. Twenty-seven samples were taken for water determination, and these were united into four lots, representing various depths in the silo, and complete analyses made for each lot.

The second silo was filled September 13, with the flint variety of maize, between the stage of glazing and full maturity, as indicated in a previous table, showing the composition of the maize cut at the various stages of growth. We now have two silos filled with maize at two stages of growth; it would be better were they of the same variety, but we will continue the comparison under the conditions as they exist.

### ENSILAGE FROM IMMATURE MAIZE.

The silo filled with immature maize September 5 was opened on October 10, the top or surface having been covered in the meantime with tarred paper and lightly weighted about the corners of the silo.

The results of the analyses of the maize as put into the silo and of the ensilage as taken out is shown in the next table.

A represents the ensilage from the bottom of the pit and E that from the surface.

ANALYSES OF IMMATURE MAIZE FOR ENSILAGE.

| | Water. | Dry Matter. | Ash. | Albuminoids. | Crude Fibre. | Nitrogen-Free Extract. | Fat. |
|---|---|---|---|---|---|---|---|
| Maize A..... | 81.18 | 18.82 | 4.53 | 9.94 | 28.12 | 53.83 | 3.58 |
| " B..... | 80.39 | 19.61 | 4.50 | 10.06 | 25.83 | 56.14 | 3.47 |
| " C..... | 81.48 | 18.52 | 4.75 | 9.25 | 28.16 | 54.92 | 2.92 |
| " D..... | 81.81 | 18.19 | 5.07 | 11.18 | 26.37 | 53.43 | 3.75 |
| **Average.....** | **81.08** | **18.92** | **4.71** | **10.11** | **27.12** | **54.38** | **3.68** |

*ANALYSES OF ENSILAGE FROM IMMATURE MAIZE.

| | Water. | Dry Matter. | Ash. | Albuminoids. | Crude Fibre. | Nitrogen-Free Extract. | Fat. |
|---|---|---|---|---|---|---|---|
| Ensilage A.... | 83.37 | 16.63 | 5.84 | 9.37 | 32.32 | 44.71 | 7.76 |
| " B.... | 82.98 | 17.02 | 4.32 | 9.06 | 32.17 | 50.13 | 4.32 |
| " C.... | 82.18 | 17.82 | 6.02 | 9.25 | 31.58 | 48.88 | 4.47 |
| " D.... | 84.11 | 15.89 | 5.98 | 9.12 | 33.36 | 45.73 | 5.81 |
| " E.... | 84.86 | 15.14 | 7.69 | 11.12 | 33.12 | 44.26 | 3.81 |
| **Average.....** | **83.50** | **16.50** | **5.97** | **9.58** | **32.50** | **46.71** | **5.23** |

The sample A contains less water than the average for the silo, yet in removing the last foot of ensilage from the bottom of the pit, there was so much juice that it would ooze quite rapidly through the open spaces in the box used for weighing up the ensilage. The low per cent. of water in the ensilage, from the bottom of the silo was something of a surprise, but it seems, from our own and other experiments, that there was probably a diffusion of soluble matter from above into the lower part of the silo, so that this liquid probably contained in solution or suspension considerable solid matter. During the 36 days that the maize remained in the silo there was a loss in total weight of 5.13 per cent., and of dry matter, as calculated from the water determination, of 13.50 per cent. It should be borne in mind that these silos

*Since our investigation had to do only with the practical side of the question, no account was taken of the nitrogen that existed in the ensilage as ammonia, for as such it would be valuless to the agriculturist.

were of small capacity, 10 to 12 tons only, so that we should expect the loss in pr. ct. to be greater than for a large silo of 100 to 150 tons capacity. The following table gives the actual results as found for the maize as put into the silo, and the ensilage as taken out:

| | Put in Silo, lbs. | Taken out of Silo, lbs. | Loss or Gain per cent. |
|---|---|---|---|
| Total weight | 23,382 | 22,291 | 5.13— |
| Total water | 18,958 | 18,466 | ---- |
| Total dry matter | 4,424 | 3,825 | 13.50— |
| Ash | 208 | 207 | .69— |
| Albuminoids | 447 | 349 | 21.99— |
| Crude fibre | 1,199 | 1,310 | 9.24+ |
| Nitrogen-free extract | 2,406 | 1,777 | 26.13— |
| Fat | 163 | 182 | 11.83+ |
| Total nitrogen | 72 | 55 | 23.75— |
| Albuminoid nitrogen | 49 | 35 | 28.55— |
| Amide nitrogen | 23 | 20 | 13.04— |
| Invert sugar | 493 | 88 | 82.12— |
| Sucrose | 373 | 19 | 94.77— |
| Starch | 625 | 783 | 25.22— |
| Silage per cubic foot | --- | 37.7 | ---- |

In the contents of this silo the loss was mainly upon the albuminoids and nitrogen-free extract. The sugars were nearly all destroyed by fermentation, only about 100 pounds remaining against about 800 put into the silo.

ENSILAGE FROM MAIZE NEARLY MATURE.

The maize as put in the second silo was cut at period of full glazing, or between the period of glazing and ripeness. It was run through an ensilage cutter and 24 samples were taken for water determination, which samples were united into four lots for analyses representing different depths in the silo. The silo was filled September 13 and opened December 2, the maize being carefully weighed when put in, and when opened the ensilage was taken out in blocks according as the product seemed uniform in general appearance, the same as with the first silo. Of ensilage there were taken 44 samples, of about 2 kilos each, for water determination, and these were united into five lots representing the several depths in the silo. Again, A indicates the sample from the bottom and E that from the top of the silo.

ANALYSES OF MATURE MAIZE FOR ENSILAGE.

| | Water. | Dry Matter. | Ash. | Albuminoids. | Crude Fibre. | Nitrogen-free extract. | Fat. |
|---|---|---|---|---|---|---|---|
| Maize A ....... | 76.28 | 23.72 | 3.38 | 10.25 | 21.30 | 60.94 | 4.13 |
| " B ....... | 72.41 | 27.59 | 2.90 | 9.06 | 21.09 | 62.02 | 4.93 |
| " C ....... | 74.47 | 25.53 | 3.19 | 10.12 | 22.58 | 59.97 | 4.14 |
| " D ....... | 75.82 | 24.18 | 3.48 | 9.56 | 22.91 | 59.13 | 4.92 |
| **Average** ..... | **74.93** | **25.07** | **3.24** | **9.77** | **21.97** | **60.49** | **4.53** |

ANALYSES OF ENSILAGE FROM MATURE MAIZE.

| | Water. | Dry Matter. | Ash. | Albuminoids. | Crude Fibre. | Nitrogen-free extract. | Fat. |
|---|---|---|---|---|---|---|---|
| Ensilage A .... | 80.34 | 19.66 | 6.39 | 7.75 | 26.18 | 55.22 | 4.46 |
| " B .... | 77.67 | 22.33 | 4.31 | 7.63 | 27.67 | 55.57 | 4.82 |
| " C .... | 76.92 | 23.08 | 4.30 | 8.56 | 24.04 | 58.00 | 4.90 |
| " D .... | 79.10 | 20.90 | 4.70 | 8.44 | 26.38 | 56.79 | 3.69 |
| " E .... | 75.22 | 24.78 | 6.39 | 9.87 | 26.27 | 54.38 | 3.09 |
| **Average** ..... | **77.85** | **22.15** | **5.26** | **8.45** | **26.11** | **55.99** | **4.19** |

The ensilage came out in exceedingly good condition, and the average of several determinations gave but 0.28 per cent. of acid calculated as acetic, so that this may be classed among what is commonly termed sweet ensilage ; that is, relatively sweet compared with the acid ensilage not unfrequently met with. In total weight there was a loss of 3.25 per cent. during the process, a period of 38 days. Of dry matter there was a loss of 15.21 per cent. These figures must not be interpreted too closely, for although the work from beginning to end was done with all the care I could personally give, yet it is evident that the samples, although 44 were taken from the silo and 24 from the maize as put in the silo, do not fairly represent the true composition of the ensilage as judged by the tota ash put in and taken out of the silo. This same fact is true for every investigation thus far made, so far as the results have com under my observation. It would seem then that calculations base on the ash as a constant to work from, may lead us very far from a true understanding of the actual changes which have taken place in the silo.

I had hoped to make some chemical examinations of the juices and soluble portions from another silo, but was unable to do so. I assume, however, that it will be found that much of the matter contained in the juices at the bottom of the silo is made up of soluble matter diffused from the overlying layers, and the more water contained in the ensilage the greater should we expect to find the diffusion. If this be true, it is plain to see how we may be mislead, when but one or two samples are taken from a silo, as to the real conditions that exist. I offer these suggestions hoping that others who are engaged in similar work may find it worthy of further investigation.

Generally it has been supposed that the greatest loss came upon the carbohydrates, but in this case our investigation shows a greater loss per cent. for the albuminoids than for the carbohydrates as a whole. Of the carbohydrates the sugars have suffered the heaviest loss—more than three-fourths of the total amount having disappeared, as will be manifest by the accompanying table:

| | Put in silo, lbs. | Taken out of silo, lbs. | Loss or gain per cent. |
|---|---|---|---|
| Total weight | 21,054 | 20,368 | 3.25— |
| Total water | 15,776 | 15,893 | |
| Total dry matter | 5,278 | 4,475 | 15.21— |
| Ash | 171 | 215 | 25.60+ |
| Albuminoids | 516 | 373 | 27.53— |
| Crude fibre | 1,159 | 1,149 | .92— |
| Nitrogen-free ex't | 3,193 | 2,536 | 20.55— |
| Fat | 239 | 201 | 15.83— |
| Total nitrogen | 82 | 60 | 27.53— |
| Albuminoid nitrogen | 70 | 44 | 37.17— |
| Amide nitrogen | 12 | 16 | 33.33+ |
| Invert sugar | 307 | 65 | 78.73— |
| Sucrose | 190 | 40 | 79.24— |
| Starch | 1,938 | 1,437 | 25.98— |
| Per cent. acid in ensilage | | 0.28% | |
| Ensilage to the cubic foot | | 35 lbs. | |

An inspection of the preceding table shows the sugars to have been largely lost by chemical changes which took place in the ensilage and the albuminoids to the extent of more than one-fourth of the total amount. No investigation was made to determine the kind and nature of the fermentation that took place, but to the careful observer it seemed evident that the changes were not wholly alike for the two silos, and, further, that the class of ferments was not the same for all parts of the same silo. Thus near the surface of the ensilage in the silo both observation and the chemical products indicated that a different ferment was at work from that at the middle of the silo or near the bottom, each of which seemed to have characteristic properties peculiar to that part of the silo. Had I been competent to do so I would have made a study of these changes along with a determination of the ultimate chemical products, but this field of research is a broad and difficult one, requiring great skill, so no attempt was made to study the biological side or even to trace the proximate chemical products, as the two fields, for a thorough study of this subject, are inseparable.

I stated that it seemed probable that the kind of fermentation was not the same for all parts of the silo. My reasons for this statement are two. Careful observation of the ensilage as removed from the silo showed unmistakable difference in appearance for those parts of the silo—top, centre and bottom—and these observations led me to note more carefully the chemical composition of the ensilage. The maize as put in the silo was very uniform, but that at the bottom of the silo was shown by analyses to have the largest per cent. of albuminoids; still this difference was not marked. Now, had the changes been similar throughout, then the relation of the albuminoids to the other constituents should have remained about the same, or rather the highest per cent. of albuminoids should have been at the bottom of the silo. The chemical analyses show the reverse of this to be true, while the ensilage near the surface contained over two per cent. more albuminoids than that near the bottom of the silo.

The changes that took place near the surface in the silo seemed to have been more processes of decay and oxidation dependent upon the oxygen of the air for their action while near the bottom, the albuminoids seemed to have been the active agents in promoting the continued fermentation. Judged by the ash, the greatest loss was near the surface and at the bottom of the silo. Undoubtedly this is true for the surface, but it seems probable that the accumulation of ash near the bottom came as the result of diffusion, as already indicated.

### MAIZE, FIELD CURED.

At the same time that the second silo was filled, another lot of maize from the same field was selected by taking here and there a bundle, so as to have it represent a fair average of the entire lot. This was put in shocks in the field and there left for curing. The maize was cut September 13, and remained standing in the field until October 21, when it was drawn to the barn, weighed, run through the cutter and sampled for analyses. The following table shows the results of the investigation :

| | Calculated Sept. 13, lbs. | Found Oct. 21, lbs. | Loss or Gain per cent. |
|---|---|---|---|
| Total weight | 2,348 | 1,055 | .... |
| Total water | 1,759 | 533 | .... |
| Total dry matter | 589 | 522 | 11.25— |
| Ash | 19 | 23 | 21.05+ |
| Albuminoids | 56 | 38 | 32.06— |
| Crude fibre | 129 | 140 | 8.52+ |
| Nitrogen-free extract | 356 | 294 | 17.41— |
| Fat | 27 | 16 | 40.74— |
| Total nitrogen | 9.1 | 6.1 | 32.89— |
| Albuminoid nitrogen | 7.7 | 4.5 | 41.54— |
| Amide nitrogen | 1.4 | 1.6 | 15.00+ |
| Invert sugar | 34. | 22. | 35.14— |
| Sucrose | 21. | 6. | 71.43 |
| Starch | 227. | Undetermined | .... |

The loss of albuminoids in field curing maize was even greater than for the ensilage, and in a period of 38 days, the loss in dry matter amounted 11.25 per cent. or nearly as great as for one of the silos. The increase in ash was probably due to the earth that adhered to the butts of the stalks since they stood upon the loose soil. The rain during this period was not excessive, but there was much damp, cloudy weather.

### MAIZE, BARN CURED.

A second lot of maize, taken in the same manner as that for field curing, was reserved for barn curing. This was drawn to the barn, weighed, and then put in good condition for drying by standing the bundles openly against a fence near the barn. It was hoped this lot might be dried for storing without having any rain fall upon it, but in this we were disappointed, since one quite heavy rain wet it down before it was in condition to go into the barn for storing. The bundles were then put in a barn loft, where they remained until November 13th or just two months from date of harvesting. The results are shown by the following table :

| | Calculated Sept. 13, lbs. | Found Nov. 13, lbs. | Loss or Gain per cent. |
|---|---|---|---|
| Total weight | 2,690 | 1,034 | 34.87— |
| Total water | 1,916 | 414 | ---- |
| Total dry matter | 774 | 620 | 19.98— |
| Ash | 25 | 26 | 4.74+ |
| Albuminoids | 76 | 43 | 42.66— |
| Crude fibre | 170 | 176 | 3.64+ |
| Nitrogen-free extract | 468 | 357 | 23.86— |
| Fat | 35 | 17 | 51.24— |

Up to date of closing my connection with the station, I had not found opportunity to complete the further analytical work with this part of the investigation.

These results are somewhat astounding, especially regarding loss of albuminoids ; but with the best of care, the Autumn was so damp and cloudy, that the fodder moulded badly in the barn although well spread about in an open space.

These are the results of but single experiments, and need to be repeated again in detail before any positive facts can be ascertained. Yet it would seem from these trials that there is no greater loss of nutritive matter in a silo properly filled with good maize, than for the same plant, field or barn cured, as is commonly practised.

### DIGESTION EXPERIMENTS.

Having considered somewhat in detail our investigation with the maize as growing, as dried fodder and as ensilage, we have now to record the result of our experiments for determining the digestibility of its several products. The digestibility of ensilage from immature maize, from the matured and for the field cured maize was determined. For our subject of experimentation we had two heifers, the same animals used in the digestion work the winter previous. The heifer Star was due in calf in February, while Spot was an unbred animal. The animals were put in the experimental feeding barn at the station, October 7, and preceding each trial one week's preliminary feeding was had with the same fodder and in like quantities as during the digestion proper, in order that the digestive tract might become cleared of all traces of other food. Watchmen were stationed with the animals night and day and the dung and urine caught in separate pails, and at once transferred to covered galvanized iron receptacles, sufficiently large to hold the voidings for 24 hours. Each noon the dung and urine were carefully weighed on a Fairbanks silk scale, sensitive to one-fourth ounce and an aliquot part of the well mixed dung taken for water determination. These last samples were then united for further analyses.

### EXPERIMENT NO. 1.

In this trial ensilage from the immature maize was tested. The chemical composition of the ensilage fed was as follows :

| | Per Cent. |
|---|---|
| Water | 82.58 |
| Dry matter | 17.42 |
| | 100.00 |
| DRY SUBSTANCE. | |
| Ash | 4.32 |
| Albuminoids | 9.06 |
| Crude fibre | 32.17 |
| Nitrogen-free extract | 50.13 |
| Fat | 4.32 |
| Albuminoid nitrogen | 0.87 |

| | |
|---|---|
| Amide nitrogen | 0.58 |
| Total nitrogen | 1.45 |
| Invert sugar | 2.08 |
| Sucrose | .36 |
| Starch | 21.20 |

The weights of the animals for ten consecutive days, the last four being the digestion period proper, are shown below:

| | Star. lbs. | Spot. lbs. |
|---|---|---|
| Oct. 10 | 1,091 | 1,114 |
| " 11 | 1,108 | 1,100 |
| " 12 | 1,096 | 1,086 |
| " 13 | 1,087 | 1,088 |
| " 14 | 1,087 | 1,080 |
| " 15 | 1,081 | 1,078 |
| " 16 | 1,089 | 1,074 |
| " 17 | 1,086 | 1,076 |
| " 18 | 1,092 | 1,078 |
| " 19 | 1,089 | 1,076 |

These figures indicate that ensilage of the kind under experiment hardly served for maintenance when fed as the exclusive feed.

The average temperature of the barn for each two hours, as recorded by a self-registering thermometer, is shown below:

TEMPERATURE OF BARN.

| | October | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TIME. | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 12:2 A. M. | 50 | 49 | 47 | 46 | 51 | 51 | 56 | 54 |
| 2:4 " | 49 | 48 | 46 | 46 | 51 | 51 | 55 | 53 |
| 4:6 " | 48 | 47 | 46 | 45 | 51 | 50 | 54 | 53 |
| 6:8 " | 48 | 47 | 46 | 44 | 50 | 49 | 53 | 52 |
| 8:10 " | 49 | 47 | 43 | 45 | 51 | 50 | 51 | 51 |
| 10:12 " | 50 | 46 | 46 | 47 | 52 | 52 | 53 | 52 |
| 12:2 P. M. | 54 | 47 | 49 | 49 | 55 | 56 | 56 | 56 |
| 2:4 " | 53 | 47 | 49 | 51 | 57 | 58 | 58 | 57 |
| 4:6 " | 52 | 47 | 49 | 53 | 58 | 57 | 57 | 58 |
| 6:8 " | 50 | 46 | 47 | 53 | 55 | 57 | 56 | 57 |
| 8:10 " | 50 | 46 | 47 | 52 | 52 | 56 | 55 | 55 |
| 10:12 " | 49 | 46 | 47 | 52 | 51 | 57 | 54 | 55 |

The amount of ensilage fed per day to each animal was sixty pounds, as expressed in tabular form we have:

| | STAR. | SPOT. |
|---|---|---|
| Ensilage fed per day | 960.00 ozs. | 960.00 ozs. |
| Water per day | 154.00 ozs. | 246.00 ozs. |
| Ensilage eaten per day | 958.46 ozs. | 957.54 ozs. |

The animals drank no water during the entire period they were fed on ensilage although water was offered twice each day.

The amount of dung per day and the per cent. of water is shown below:

| | STAR. | | SPOT. | |
|---|---|---|---|---|
| | Ozs. | % water. | Ozs. | % water. |
| Oct. 16 | 309.5 | 83.37 | 398.7 | 84.07 |
| Oct. 17 | 387.0 | 84.88 | 358.0 | 85.27 |
| Oct. 18 | 389.5 | 84.74 | 401.5 | 85.73 |
| Oct. 19 | 344.7 | 83.99 | 368.7 | 85.00 |

The urine voided, per day together with per cent. of nitrogen in the urine, is given below:

| | STAR. | | SPOT. | |
|---|---|---|---|---|
| | Ozs. | % nitrogen. | Ozs. | % nitrogen. |
| Oct. 16 | 398.0 | .271 | 401.5 | .250 |
| Oct. 17 | 344.2 | .307 | 314.7 | .359 |
| Oct. 18 | 342.5 | .325 | 280.7 | .381 |
| Oct. 19 | 322.7 | .337 | 157.2 | .390 |

Analyses of the water-free dung, gave the following results:

| | STAR. | SPOT. |
|---|---|---|
| Ash | 11.11 | 11.57 |
| Albuminoids | 12.87 | 12.87 |
| Crude fibre | 29.32 | 27.83 |
| Nitrogen-free extract | 44.60 | 45.76 |
| Fat | 2.10 | 2.06 |
| Albuminoid nitrogen | 1.80 | 1.78 |
| Crude nitrogen | .26 | .28 |
| Total nitrogen | 2.06 | 2.06 |

The data for the digestion coefficients are presented in the next table :

| | Dry Matter. | | Albuminoids. | | Crude Fibre. | | Nitrogen-Free Extract. | | Fat. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Star, ozs. | Spot, ozs. | Star, ozs. | Spot, ozs. | Star, ozs. | Spot, ozs. | Star, ozs. | Spot, ozs. | Star, ozs. | Spot, ozs. |
| Total eaten | 166.63 | 166.58 | 15.41 | 15.41 | 53.59 | 53.59 | 83.52 | 83.50 | 7.19 | 7.19 |
| Dung | 56.16 | 57.22 | 7.23 | 7.36 | 16.47 | 15.92 | 25.05 | 26.18 | 1.18 | 1.18 |
| Digested | 110.47 | 109.36 | 8.18 | 8.05 | 37.12 | 37.67 | 58.47 | 57.32 | 6.01 | 6.01 |
| Per cent. digested | 66.36 | 65.65 | 53.08 | 52.23 | 69.26 | 70.29 | 70.00 | 68.67 | 83.58 | 83.58 |
| Average | 66.00 | | 52.65 | | 69.77 | | 69.32 | | 83.58 | |

EXPERIMENT No. 2.

In this trial the same animals were used as in the previous one. The fodder was the field cured maize already reported upon. The chemical composition of the maize proved to be as follows :

| | Per cent. |
|---|---|
| Water | 50.48 |
| Dry matter | 49.52 |
| Dry substance | 100.00 |
| Ash | 4.43 |
| Albuminoids | 7.31 |
| Crude fibre | 28.81 |
| Nitrogen-free extract | 56.34 |
| Fat | 3.11 |
| Albuminoid nitrogen | .87 |
| Crude nitrogen | .30 |
| Total nitrogen | 1.17 |
| Invert sugar | 4.30 |
| Sucrose | 1.20 |
| Starch | 32.37 |

During the trial, the weights of the animals were as shown below, the last four days being the time for which the dung was saved:

| | STAR. | SPOT. |
|---|---|---|
| Oct. 22 | 1,099 | 1,074 |
| Oct. 53 | 1,081 | 1,062 |
| Oct. 24 | 1,080 | 1,074 |
| Oct. 25 | 1,082 | 1,074 |
| Oct. 26 | 1,086 | 1,086 |
| Oct. 27 | 1,082 | 1,066 |
| Oct. 28 | 1,099 | 1,075 |
| Oct. 29 | 1.100 | 1,079 |
| Oct. 30 | 1,102 | 1,078 |
| Oct. 31 | 1,095 | 1,079 |
| Nov. 1 | 1,101 | 1,088 |

It will be seen from an inspection of the last table that the animals consumed just about enough for maintenance.

The average temperature of the barn for each two hours as recorded by a self-registering thermometer is shown in tabular form below:

| TIME. | OCTOBER. | | | | | | | | NOV. |
|---|---|---|---|---|---|---|---|---|---|
| | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 1 |
| 12– 2 A. M. | 43 | 46 | 50 | 55 | 52 | 50 | 50 | 49 | 54 |
| 2– 4 " | 45 | -- | 50 | 55 | 51 | 50 | 49 | 48 | 53 |
| 4– 6 " | 46 | -- | 50 | 55 | 51 | 50 | 49 | 48 | 53 |
| 6– 8 " | 48 | -- | 50 | 55 | 51 | 50 | 49 | 48 | 53 |
| 8–10 " | 50 | -- | 51 | 54 | 51 | 50 | 49 | 48 | 52 |
| 10–12 " | 50 | 46 | 52 | 54 | 50 | 50 | 49 | 49 | 52 |
| 12– 2 P. M. | 49 | 47 | 54 | 55 | 50 | 50 | 50 | 49 | 52 |
| 2– 4 " | 49 | 47 | 54 | 55 | 49 | 50 | 50 | 50 | -- |
| 4– 6 " | 48 | 49 | 55 | 54 | 50 | 50 | 50 | 50 | -- |
| 6– 8 " | 49 | 49 | 55 | 54 | 50 | 51 | 50 | 51 | -- |
| 8–10 " | 47 | 49 | 55 | 53 | 50 | 50 | 49 | 52 | -- |
| 10–12 " | 45 | 49 | 55 | 52 | 50 | 50 | 49 | 52 | -- |

The amount of fodder fed each animal per day was 25 pounds, as in tabular form we express the results, as follows:

| | Star. Ozs. | Spot. Ozs. |
|---|---|---|
| Fodder fed per day | 400.0 | 400.0 |
| Waste per day | .4 | 4.65 |
| Fodder eaten per day | 399.6 | 395.35 |

The amount of water drunk per day was as follows:

| | Star. Lbs. | Spot. Lbs. |
|---|---|---|
| Oct. 28 | 17.0 | 25.0 |
| " 29 | 15.5 | 28.5 |
| " 30 | 15.3 | 29.6 |
| " 31 | 16.2 | 24.6 |
| Nov. 1 | 4.4 | 29.2 |

The amount of dung per day and per cent. of water in same, is here given :

| | Star. | | Spot. | |
|---|---|---|---|---|
| | Ozs. | % Water. | Ozs. | % Water. |
| Oct. 29 | 341.5 | 77.63 | 400.7 | 81.82 |
| " 30 | 356.5 | 77.94 | 396·2 | 81.59 |
| " 31 | 337.0 | 76.84 | 396.7 | 81.86 |
| Nov. 1 | 322.5 | 76.34 | 394.2 | 83.19 |

The urine voided per day together, with per cent. of nitrogen contained in same, are here given :

| | Star. | | Spot. | |
|---|---|---|---|---|
| | Ozs. | % Nitrogen. | Ozs. | % Nitrogen. |
| Oct. 29 | 112.0 | .585 | 180.0 | .590 |
| " 30 | 157.7 | .650 | 121.0 | .622 |
| " 31 | 102.0 | .715 | 141.5 | .671 |
| Nov. 1 | 143.5 | .584 | 189.5 | .522 |

Analysis of the water from dung gave the following results :

| | Star. | Spot. |
|---|---|---|
| Ash | 7.22 | 8.68 |
| Albuminoids | 11.81 | 12.75 |
| Crude fibre | 22.75 | 21.46 |

| | | |
|---|---|---|
| Nitrogen-free extract | 56.09 | 55.05 |
| Fat | 2.13 | 2.06 |
| Alb. nitrogen | 1.69 | 1.72 |
| Amide nitrogen | .20 | .32 |
| Total nitrogen | 1.89 | 2.04 |

Having now the essential data we may consider the results of the digestion proper :

| | Dry Matter. | | Albuminoids. | | Crude Fibre. | | Nitrogen Free Extract. | | Fat. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Star. Ozs. | Spot. Ozs. | Star. Ozs. | Spot. Ozs. | Star. Ozs. | Spot. Ozs. | Star. Ozs. | Spot. Ozs. | Star. Ozs. | Spot. Ozs. |
| Total eaten | 201.65 | 198.90 | 17.74 | 14.54 | 58.09 | 57.30 | 113.62 | 112.06 | 6.27 | 6.18 |
| Dung | 77.35 | 71.01 | 9.13 | 9.05 | 17.59 | 15.24 | 43 38 | 30.09 | 1.65 | 1.46 |
| Digested | 124.30 | 127.89 | 5.61 | 5.49 | 40.50 | 42.06 | 70.24 | 70.24 | 4.62 | 4.72 |
| Per cent. digested | 61.64 | 64.29 | 38.05 | 37.75 | 69.72 | 73.40 | 61.82 | 65.11 | 73.68 | 76.37 |
| Average | 62.96 | | 37.72 | | 71.56 | | 63.46 | | 75.02 | |

One point worthy of note is the low coefficient of digestibility for the albuminoids in the above results.

## EXPERIMENT NO. 3.

The same animals were the subjects in this trial as in the previous ones and the food was the ensilage from mature maize already discussed.

The chemical composition of the ensilage fed was, as follows :

| | Per cent. |
|---|---|
| Water | 76.92 |
| Dry matter | 23.08 |
| Dry substance | 100.00 |

| | |
|---|---|
| Ash | 4.50 |
| Albuminoids | 8.56 |
| Crude fibre | 24.04 |
| Nitrogen-free extract | 58.00 |
| Fat | 4.90 |

| | |
|---|---|
| Albuminoid nitrogen | .95 |
| Amide nitrogen | .42 |
| Total nitrogen | 1.37 |
| Invert sugar | 1.28 |
| Sucrose | .92 |
| Starch | 34.08 |

The weights of the animals taken each morning before receiving food or water are given below :

| | Star. | Spot. |
|---|---|---|
| Nov. 22 | 1,107 | 1,084 |
| 23 | 1,112 | 1,083 |
| 24 | 1,109 | 1,085 |
| 25 | 1,111 | 1,078 |
| 26 | 1,110 | 1,081 |
| 27 | 1,111 | 1,080 |
| 28 | 1,107 | 1,084 |
| 29 | 1,106 | 1,086 |
| 30 | 1,103 | 1,076 |

The average temperature for each two hours at the barn is recorded below :

| Time. | November. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 12– 2 A. M. | 47 | 47 | 46 | 45 | 50 | 39 | 42 | 48 | 45 | 42 |
| 2– 4 " | 47 | 47 | 47 | 46 | 50 | 39 | 42 | 49 | 45 | 42 |
| 4– 6 " | 45 | 47 | 47 | 45 | 49 | 39 | 41 | 49 | 45 | 42 |
| 6– 8 " | 46 | 48 | 47 | 43 | 49 | 39 | 40 | 49 | 45 | 42 |
| 8–10 " | 47 | 48 | 47 | 42 | 46 | 40 | 40 | 47 | 43 | 42 |
| 10–12 P. M. | 49 | 49 | 47 | 43 | 45 | 40 | 40 | 46 | 43 | 41 |
| 12– 2 " | 50 | 50 | 47 | 46 | 45 | 41 | 41 | 42 | 44 | 41 |
| 2– 4 " | 51 | 50 | 47 | 49 | 43 | 42 | 41 | 42 | 42 | 42 |
| 4– 6 " | 51 | 50 | 46 | 50 | 44 | 42 | 41 | 43 | 41 | |
| 6– 8 " | 49 | 48 | 45 | 50 | 43 | 43 | 42 | 44 | 42 | |
| 8–10 " | 48 | 47 | 45 | 50 | 42 | 43 | 44 | 43 | 42 | |
| 10–12 " | 47 | 47 | 45 | 50 | 41 | 43 | 45 | 43 | 42 | |

The amount of ensilage fed each day was 50 pounds with results as follows:

| | STAR. Ozs. | SPOT. Ozs. |
|---|---|---|
| Ensilage fed per day | 800. | 800. |
| Water per day | 0 | 0 |
| Ensilage eaten per day | 800. | 800. |

Both animals refused water although offered twice each day.

The amount of dung per day and per cent. of water in same are shown below:

| | STAR. Ozs. | STAR. % Water. | SPOT. Ozs. | SPOT. % Water. |
|---|---|---|---|---|
| Oct. 27 | 265.5 | 80.44 | 284.0 | 83.44 |
| " 28 | 314.7 | 82.22 | 356.5 | 84.25 |
| " 29 | 334.5 | 81.23 | 300.5 | 84.00 |
| " 30 | 325.5 | 81.35 | 322.5 | 83.20 |

The urine voided per day together with the per cent. of nitrogen are indicated below:

| | STAR. Ozs. | STAR. % Nitrogen. | SPOT. Ozs. | SPOT. % Nitrogen. |
|---|---|---|---|---|
| Oct. 27 | 209.5 | .364 | 170.0 | .600 |
| " 28 | 227.5 | .321 | 189.0 | .550 |
| " 29 | 279.0 | .337 | 297.2 | .464 |
| " 30 | 281.2 | .311 | 290.5 | .400 |

The chemical composition of the water from dung was as follows:

| | STAR. | SPOT. |
|---|---|---|
| Ash | 8.11 | 9.08 |
| Albuminoid | 11.75 | 11.62 |
| Crude fibre | 23.88 | 23.63 |
| Nitrogen-free extract | 54.13 | 53.41 |
| Fat | 2.13 | 2.26 |

The digestibility of the ensilage as determined from the data given is shown by the following table :

| | Dry Matter. | | Albuminoids. | | Crude Fiber. | | Nitrogen Free Extract. | | Fat. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Star.. | Spot. | Star. | Spot. | Star. | Spot. | Star. | Spot. | Star. | Spot. |
| Total eaten, ozs.... | 184.64 | 184.64 | 15.80 | 15.80 | 44.39 | 44.39 | 107.09 | 107.09 | 9.05 | 9.05 |
| Dung, ozs ......... | 57.91 | .53.86 | 6.80 | 6.26 | 13.83 | 13.73 | 31.34 | 28.76 | 1.23 | 1.22 |
| Digested, ozs....... | 126.73 | 130.78 | 9.00 | 9.54 | 30.56 | 30.66 | 75.75 | 78.33 | 7.82 | 7.83 |
| Per cent. digested.. | 68.63 | 70.83 | 56.90 | 60.37 | 68.84 | 69.07 | 70.73 | 73.14 | 86.41 | 86.52 |
| Average............ | 69.73 | | 58.66 | | 68.95 | | 71.93 | | 86.64 | |

GENERAL SUMMARIES.

For comparison let us bring together the average results for the three digestive trials :

COEFFICIENTS OF DIGESTIBILITY.

| | Ensilage Immature Maize. | Ensilage Mature Maize. | Field Cured Maize. |
|---|---|---|---|
| Dry matter.. ......... | 66.00 | 69.73 | 62.96 |
| Albuminoids.... .... | 52.65 | 58.66 | 37.72 |
| Crude fibre........... | 69.77 | 68.95 | 71.56 |
| Nitrogen-free extract. | 69.32 | 71.93 | 63.46 |
| Fat................. | 83.58 | 86.46 | 75.02 |

These trials give a better showing for ensilage from mature maize than for either of the others, but we should bear in mind, however, that the two ensilages are not from the same variety of maize. The field cured maize and ensilage from mature maize were identical products from the same lot and harvested at the same date.

Carrying our comparison still further, using the data already secured, one ton of the original maize would furnish, of digestible matter, as follows, expressed in pounds :

| | Ensilage Immature Maize. | Ensilage Mature Maize. | Field Cured Maize. |
|---|---|---|---|
| Dry matter | 198.9 | 295.8 | 270.2 |
| Albuminoids | 14.4 | 21.0 | 11.9 |
| Crude fibre | 67.6 | 76.3 | 91.7 |
| Nitrogen-free extract | 104.7 | 170.8 | 159.1 |
| Fat | 10.9 | 15.3 | 13.8 |

So far as our investigation has been carried the results are in favor of ensilage from maize well advanced towards maturity, and we feel confident that the ensilage of the future will be from maize that has the corn glazed.

In closing I wish to thank W. H. Whalen, assistant chemist, and R. D. Newton, laboratory attendant, for their incessant fidelity in all the details of this investigation.

New York City, September 15, 1890.

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*Since this article was read Mr. Ladd has been appointed Prof. of Chemistry in the Dakota Agricultural College, Fargo, N. Dakota, and Director of the Experiment Station.—*Ed.*

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## STUDIES UPON RESINS.*

BY L. H. FRIEDBURG, PH. D.

### II.

In order to determine exactly the temperature of melting kauri gum and the vapors arising from the same, simultaneously, the following experiment was performed, in which I was assisted by Professor A. H. Sabin, in whose laboratory the work was done.

222 grms. of coarsely powdered kauri (copal) gum, very pale but rather soft, known in the New York market as "four cross" gum, was put into a retort 125 m.m. in diameter and 125 m.m. deep from the bottom of the bulb of the retort to the lower side of the throat. Through the tube were inserted two thermometers (mercury un-

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*See J. Amer. Chem. Soc., **12**, 285, and foot note, 287.