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COLORADO FODDERS

A STUDY OF COMPARATIVE VALUES
BASED ON BULLETIN 124

—BY—

W. P. HEADDEN.

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A STUDY OF RELATIVE VALUES OF COLORADO FODDERS

A Continuation of Studies in Bulletins 39 and 93.

By W. P. Headden.

§ 1. The scientific feeder and student of animal nutrition has, for the past forty-five or fifty years, been accustomed to divide fodders into certain big groups to which different names have been applied and now the veriest tyro can talk very glibly of proteids and carbohydrates, but, after all, the practical man, and even our scientific friends, do not adhere tenaciously to the data indicated by the results of the calculations based on the analytical data, but adopt the plainer and easier way of judging the value of a fodder by the effect it produces. A grass may have, according to the results obtained by the analyst, an admirable composition, but if animals will not eat it, its good composition goes for nothing, or if they eat it and constantly lose in weight, the excellent analytic results are of no value. Facts similar to these are met with, sometimes in this extreme form, sometimes in a milder form.

§ 2. Hays made from different plants vary in quality, i. e., in their fitness to be used as fodders and in their fattening qualities. These differences are very great even when no individual idiosyncrasies of the animals fed can be appealed to to explain away the facts. In a bulletin published by the Colorado Experiment Station we have made an attempt to explain the reasons for these differences. It appears from this work that the extract obtained by boiling the fodder repeatedly with 80 per cent alcohol, is the most important part of the fodder; it contains a large, if not the largest, part of the nitrogenous substances and very large quantities of other matters.

§ 3. It is pointed out that water alone will extract as much as 40 per cent of alfalfa hay, This hay is easily damaged by rain. The explanation offered is the ready solubility of so large a portion of the hay.

§ 4. The alcoholic extract is itself highly digestible. This is true, too, of the nitrogenous matters contained in it. It is further demonstrated that this alcoholic extract furnishes more energy to the animal than any other portion of the fodder. This is true in each of the six fodders whose composition is presented.

§ 5. It is shown that the fodders yield extracts to muriatic acid, also to a solution of caustic soda, which vary in value in the different fodders. In some fodders, the former extract, but in others the latter, has the greater value. In alfalfa, the portion removed by the caustic soda, but in the Colorado native hay that removed by the muriatic acid is the more valuable portion. To the most of us, however, the surprising feature is the high value possessed by what is designated as residue or cellulose, the portion left after treating the hay with alcohol, muriatic acid, caustic soda and chlorin. It would seem that there would be but little or nothing remaining of a hay after being treated with these chemicals in the succession given, still

it is shown that one-half or more of this residue is digested by sheep in the case of alfalfa hay, native hay and corn fodder, but less than one-half in the case of timothy hay and sorghum fodder, and even less than one-third in the case of one of our native saltbushes which was studied with the purpose of seeing whether it might be used as a fodder. This residue or cellulose is not only digested by the animals to a large extent, over one-half of it being digested in the fodders which gave good feeding results, but the energy which it yielded to the animal was large, in the corn fodder, the alcoholic extract alone furnished more energy.

§ 6. We have heard so much about proteids and their value that we have come to think of these substances as the most important portions of a fodder. This is largely because they are not as abundant as some other kinds of substance and may be present in a fodder in such small quantities that the feeder may have to purchase them in order to obtain results which he desires. This bulletin does not in any way lower the value to be placed on the nitrogenous portions of the fodder, but it shows that the value of a fodder depends largely upon the character of its other constituents. The writer shows that two lots of sheep, one receiving alfalfa hay, the other salt bush hay, were digesting very large and nearly the same amounts of porteids but very different amounts of other substances included under the general term of carbohydrates, particularly was this true of the cellulose which represents those carbohydrates which were capable of resisting the action of the several chemicals previously named. The sheep receiving alfalfa gained nine pounds in live weight during the five days elapsing between he two weighings, and those receiving saltbush hay lost eight and one-half pounds. Attention is called to this fact and in explanation, it is pointed out that the cause of loss in the latter case is not due to a lack of proteids, for the amount of this class of substances digested is nearly as large as in the former case. The question in regard to the relative value of the nitrogenous constituents of the fodders is suggested and while it is admitted that there may be a difference in this respect they are assumed to be equal, no data being at hand to justify any assertion to the contrary.

§ 7. The two lots of sheep digested approximately the same amounts of proteids and it is held that assuming them to have the same value in the two fodders, the explanation of gain in the one case and the loss in the other is not to be found in this part of the fodder and consequently we have to study the effects of the other constituents.

§ 8. The amount of the different extracts, their digestibility and their fuel values are taken as indicators of their respective values. It is acknowledged that a small amount of some therapeutically active substance might exert a very markedly disturbing action, but though this fact was known and looked for no indication is given that such effects were noticed. In fact, the statement is repeatedly made that the animals appeared comfortable and contented, that they chewed their cuds contentedly or equivalent expressions. This assumption re-

garding the relative value of the proteids in the two fodders, which, by the way, have high coefficients of digestion, 72.99 in the alfalfa, and 66.2 in the saltbush, and the probable absence of any deleterious substances having been made, there is left as the next important group, the substances represented by the nitrogen-free extract, which is divided into several parts, each of which, however, contains some proteids, except possibly the chlorin extract and the cellulose or residue.

§ 9. The alcoholic extract represents these nitrogen-free substances in a large measure, but contains at the same time a large portion of the nitrogenous matter of the plant; the extract obtained by exhausting the hays with cold water and hot water with subsequent addition of malt extract are, taken together, of some moment, as they represent in round numbers one-tenth of the air-dried hay and usually show from fair to good coefficients of digestion; it is also true that the portion removed by treating the portion remaining after boiling with one per cent caustic soda, with chlorin, again heating with caustic soda and subsequently with a solution of sulfurous acid, may amount to a noticeable quantity, but its coefficient of digestion is always low, often zero. So that the carbohydrates are practically divided into four parts, those soluble in alcohol, those soluble in muriatic acid, those soluble in caustic soda and those which are insoluble. The value of this class of substance has always been recognized but in this work it is emphasized, particularly in the comparison of these two fodders, the alfalfa hay and saltbush hay. In the former they are not only abundant in the alcoholic extract but they are also highly digestible; but this is not true of the other three important parts of the saltbush hay, i. e., the parts soluble in muriatic acid, caustic soda and that which is insoluble in any of the solvents used; these parts of alfalfa hay have high coefficients of digestion and the sheep gained in weight, but in the case of the saltbush hay they have low coefficients of digestion and the sheep lost in weight.

§ 10. The great difference between these two fodders, alfalfa, an excellent one, and saltbush, a very poor one, lies in the character of the carbohydrates present in the two plants. While the proteids may be different, they are abundant in both plants and are both highly digestible. In this respect these two fodders are much more nearly alike than any other two fodders studied. This is fortunate for in regard to the quantity of proteids present and their digestibility, the hays are similar but the carbohydrates in three of the important portions of the plants are very unlike, though abundant in both plants. They are very difficultly digestible in the saltbush and required so much energy to effect their digestion that there was not enough appropriated from the fodder to do the work and carry on the animal functions without using some of that already stored in the body, therefore the animals lost flesh.

§ 11. The large amount of proteids digested in each instance and their high coefficients of digestion are tacitly assumed to be presumptive evidence that they yielded more energy to the animals than

was necessary to do the work of fitting them for assimilation by the system. Their similarity in quantity and coefficients of digestibility is considered fortunate as practically eliminating the question of their influence, the difference of the effects of these food elements not being great enough to materially change the effects of the other elements in consideration.

§ 12. The carbohydrates are not divided into classes except to the extent and in the manner explained in the following: The familiar members of this class, glucose and cane sugar, do not occur in large quantities in ordinary hays, but they are wholly digestible and where present constitute a valuable factor in the fodder. The saltbush contains more of these two sugars taken together than the alfalfa does, so if we consider the value of the saltbush as depending on the quantity of these two substances alone it should be better than the alfalfa, but this is not the case. The same is true in regard to two others of these carbohydrates, the gums and starch which are more abundant in the saltbush than in the alfalfa. The frame work and tissues of the plants themselves very largely belong to this class of substances, carbohydrates, and though we do not know the definite composition of some of these plant constituents, they can be changed, in part at least, so as to yield compounds whose composition is known and the yield of such compounds by the different hays when treated with different agents has been made use of to establish the differences in the fodders themselves. The sugars already named are only two well-known members of this class of substances which include a number of others not so commonly known to the general public. Some of these related substances yield one and some another sugar under the action of certain agents. By taking advantage of these properties, the following differences between the alfalfa and the saltbush have been established.

§ 13. It should be kept in mind that the object had in view in doing this work, was not primarily to establish the value of the fodders but to find out, if possible, why one gives goods results and the other poor ones. There is a kind of sugar to which the name wood-sugar has been given because it is formed when wood is subjected to a certain treatment. The sugar or the material from which it can be made, is capable of being determined with approximate accuracy by methods which have been worked out. In this way, it is shown that certain carbohydrates are present in that portion of the alfalfa soluble in alcohol which are wholly absent from the saltbush and these substances in the alfalfa are easily digestible. A similar carbohydrate is present in the muriatic acid extract of the alfalfa. There is, however, twice as much of this substance in the corresponding extract of the saltbush, but that found in the alfalfa is wholly digestible, while that in the saltbush is wholly indigestible; this may simply mean that but little of this portion of the hay is changed while passing through the alimentary tract and fecal matter capable of yielding this substance is present in the dung in such large quantities that there is more in the feces than was taken

into the animal as food. But here is a big difference, one which appears to be too great to be explained away by unavoidable errors in the work. The individual extracts in the different fodders were examined in this way and also the residues or the cellulose that resulted from the treatment adopted. In this connection, it is shown, the carbohydrates yielding this substance taken as a common measure, that these residues or celluloses are very different in their values. The caustic soda does not, it is true, dissolve very much of this class of substances, but the alfalfa yields about one-third as much as the saltbush, of which but a small part was digested, while that dissolved out of the saltbush is not only nearly three times as great but a very much larger proportion of it serves as food. The most striking difference in the character of these carbohydrates is presented by the residues obtained which ought to be approximately pure cellulose and consequently have nearly the same value. This, however, is not at all the case, for this portion of the alfalfa has almost three times the value of that of the saltbush if the coefficient of digestion is a proper guide in judging of their value. A little later we will find that this fact is shown by another method, establishing with a considerable degree of certainty, that there is a very great difference in the character of this portion of the respective fodders.

§ 14. The muriatic acid extract of the alfalfa contains, as previously stated, less of the substance corresponding to the wood sugar than the saltbush, but the alfalfa yields a sugar that may also be obtained from milk sugar and which is not present in the saltbush, or if present at all, constitutes a very small portion of the fodder. This sugar is apparently very digestible. The coefficient obtained for all the sugar found in the muriatic acid extract which included both kinds of sugar mentioned is high. There is but little of the material corresponding to the wood sugar present in this portion of the alfalfa, but there is some. The alfalfa and the saltbush belong to entirely different orders of plants, and the pea family, to which the alfalfa belongs, yields this sugar which may be derived from the sugar of milk, while the saltbush and ordinary hays yield but little of this, yielding wood sugar in its stead.

§ 15. The energy relations, i. e., the amount of heat gotten out of the fodder by the animals and also out of the different parts or extracts of the fodders were determined and the fodders were found to be very different in this respect, as well as in those respects already pointed out. Furthermore, it was shown that the same amounts of energy appropriated from different fodders produce different results, measured by the loss or gain in the live weight of the animal, or we may say that the efficiency of the energy varies in different fodders.

§ 16. As we have, in the main, taken alfalfa and the saltbush for our purpose so far, we will continue to use them though we will have to take up the grasses later.

§ 17. We have previously related that it was found that the extract obtained by treating the fodders with alcohol appeared to be

the most important portion in all cases, though they showed a great difference in value in the cases of the different fodders. In these, the alfalfa and the saltbush, the amounts of alcoholic extract digested by the lots of sheep in five days chance to be the same, but the energy appropriated by the lot which received alfalfa was very much greater, nearly twice as great as that appropriated by the lot that received saltbush. It will be recalled that it was stated that there was so big a difference in the character of the carbohydrates of these two plants that it could not in any way be ascribed to errors of manipulation. We here find, by another method, that the alcoholic extract of the saltbush yielded only a little more than one-half of the energy that the corresponding alfalfa extract yielded. This difference might be due to the different quantities of proteids in the two extracts, but it is not, provided that they have even approximately the same value in the two fodders, for they received and digested a larger quantity of proteids in the form of saltbush hay than they did as alfalfa hay, showing that, viewed from the standpoint of fuel value, the difference very probably lies in the character of the carbohydrates. While it is admitted that little is known of the character of the proteids dissolved out of these or any other fodders by alcohol, we have as good a guide for our judgment in this case as we have in others pertaining to the character of fodders, i. e., the animals digested not only a larger quantity of nitrogenous matter when fed on saltbush but assimilated a larger proportion of that that they received. We will not consider all of the extracts in this manner lest too many similar statements should obscure rather than emphasize the facts intended to be brought out, so we will only consider the muriatic acid extract and the residue or cellulose. The former, muriatic acid extract, furnished very much more digestible dry matter in the case of the saltbush than in that of the alfalfa, one-third more, but its coefficient of digestibility was materially lower, two-thirds that of the alfalfa, and we find the energy almost exactly one-half of the amount yielded in the case of alfalfa. The proteids in this extract of these two fodders were nearly the same, both in regard to their quantity and digesibility, showing again that the difference was probably due to the character of the carbohydrates. The only other and last big feature of these two fodders that we will mention will be the cellulose which, owing to the method of preparation, contains very little nitrogen, no ready formed sugars or subsances soluble in alcohol, water, muriatic acid, caustic sodic or removable by chlorin, in other words, the soluble substances and those portions of the woody tissue capable of being broken up and removed by these agents had already been eliminated and though this residue would appear to be of but little value as food for the animal, we find it always one of the first three portions in importance. We would probably, without definite knoweldge to the contrary, not only consider this portion of but little value, but would expect to find it of nearly equal value in all cases, which is no nearer the truth than the former. In these two cases, we find that over one-half of the alfalfa cellulose is digestible while less than three-tenths of the saltbush

cellulose can be digested by sheep, and further, while the sheep received a much larger amount of energy in the form of saltbush cellulose than in that of the alfalfa cellulose, they were able to utilize only two-thirds as much energy, again showing that it is the character of the carbohydrates, peculiar, perhaps, to each individual tribe of plants which determines its feeding value.

§ 18. We have now rapidly examined these fodders in their main features, the most interesting of which is the relation of the energy values. There may be many errors in our work and serious mistakes of judgment, but all of these can not obscure the fact that a smaller amount of energy consumed as alfalfa produced a bigger result than a larger one consumed in the form of saltbush. In order to make this clearer to the casual reader, I will state this result a little more fully. The sheep consumed forty-nine million units of energy as alfalfa hay and gained nine pounds; the same sheep under as favorable conditions as could be produced, consumed fifty-nine million units of energy as Saltbush and lost eight and one-half, a total difference of seventeen and one-half pounds of flesh. The repeated observation that the carbohydrates of the saltbush, whether in the form of cellulose or the other forms making up the whole structure of the hay, are more difficulty digestible than those of the alfalfa may be interpreted as indicating that the work necessary to prepare the carbohydrates for assimilation is so great that it cannot be accomplished by the digestive processes in the sheep, when the saltbush is the only fodder fed, except by using up energy stored in the body in the form of flesh, muscle or fat. The amount of energy supplied was more than abundant to have produced excellent results, had the sheep been able to set it free without the expenditure of too much energy previously stored in the form of flesh. In the case given, there were actually ten million more units of energy in the fodder consumed as saltbush than in that consumed as alfalfa, but the energy which the sheep appropriated from the saltbush was, in round numbers, eight millions less than that appropriated from the alfalfa.

§ 19. The amount of energy appropriated by the sheep with which this experiment was conducted was a little over twenty-three millions units, a quantity somewhat in excess of the amount appropriated from two other fodders on which each lot of sheep made a gain of three and one-half pounds. This indicates that the absolute amount of energy appropriated in the case of the saltbush was considerably more than would have sufficed to maintain the animals in the condition in which they were at the beginnig of the experiment, but the fact is that they each lost. The question in regard to the cause of this loss is answered above in that we suggest that not only this energy was used up, but as much more as corresponds to eight and one-half pounds of flesh, in converting these carbohydrates into proper food for the animals, in warming the excessive amount of water which this fodder caused the sheep to drink, and in maintaining the animal functions.

§ 20. We have so far presented the study of the two fodders, alfalfa and saltbush, only incidental mention having been made of the

other fodders studied, one of which was studied as fully as the two already mentioned, namely corn fodder. This fodder is one easily digested in the sense in which we have indicated that the saltbush is difficulty digestible. By this I mean that comparatively small amounts of heat are used in the work of preparing this fodder for assimilation. In this case, we have a little less than nineteen and a half million units of energy appropriated and each sheep gained, the lot making an aggregate gain of three and a half pounds. This is the smallest amount of heat on which an actual gain was made. This shows the relative efficiency of the energy in the corn fodder, as compared with saltbush. This relative efficiency of the corn fodder would appear to be much greater if compared to that of sorghum in which form the animals appropriated twenty-five million units of energy and lost 8½ pounds. The fuel or energy values of the various extracts of sorghum were not determined but the coefficients of digestion, especially for the two large and important divisions represented by the muriatic acid extract and the residue, cellulose, indicate a low digestibility of the carbohydrates. The proteids probably do not influence these results in any material way. The results obtained with sorghum, it having been fed alone, were surprisingly unfavorable. The large amount of heat used and the low coefficients of digestion found for the greater portion of the fodder indicates that it, like the saltbush, requires more work to bring it to an assimilable form than is an equivalent to the energy yielded by the fodder. In the case of sorghum, the alcoholic extract is abundant and has a high coefficient of digestion, due, very probably, to the fact that it is rich in the two sugars, glucose and cane sugar. I did not determine the fuel values of this or any other of the extracts made of the sorghum. The fuel value of the fodder itself is almost exactly the same as that of the saltbush, which is low, thirty-eight hundred units of energy against forty-two hundred in the corn fodder, the actual difference being three hundred and fifty units for each gram of dry hay.

§ 21. The three important portions of corn fodder are, the portion dissolved by eighty per cent. alcohol, the cellulose and the portion soluble in muriatic acid. These extracts, the alcohol and muriatic acid extracts, both have very high fuel values and are easily digestible. The residue or cellulose has a rather low fuel value but owing to its coefficient of digestion being high, it furnishes more energy than any other portion of the fodder, the alcoholic extract excepted.

§ 22. The deportment of the proteids in this fodder is very different from those of alfalfa. The greater portion of them being found in the caustic soda extract in the latter case, while the greater portion is found in the alcohol extract of the corn fodder. The cellulose of the saltbush proved to be much less efficient in furnishing energy to the animal than that of alfalfa, but in comparing the efficiency of the cellulose of corn fodder and alfalfa we find that that of corn fodder is the more efficient. The animals did not eat the stalk with the pith cellulose if they could avoid it, so the cellulose in this case does not include much of the pith cellulose, though it does include some.

§ 23. The amount of proteids in the corn fodder is comparatively small and their coefficient of digestion low, so that, whatever their distribution and importance, their influence cannot materially alter the general results obtained. The corn fodder cellulose is instructive because it has a rather lower fuel value than the other celluloses, but it has the highest coefficient of digestion of any of them.

§ 24. We have now presented a hay made from a member of the pea family, one of the goosefoot family and one from a very coarse grass, corn. We will next consider a mixture of small grasses, our native hay, and pure timothy.

§ 25. The native hay is a mixture of grasses and sedges with some rushes. We find this hay quite similar in composition to the corn fodder but a smaller proportion of the digestible proteids is taken into solution by alcohol than in the corn fodder. The combined amount of glucose and cane sugar is less, the wood is greater and the amount of still another sugar to which I have not specifically referred, but which is found in the caustic soda solution, is large enough to be considered separately. Such are the striking features of similarity in the composition of the two. The fuel values of the native hay were not studied in detail but the general results were that twenty-two and a quarter million units of energy appropriated as native hay proved to be exactly equivalent to nineteen and a half million units appropriated as corn fodder, if the gain in live weight is a correct standard by which to measure their effects.

§ 26. The native hay contains more proteids than the corn fodder but not as large a quantity as alfalfa hay, and they have a high coefficient of digestion. The carbohydrates are easily digestible but less so than those of either the alfalfa or corn fodder, and we find that it takes some three million units more of energy in the form of native hay than in the form of corn fodder to produce the same result, which is in perfect keeping with the lower coefficient of digestibility of the carbohydrates of the native hay.

§ 27. The timothy hay was studied to the same extent and in the same manner as the native hay. We find in it the same characteristics that we found in the native hay; a moderate amount of proteids, but their coefficient of digestion is somewhat lower. The nitrogenous constituents are soluble in eighty per cent alcohol to the extent of about one-third of the total amount present and this portion has a high coefficient of digestion.

§ 28. It seems to be generally true that the nitrogenous matters soluble in alcohol are readily digestible, for instance, we find that of this portion of alfalfa, eight-tenths is digestible; of the timothy hay, eight-tenths; of the saltbush, nearly nine-tenths; of the native hay, six-tenths, and of the corn fodder, six-tenths. I have stated that the alcoholic extract of a hay stands before any other portion in feeding value, as indicated by its amount, general coefficient of digestion and fuel value. The statement seems to hold to a large extent in regard to the proteids. No distinction being made between the amids and the proteids.

§ 29. We find that the fuel value of the timothy hay is quite high, about forty-four hundred heat units for each gram of dry matter but the sheep can only utilize this energy to an extent of a little less than one-half, and as a result we find that timothy hay does not furnish enough energy to make a good fodder. The lot of sheep receiving the timothy appropriated nearly seventeen and a half million units of energy and showed a slight loss in flesh.

§ 30. I have in this work refrained from analyzing the extracts further and have permitted some indefiniteness in the statement of the results, but I consider these points of no material importance to our present purpose. For instance, I have made no effort to determine whether the wood sugar, xylose, is made up wholly of this sugar, or is mixed with another closely related one. I have also considered it a matter of small importance in this study whether the reducing power found in the caustic soda extract is really due to wood-sugar or to one more nearly related to cane sugar. The fact has been established that in some hays, at least, the wood sugar is a mixture of two sugars and that the sugar present in the caustic soda solution probably does not belong to the group of wood sugars at all. These questions pertaining to the nearer chemical composition of the hays are interesting and important but for the purpose of this bulletin, I have deemed them omissible. The difference in the sugars from the alfalfa and other fodders has been mentioned, but this sugar, galactose, appears to be present in some of the other fodders, too, to a smaller extent.

§ 31. We find the difference between these fodders so marked, especially, in regard to the readiness with which they appear to yield their energy to the animals and the work which is necessary to prepare the food constituents for assimilation, that it does not appear strange that the fodders acually have very different feeding values.