Relation of Nutriment to Product in Animal Nutrition

A Thesis Submitted

by

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Outline

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        (a) Maintain in given condition.

        (b) Rebuild proteid tissues.

        (c) Increase vigor, endurance etc.

    2. Product from excess nutriment over maintenance

        (a) Bear burdens

        (b) Produce meat

        (c) Produce dairy products

        (d) Produce wool.

2. Difficulties of Experimenters.

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That branch of animal industry which has to do with the feeding of animals, in order to properly nourish the body, is known as Animal Nutrition. The objects, for which the body is to be nourished, are many but nevertheless very distinct. The horse must maintain his present condition and if possible increase his endurance and gather more strength. He must also be nourished to bear burdens. The dairy cow must maintain her normal body weight and vigor and in addition is called upon to produce quantities of dairy products. The sheep produces wool and mutton in addition to preserving its condition.

While there are many and distinct reasons for nourishment, at the same time there are primary and secondary classes of reasons. In the case of all animals, the primary object is a law of life which we commonly express as the law of self preservation. To careful observers, it is evident that only the excess of food above maintenance requirements will be used for secondary objects of nutrition; viz. bearing burdens, producing dairy products, growing wool or whatever the case may be. Conceding the above, it becomes important to know the exact factor to satisfy the primary object in nutrition. Let it be known that a certain definite quantity of nutriment is supplied. Of this a known factor is required for maintenance. Then, by a simple process of elimination, determine the nutriment required for a definite quantity of product.

Such a solution seems entirely feasible and no doubt would be applicable were it not for the fact that the element, "life", enters into every step. Every twitch of a muscle, every nerve message, every ache, every disorder and every disposition enters forcibly into all calculations.

Difficulties of Experimenters. Subjective.

Reference has been made to the fact that our problem, which at first seemed so easy of solution, becomes greatly complicated because the object, with which we are dealing, is a living self-repairing organism. Individuals, of the same class, differ very widely as to habits of feeding, nervousness and handling qualities. One animal is very sensitive to cold while another is affected more by heat. One is docile while another is vicious. One is affectionate and readily responds to acts of kindness; another can not be won by petting or fondling. This individual difference we may designate as subjective. If, to all outward appearances and physical tests, we find two animals very much alike as to disposition, size, conformation, feeding and handling qualities; still when we come to analyze the products chemically, one finds that the digestion of one is not equal to that of the other. The constituents of the products of one varies widely from that of the other. Milk, of the same percent of fat content, often differs markedly in other constituents.

Because individual differences are of so marked a character, many investigators have often had their results reversed by reversing the individuals. It is as a result of this that we scrutinize very closely any conclusions drawn from observations of the investigators, on a limited number of individuals.

The second great subjective difficulty is that the food, known minutely as to its chemical elements, undergoes radical changes in the complexities of the animal anatomy. All are agreed that the elements, as they appear in the food, do not so reappear in the product. Agreement is quite unanimous that different elements in food perform more or less distinct functions in nourishment. For example, the protein element is required to establish a nitrogen equilibrium in the body and to build and repair the body tissue. The exact amount of this element is not definitely known. The quantity varies according to conditions. It might further be stated that, under known conditions, the exact amount can not be definitely ascertained. Investigators state that in the mature animal the proteid tissue of the body can not be materially increased. The excess of protein, according to German Scientists, may be changed to body fat. The non-nitrogenous compounds,have as their office, the duty of supplying heat and energy. The fact is, the animal mechanism is a great machine that adjusts itself to a considerable degree to conditions as they exist. So it is often difficult to say whether a certain apparent phenomenon, in bodily observations, is due to readjustment of forces by animal mechanism or due directly to the food supplied.

The objective difficulties of Experimenters, though not so complicated, are just as real. To be sure that results are correct, check lots are necessary. The time to gain a small and doubtful result is long and the details become very tedious. Few have the patience and mental apitiude to carry an experiment to its logical conclusion. Again, many experiments are dependent largely on the faithfulness of employees who often have little or no interest in the matter. A quarter of a pound of grain, more or less, given in each feed, is immaterial to such a person but makes a great difference when percentages are figured on a small gain or loss. Another difficulty is this, that chemists apparently differ on the analysis of a sample of feed from the same lot. The difference in results may be due to the sample taken but who knows what sample was representative of the feed used? To illustrate this the writer recently saw nine analyses of a sample of stock food. The analyses purported to be of so many Experiment Stations and no two agreed. Lastly, Investigators are largely public men. They often need immediate results. Lack of funds annoy and conflicting duties deter.

Interpretation of Results.

Before any decided results can be secured it is evident that the amount of nourishment required for maintenance must be definitely known. This was pointed out as early as 1858 by Henneberg and Stohmann. Next, the chemical composition of the feed must be reduced to digestible equivalent. In this, feeds vary greatly. Lastly, the relation of the excess of nourishment to the product, must be established. Following will be a brief review of the efforts of some noted scientists in their attempts to establish,- first, the food of maintenance requirements, second, the digestibility of feed stuffs, third, interpretations of results obtained from nutriment provided in excess of maintenance requirements.

Before proceeding with the discussion, outlined above, let it be observed that the greatest factor, back of a scientific study of body nourishment, was the introduction of chemistry to reduce all effects and causes to a common unit of comparison. In a meeting of the Mass. Board of Agriculture* in 1882, Prof. Charles A. Goessmann brought out a paper on, "The Influence of Chemistry on the Development of a Rational System of Stock Feeding".

* See Mass. Board of Agriculture Report 1882, pp. 89-134.

In this article attention is called to the fact that until 1820. inorganic substances, almost entirely, engaged the attention of chemists. It was about this time that Justus Von Liebeg entered the field of analytical chemistry. His training was obtained from the German Universities for four years and later two years in the laboratory of Gay-Lussac at Paris. The later was the most famous experimenter of the time in organic chemistry. In 1824, Liebeg was made Professor of Chemistry in the University of Giesen, Germany. From this time, to 1840, the great work accomplished was to map out methods of determining the constituents of the organic compounds of plants and animals. He maintained that organic chemistry was governed by the same laws as inorganic chemistry.

His investigations led him into the analysis of the blood and flesh of animals and to determine the composition of bile and urinary secretions. Since 1840 Liebeg's efforts were directed mainly toward the application of chemistry in agriculture and physiology. In 1840 appeared a publication by Liebeg,- "Chemistry in its Application to Agriculture and Physiology". Of the work, there were six revised editions. These contained much experimental observations on organic compounds and his own personal views on the vital points in the life of plants and animals.

Briefly then, Liebeg's contributions were two- first, an extensive analytical examination of numerous organic compounds in plants as animal food. Also of the chemical changes which the plants undergo in their passage through the animal system. Second, he directed the observation in the study of animal physiology by substituting empirical experimental methods for the speculative philosophical one of preceeding periods. Liebeg classified the constituents of animal food into three classes; namely, nitrogenous, non-nitrogenous and mineral substances. Undoubtedly Liebeg's work furnishes the framework for our present knowledge of rational feeding of live stock.

Coming more particularly to the points of animal maintenance, we now refer to the experiments of Henneberg and Strohmann at the Wende Experiment Station'. These were the earliest exact investigations on the maintenance of cattle. In these early trials, two mature draft steers, weighing a little more than 1000 pounds each, were used. Three trials were conducted and careful computation made of food consumed and digested. Loss or gain and energy was measured. Even now, in the light of present day knowledge of how to conduct experiments, those experiments of Henneberg and Strohmann would be considered very creditable work.

' Original in Beiträge zur Begründung einer rationellen Fütterung der Weider Käuer, Heft 1. 17-188.
Review by Armsby, Penn. bulletin 42, --. 9-25.

The experiments, just referred to, were those used as a basis by Wolff to formulate the famous German Feeding Standard'. This standard passed current for about two decades without a question. Even yet, in many places, it is very largely employed for the want of a better one.

About thirty years ago Kühn and Kellner began to work at the problem at the Moeckern Experiment Station. They were well equipped and obtained lasting data on the subject. Armsby, of Penn." took up the matter with possibly a feeling that the Wolff Feeding Standard was in excess of the necessity on the maintenance ration. At least he proved, that for American conditions, it was too high. Likewise, Sandborn*, first at New Hamshire and later at the Missouri Experiment Station, called the Wolff Feeding Standard into question. He fed different lots of steers and found that they made a decided gain on a ration less than the one prescribed by Wolff.

Another notable experiment that attracted wide attention along this line is one reported from Wesleyan University, Middletown, Conn.@

' Wolff's Feeding Standard reprinted from Mentzel and Lengerke's Land. Kalender for 1898 in Henry's Feeds & Feeding pp.635-637.

'' Penn. Bulletin 42.

* Farm experiments at the New Hamshire College of Agriculture. pp. 8-26.

@ Office Experiment Station, U.S.Dept. of Agri. Bulletin 63.

This experiment was probably the best equipped and most carefully planned investigation ever attempted in this country, from a scientific standpoint, on the subject. The idea was to prove that there was no loss of energy and it was hoped that exact and lasting data might be obtained on the subject of heat units as a method of measuring food values.

About sixteen years ago, Haecker, of the Minn. Experiment Station*, decided, from his work in feeding dairy cows, that the maintenance ration prescribed by Wolff was in excess of the demands of the dairy cow. Consequently he experimented for at least three winters on two barren cows. The cows were gentle and docile and excellent subjects to work on. It was found that on a ration of .63 digestible protein, 5.75 lbs. digestible carbo-hydrates and .12 lbs. digestible ether extract per 1000 lbs. live weight produced a gain of one-fourth pound daily. While dry, barren, dairy cows are at rest in the stall, Prof. Haecker suggests, as his opinion, that .6 lbs. protein, 6.0 lbs. carbo-hydrates and .1 lb. ether extract per 1000 lbs. live weight, would be sufficient for body maintenance per day. But dairy cows are machines, and while at work producing milk and taking exercise, .7 lbs. protein, 7.lbs. carbo-hydrates and .1 lb. ether extract would more nearly express the coefficient for

* Minn. Experiment Station Bulletin 79.

maintenance. At the time the experiments were performed, no pretense, of a highly scientific nature, was assumed. Practical results were desired. Subsequent data of several winters work, under varying conditions, prove the factor for maintenance to be not only practically but also scientifically correct.

To attempt to enumerate the trials of digestion or to cite cases of analysis of food stuffs, would lead into much and useless details. Of the first point let it suffice to know that in all carefully planned experiments, in which relative food value is considered, a digestion experiment is, in most cases, conducted. For a tabulated and detailed account of the digestibility of American feeding stuffs, the reader is referred to a publication by Whitman H. Jordan, Director of the N.Y. Agri. Experiment Station, Geneva'.

On the second point, the reader is referred to a work by W.O. Atwater Ph. D. and A.P. Bryant M.S. on "The Chemical Composition of American Food Materials"*. This work is a compilation and tabulation of results from many sources. Again let it be said of this point, that in careful experiments conducted today, few investigators would think of

' Office Ex. Sta. Report, U.S. Dept. of Agri. Bulletin 77, pp. 5-100.

* U. S. Dept. of Agriculture, Office Experiment Station Reports, Bulletin 28 (Revised).

accepting anything but the chemical analysis of the feeds employed. They then figure the percentages of digestibility on the digestion experiment conducted in conjunction with the main experiment.

In dealing with the third point; namely, the results obtained in product from the excess of nutrients provided, an overlapping of points, one and two, cannot be avoided. This third point is the one the writer desires to elaborate. For this purpose data has been obtained from the books of the Dairy Division of the University of Minn. through the permission of Prof. T. L. Haecker. Much of the data is in published form. Other data employed is not yet published. The writer desires to claim for himself no originality in obtaining the data and desires to bestow full credit where it belongs. The computations, where otherwise not specified, and discussions, not credited to another, are the results of thought on the part of the writer.

To elucidate the method of determining the relation of nutriment to product, considerable data of the relation of dairy production to the nutriment provided, is introduced. This is because no other branch of live stock industry has been so thoroughly worked out.

Every Monday morning it is the first duty of the stock foreman, of the Dairy Division of the Minn. Experiment

Station, to see that a new milk blank is placed in position to be used in the dairy barn. Every day an official tester samples the milk of each cow, at every milking, and makes a butterfat determination by means of the Babcock test. Weighing of milk and results of tests are recorded at least once per week, by an office assistant, in the Dairy Division Books. From the week of Jan.25-31,'09 the following is selected:

Table 1. Daily milk and % test.

	Sweet Cicily.					Duchess.				
Day of Week	A.M.	% Test	P.M.	% Test	Lbs. Daily B. Fat	A.M.	% Test	P.M.	% Test	Lbs. Daily B. Fat
Monday	11.7	4.2	8.5	4.2	.84	13.5	5.2	11.9	5.0	1.29
Tues.	11.3	4.2	9.1	4.2	.85	14.5	5.5	12.1	5.7	1.61
Wed.	11.5	4.0	9.3	4.3	.86	14.2	5.2	11.9	5.5	1.39
Thurs.	11.6	4.4	8.9	4.1	.87	14.2	5.0	11.7	5.5	1.25
Friday	11.5	4.1	9.0	4.1	.84	13.5	5.1	11.3	5.6	1.32
Sat.	11.2	4.6	9.4	4.4	.92	13.6	5.2	11.1	4.2	1.18
Sunday	11.6	4.6	7.8	4.0	.84	13.2	4.9	11.7	5.3	1.27

Lou.

Monday	19.0	2.4	15.4	2.3	.81
Tues.	16.9	2.7	14.5	2.4	.80
Wed.	17.8	2.5	15.9	2.5	.83
Thurs.	17.7	2.6	15.3	2.6	.86
Friday	17.7	2.4	15.8	2.1	.75
Sat.	18.1	2.4	15.5	2.7	.85
Sunday	19.3	2.2	16.2	2.4	.81

Table 2.

	Daily Average for Week			Daily feed supplied for each			
	Daily Lbs. Milk	% Test	B. Fat	Hay	Silage	Grain	
Sweet Cicily	20.3	4.23	.86	8	24	9	barley 2
							corn 2
							oil meal 2
Duchess	25.5	5.22	1.33	10	24	11	bran 4
Lou	33.6	2.43	.816	6	20	11	

Dairying from a purely commercial standpoint would be well served if every farmer could be induced to keep such simple data as is prescribed in tables 1, 2 and 3. Solids not fat, in milk, are found by means of the specific gravity of a sample of the milk. This is generally accomplished by means of the Quevenne Lactometer or the N.Y. Board of Health Lactometer. The lactometer is a hydrometer. The scale differs from the scale of the hydrometer in that the graduations are marked by fives from fifteen to forty. To use the instrument, the milk is first brought to a temperature of from 50° to 70° F. It is next placed in a cylinder about ten inches or a foot long. Then the lactometer is suspended in the milk and left until it becomes quiet. The reading is then made at the point where the lactometer reading comes in contact with the upper surface of the milk. The graduations are so arranged that by placing 1.0 before the reading, the specific gravity is obtained.

The relation, briefly outlined, is,-

Reading of Quevenne Lactometer.	Specific Gravity.
15	1.015
20	1.020
25	1.025
30	1.030
35	1.035
40	1.040

To give correct readings, the milk must have a temperature of 60 degrees. If other than 60 degrees is the temperature, corrections in the readings must be made. To add .1 to lactometer readings, for every degree of temperature above 60 degrees or substracting .1 for temperatures below 60 degrees, makes nearly a proper correction. Tables have been prepared for exact corrections*. The N.Y. Board of Health Lactometer is similar to the Quevenne lactometer in principle but graduated differently. Either arrives at the same result. On Jan. 26,'09, the lactometer reading for the milk of the three cows is as follows,-

Table 4.

Temp.	Lactometer reading	Corrected reading	% Fat	% S.N.F.	% T.S.
	Lou.				
60	29.5	29.5	2.65	7.885	10.535
	Duchess				
59	30.5	30.4	5.2	8.64	13.84
	Sweet Cicily				
60	34.5	34.5	4.2	9.465	13.665

* See Modern Methods of Testing Milk and Milk Products. By L.L. Van Slyke. p. 132.

Explanation of columns five and six in table 4. Percent solids-not-fat are determined according to Babcock's formula,- solids-not-fat=$\frac{1}{4}$ L.+.2×f, in which L stands for the corrected lactometer reading and f stands for the percent test. To obtain percent total solids, a second formula of Babcock's is used.-Milk solids=$\frac{1}{4}$ L.+1.2×f. Note that the results here are for only one reading. A little later when a feeding standard is formulated, the average daily solids in the milk for the week, will be used.

In a preceeding table the food supplied to each cow is tabulated. Samples of the feed were taken to the Chemical labratory of the Minn. Experiment Station and table 5 presents the average chemical composition of the feed employed. Results given in percentages.

Feed	D.M.	Prc.	Fibre	N. Free Ex.	Fat
Barley	87.31	11.19	5.26	66.01	2.202
Corn	85.15	8.717	1.98	67.66	4.314
Oil meal	91.14	34.36	7.30	31.53	8.45
Bran	88.27	14.30	11.30	51.47	5.131
Prairie H.	86.45	6.51	27.68	41.86	2.33
Silage	27.04	1.904	7.24	12.82	.77

From digestion experiments conducted in the Minn. Dairy Division, it was found that the percentages of digestible nutrients of each of the constituents in the feeds above, are as follows,-

Table 6.

	% Protein	% Fibre	% Nit. F. Ex.	% Ether Ex.
Barley	70	50	92	89
Corn	60	50	93	86
Oil Meal	89	57	78	89
Bran	80	24	70	76
Prairie Hay	47	61	57	48
Silage	52	62	69	85

If known percents of the chemical constituents of a feed is digestible, then the percentage obtained, (by multiplying the percent constituent by the percent of same which is digestible), is the percent of a given feed which is digestible. For example, we find that the sample of barley analyzed, during the week under discussion, contained 5.26% of fibre. Table 6 shows that 50% of this constituent is digestible. The product of 5.26% and 50% is 2.63%. 50%, as used above, is called the digestion coefficient of fibre in barley. 2.63% is the percent of barley which is digestible and forms a part of the digestible nutrients in barley.

By using the digestion coefficients, in table 6, as indicated above, we find that the digestible nutrients, indicated in percents, are as follows,-

Table 7.

Percents digestible nutrients in each

	% Protein	% Fibre	% Nit. F. Ex.	% Ether Ex.
Barley	7.82	2.63	60.73	1.96
Corn	5.23	.99	63.93	3.71
Oil Meal	30.58	4.16	24.59	7.52
Bran	11.44	2.71	36.03	3.9
Prairie Hay	3.06	16.88	23.86	1.12
Silage	.99	4.49	8.85	.65

From table 3 we know the pounds of the different feeds supplied each cow per day. Table 7 gives the digestible percents of each of the constituents. Multiply the number of pounds of feed by the percent of its digestible compounds. The result will be pounds or decimal parts of a pound of protein, nitrogen-free-extract, fibre and fat. Do this with each feed in succession. Place the results in four columns respectively, protein, fibre, nitrogen-free-extract and ether extract. Find the total of each column. These totals represent the amounts of the digestible compounds in the ration.

In order to simplify the work at this point, we will add the amount of digestible fibre to the amount of digestible nitrogen-free-extract and together designate them as the digestible carbo-hydrates in the ration.

In this form, they are comparable to the constituents in the maintenance ration, before referred to.

By applying the digestion coefficients to the amount of feeds separately and finding the totals of the protein, carbo-hydrates and fat, we find that each cow received as follows,-

	lbs. protein	lbs. carbo-hydrates	lbs. ether extract.
Duchess	2.0068	12.8092	.8306
Lou	1.8448	10.5836	.743
Sw.Cicily-	1.6796	11.0564	.7242

Referring to table 2, the average daily milk in pounds and tenths of a pound for Lou, Duchess and Sweet Cicily is 33.6, 25.5 and 20.3. In table 4, we read that the percent of solids-not-fat in the milk of Lou, Duchess and Sweet Cicily is respectively, 7.885%, 8.64% and 9.465 %.* Multiplying the average daily milk of each, by the percent of solids-not-fat, we have Lou, 2.84 lbs., Duchess, 2.20 lbs. and Sweet Cicily 1.92 lbs. Before a comparison can be made or a ration obtained, all products and nutrients must be reduced to a common unit of comparison. Common agreement makes the food value, expressed in calories of heat units, the ground of comparison.

* Note that table 4 was computed on basis of one lactometer reading. The average for the week would possibly give a slightly different percent of solids-not-fat.

Chemists learned, long ago, that one gram of protein or carbo-hydrates produces 4.1 calories of heat units; while one gram of fat produces 9.4 calories. The usual practice is to reduce nutriment and product to starch equivalent in order to make comparison. To do this, add the protein and carbo-hydrates and 2.2 fat. (2.2 expresses nearly the ratio of 4.1 to 9.4).

Lou- Pro.+C.H.+(2.2 Fat)=14.063 lbs. total nutriment.

For maintenance* .792×9.2 cwt.=7.29 lbs.

14.063- 7.29=for product, 6.773 lbs.

Duchess- Pro.+C.H.+(2.2 fat)=16.643 lbs. total nutriment.

For maintenance .792×8.2 cwt.=6.494 pounds.

16.643- 6.494=for product, 10.149 pounds.

Sweet Cicily Pro.+C.H.+(2.2 fat)=14.329 lbs. total nutriment.

For maintenance .792×9.7 cwt.=7.682 pounds.

14.329- 7.682=for product, 6.647 pounds.

Product yielded in starch equivalent.

Lou,- Solids-not-fat 2.84+(.82 f×2.2)=4.64 pounds.

Duchess,- Solids-not-fat 2.20+(1.33 f×2.2)=5.13 pounds.

Sweet Cicily,- Solids-not-fat 1.92+(.86 f×2.2)=3.81 lbs.

For ratio of product to nutriment, divide nutriment for product by product yielded.

Lou -4.64 : 6.773 :: 1 : 1.46, Duchess- 5.13: 10.149::1:1.97

Sweet Cicily,- 3.81 : 6.647 :: 1 : 1.74

* See bottom page 11.

Reference has been made to the fact that differences exist in the digestive ability of cows. This must not be construed to mean that the range of difference is very wide. Under normal working conditions, the percent of digestible nutrients obtained by one cow from a given amount of feed, will probably not vary over five percent as the maximum from that obtained by another. Enough difference exists, however, so that it is impossible to say what a digestion coefficient is, under known conditions without a chemical analysis of waste products. Physical discomforts and body disturbances are more often the cause for differences in the amount of product yielded for known amounts of nutriment. Two of cows, under consideration, are examples to illustrate the above. It will be noticed that Duchess required 1.97 pounds nutriment for a pound of product and Lou only 1.46 pounds to one of product. The variations here are due largely to two causes. The latter cow was plainly drawing on body tissue, because it is a physical impossibility to produce a pound of dairy product for less than 1.5 pounds of nutriment. In this case it is fully confirmed that this was the fact with Lou. She was losing in body weight, from three to four pounds per week. Duchess always requires an abnormal amount of nutriment to produce product because she is affected with rheumatism. Every move seems to be accompanied by pain.

Taking an average of the three, we find that for every 1.72 pounds of nutriment provided for product, one pound was yielded. Note that the illustration here presented, is for only a limited period and does not signify what the yearly average would be. However, data of several years work in the Dairy Division, confirms the statement that these cows were doing, according to the average, very nearly normal work. Prof. Haecker's findings are from the summary of eight winters work, that 1.81 pounds net nutriments will produce one pound of product under normal conditions.

Formulating a feeding standard.

By referring to the work already accomplished in Animal Nutrition, one would think it an easy task to tabulate a standard by which anyone could place their fingers on the exact quantity of feed to supply a given requirement for any animal under any conditions. Such, however is not the case. The physical conditions of feed varies according to the way it was cured or harvested. Some over ripe feeds, in the form of forages, are almost useless. Other samples are musty, wet or damaged in other ways. Grains vary in their physical compositions in regard to their maturity, their commercial grade etc.

Very seldom do two samples of the same roughage or grain, exhibit the same constituents, chemically. Again, so far as any data which the writer has been able to obtain, no class of animals, of a given size and age, make exactly the same use of feed provided. One requires a little more for maintenance. One digests a little more thoroughly than another. Still others require varying amounts to produce a given effect. One steer requires three pounds of nutriment to produce a pound of gain; another requires four pounds. Note that in the examples of three cows quoted above, all were under careful and uniform management. Neither had an advantage as to lactation period. Still, one produced a pound of product for 1.46 pounds nutriment while another required 1.97 pounds. Another point is well illustrated by the example just cited and that is that the purpose of feeding must be considered. When butterfat instead of total solids is our unit of measurement, we find that the cow, giving one pound product for 1.47 net nutriment, requires 8.5 pounds nutriment for one pound of butter-fat, while the cow giving one pound product for 1.97 pounds net nutriment, requires only 7.55 pounds net nutriment per pound butter-fat. These few reasons are typical of many others which might be given to substantiate the statement that our feeding standards are, and always will be, approximations. Approximations, based upon general averages, will be a guide by which to begin more careful feeding. The response of the animal must be the indication of whether or not it is suited to the conditions.

If,as indicated, all these uncertain elements enter into the calculation, should we condemn all feeding standards? By no means. Some men, because of their judgment, accumulated data and practical experience, are in position to say that under given conditions, certain average results apply. They are to be accepted as a lasting contribution to the subject of animal nutrition.

When one attempts to formulate a standard, from the purely physiological standpoint, the first question that arises to confront the operator is how much protein is actually required to be most profitable in maintenance and product? Is the protein in a ration more digestible when the ration is lean in fats and rich in carbo-hydrates and less digestible when the ration is rich in fat and lean in carbo-hydrates? Is it required that a definite percent of protein, excess to actual requirements, must be supplied in a ration before sufficient will be used for the necessary purpose of proteid building? How much more digestible is a feed when mixed with another than when fed alone? *

We have been taught by eminent physiologists that heat and energy is supplied in the animal mechanism by carbo-hydrates and fat; that to do a certain piece of labor, the expenditure is in heat and energy, that when nutriment

* See Henry's Feeds and Feeding. pp. 561-562 for a notable experiment on mixed feeds.

in feed is short, body fat is first drawn upon to supply heat and energy. If these things be true, one might reason that if enough protein is provided to supply the maintenance requirement and an amount equal to that appearing in the product, it would be sufficient. In the average results obtained at the Minn. Experiment Station, 1.81 pounds of net nutriment produced one pound of product. It is evident that .81 pounds nutriment was expended in energy. From table following, it will be observed that 3% milk is composed of 2.7% nitrogenous matter and 11.2% non-nitrogenous matter.

From the composition and uses of nutrients, one would infer that a very small excess of protein, for product, would be necessary. Just how much of the .81 surplus should be protein, is not yet answered to an exact quantity. Prof. Haecker states that not less than 50% must be supplied in excess of the amount appearing in the product. For this he gives some practical reasons. First, "We do not wish to hamper the dairy cow in her progress to become more and more productive". Second, "Feeds are so uncertain in their chemical composition that we cannot risk any less". Third, "Unpublished data, in this Divisien, indicates that for cows of low fat cintent, 50% protein excess is none too much. For cows rich in fat content, a little less would do. Work, of the Division, during the winters of 1901-2, 1902-3 and 1903-4, demonstrates decidedly that the cow of low fat content suffers when less than an excess of 50% of protein, over protein in product, is supplied. The herd on a ration lean in protein did normal work for two winters but during the third winter the cows, giving milk of low fat content, failed entirely. Lou, giving the thinnest milk in fat, failed first and others failed in the order of low percent fat content. This is so because other things being equal, the lower the fat content, the higher proportionally is the nitrogen compounds. The other excesses over product constituents are fixed by Prof. Haecker as 70% for carbo-hydrates and 13% of carbo-hydrates as fat. These are a little higher than need be in order to be safe at all times.

Following is a table of average composition of milk of various percentages reduced to percentages of nitrogenous and non-nitrogenous compounds.* Applying the factors 1.5 to the nitrogenous, 1.7 to the non-nitrogenous compounds in milk and .13 of carbo-hydrates as fat, we have reproduced below, Prof. Haecker's Feeding Standard, now in current use.

* From the University of Minn. Dairy Division.

Table 8.

Gravometric Analysis of Milk

No. of Milk-ings	Organic Composition: Milk fat %	Pro. Casein & Albumen	Lactose	Components in 1 lb. of milk: Nitrogenous.	Non-Nitrogenous
658	3%	2.7	4.60	.027	.112
770	3.5	2.8	4.75	.028	.124
840	4.	3.1	4.85	.031	.136
1638	4.5	3.3	4.97	.033	.149
1442	5.	3.4	4.98	.034	.160
1246	5.5	3.6	4.92	.036	.170
546	6.	3.8	4.91	.038	.181
336	6.5	4.1	4.90	.041	.192
182	7.	4.2	4.84	.042	.202

Feeding Standard
Net nutriment to 1 lb. milk

Protein in milk plus 50%	Carbo-hydrates in milk, plus 70%	13% of Carbo-hydrates as Ether extract
.04	.19	.014
.042	.21	.016
.047	.23	.018
.049	.25	.019
.051	.27	.021
.054	.29	.022
.057	.31	.023
.061	.33	.025
.063	.34	.026

Nutrition studies, with other classes of animals, have been instituated and in time a feeding standard for beef may be expected, comparable to the one now in use in scientific dairying.

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