Brief history of California

The California alfalfa hay TDN equation is widely used in the southwestern U.S. to determine the potential feeding value of pure stand alfalfa hays for dairy cattle, but the exact origin of this equation is obscure.

By **P.H. ROBINSON** and **C.A. OLD***

ALFALFA hay has been an important feed in dairy cattle rations in California for a very long time. Indeed, it can be and has been argued that the availability of high-quality alfalfa hay allowed the dairy industry in California to become established.

Alfalfa hay is, in some ways, a unique dairy feed as it combines a number of beneficial nutritional attributes that are seldom found in the same feed. However, the key nutritional (feeding) characteristic of California alfalfa hay and the basis upon which most of it is priced and traded in California is its total digestible nutrient (TDN) content.

TDN is a very old term, dating to the late 1800s, that was developed to assess the feeding value of animal feeds. Originally based on the assays of the "proximate system" of analysis, i.e., crude protein (CP), crude fiber (CF), nitrogen-free extract (NFE) and crude fat, this TDN equation was used for almost a century to assess the feeding value of feedstuffs destined for animal feeding.

However, determining the TDN content of feeds on the farm on a routine basis is not practical because the TDN calculation is the sum of the digestible components of NFE, CF, crude fat (multiplied by 2.25) and CP, and the only way to estimate them is to measure them in cattle or sheep using a digestibility experiment in which all of the feed consumed and feces excreted are collected and assayed for NFE, CF, crude fat and CP in order to determine their individual digestibilities.

However, there are often correlations among the TDN content of a feed and one or more of its analytes. Thus, if the level of a single analyte in a feed can be measured, it may be possible to predict its TDN content with a high degree of accuracy.

Obviously, assaying for a single analyte is much less complex than completing a digestibility experiment with cattle or sheep, and this makes it a practical approach for routine, on-farm prediction of the TDN level of specific lots of feedstuffs.

This was the approach taken by Meyer and Lofgreen (1959), where the use of a single analyte to estimate quality supplemented the visual appraisal methods used at that time.

In 1989, a Western Regional Extension Publication was co-authored by Dr. Don Bath of the University of California-Davis (UC-Davis) department of animal science and Dr. Vern Marble of the UC-Davis department of plant science titled "Testing Alfalfa for its Feeding Value." In this booklet, a number of equations were presented to predict the TDN, net energy of lactation and digestible dry matter (DM) content of California alfalfa hays from single analytes of the hay.

Among these equations, there are two TDN equations of particular note because one had been widely used in the California dairy industry from the 1960s through the 1980s, and the other became widely used after publication of the Western Regional Extension Publication and remains in widespread use today.

The purpose of this article is to trace the history of these two equations since the data sets used to derive the equations affect their utility, because Bath and Marble did not reference the origin of the equations in their 1989 Western Regional Extension Publication and because the history of the development of equations that are widely used in animal feeding should not be lost to time.

Methods

Prediction of alfalfa hay TDN from modified crude fiber (MCF). In Bath and Marble (1989), the equation to predict TDN from MCF (their equation 1) was listed as:

TDN (% of DM) = 81.07 - (0.8558 * MCF [% of DM])

Bath and Marble stated the basis of this equation to be: "research at the University of California in the 1950s." Indeed, this equation is based on research conducted by Drs. Jim Meyer and Glen Lofgreen of the UC-Davis department of animal husbandry in 1956 and 1959.

Using sheep fed solely alfalfa hay at a maintenance level of intake (i.e., to maintain bodyweight), Meyer and Lofgreen published their initial findings in the *Journal of Animal Science* in 1956. In that article, Meyer and Lofgreen reported that the correlation coefficient of TDN with lignin was -0.88, while the correlation of TDN with CF was -0.86.

The latter equation (equation 2) was:

TDN (% of DM) = 79.7 - (0.84 * CF [% of DM])

However, the first published occurrence of equation 1 was in 1959 (Meyer and Lofgreen), also in the *Journal of Animal Science*, where it can be found in Table 1 (not shown here). In addition to developing new analytical procedures (CF plus silica, generally termed MCF) and regression equations, these investigators also developed sampling procedures based on the variability expected in populations of alfalfa hay bales, sampling tools and also tables so that the monetary value of alfalfa hay could be determined.

Equation 2 was based on 43 individual lots of alfalfa hay, 31 of which were also in the data set of the 1956 publication. Of the constituents evaluated in alfalfa — lignin, CF, MCF and protein — MCF was most correlated with TDN (r = -0.89). This equation was widely used in California to predict the TDN content of alfalfa hays through the 1980s.

Prediction of alfalfa hay TDN from ADF. During the 1970s and 1980s, ruminant feeding systems transitioned from the use of CF and NFE of the proximate system of analysis to the detergent fiber system developed by Dr. Peter Van Soest (Van Soest and Wine, 1967; Goering and Van Soest, 1970) at the U.S. Department of Agriculture's Agricultural Research Service station in Beltsville, Md., and later at Cornell University.

Use of the terms neutral detergent fiber (NDF) and acid detergent fiber (ADF) had almost completely replaced ruminant nutritionists' use of the terms CF and NFE by the late 1980s. Thus, in Bath and Marble (1989), the equation to predict TDN from ADF (their equation 7) was listed as:

TDN (% of DM) = 82.38 - (0.7515 * ADF [% of DM])

Bath and Marble stated that this equation was "based upon limited research conducted to date." However, their 1989 publication is the only one in which this equation appears, and its actual origin is uncertain.

Thus, in 2012, we embarked on a quest to determine the origin of the equation, not least because it was widely adopted in the 1990s by California hay growers and dairy producers to become the major basis

In 60 seconds

New indications: Merck Animal Health reported that beef and dairy producers now have the flexibility to vaccinate pregnant cows and calves nursing pregnant cows against bovine reproductive and respiratory diseases with its Vista modified-live virus (MLV) vaccine product line. Approved by the U.S. Department of Agriculture, the new indication includes the following label additions:

- Cows or heifers being vaccinated should be vaccinated prior to breeding, within the previous 12 months, with any of the vaccines in this product line.
- Fetal health risks associated with vaccination of a pregnant animal with MLV vaccines cannot be unequivocally determined by clinical trials conducted for licensure.
- Management strategies based on vaccination of pregnant animals with MLV vaccines should always be discussed with a veterinarian.

alfalfa hay TDN equation

upon which alfalfa hay is valued and traded in California and surrounding states.

It is likely that the many hundreds of millions of dollars of alfalfa hay traded annually at prices based on the alfalfa hay TDN value estimated by this equation — and its widespread use in the southwestern U.S., especially in California — continues.

Discussion

The first stop in our quest was a discussion with Dr. Vern Marble, retired in Davis, who is certain that the equation was developed by either Bath or Garrett based on digestibility studies completed by Garrett at UC-Davis in the 1980s and, possibly, by Dr. Warren Speth of the University of Nevada with whom Garrett conducted joint research under the auspices of a USDA regional research project. However, Marble was adamant that he had not created the equation.

The next stop was Dr. Don Bath, who recently passed away. Examination of original paper drafts of the 1989 Bath and Marble publication revealed that their equation 7 had originally been a different one (referred to by Marble in a written notation on the paper draft as the "Garrett/Speth equation"), but in April 1988, as the booklet was nearing final form, this equation was removed and replaced by equation 7.

This equation 7 was quite different from the one it replaced, although no surrounding text was modified. However, Bath had no memory of why this change was made or, indeed, who derived the equation that was inserted as equation 7, although he was very sure that it was based on digestibility research completed by Garrett at UC-Davis in the 1980s.

The final stop was Dr. Bill Garrett, also retired in Davis. Remarkably, Garrett has maintained all of his original digestibility data from the 1980s in computer files and kindly shared them with us. Garrett was aware of the 1989 Bath and Marble publication and its equation 7 and was certain that it was based on his data — data that represent a total of 52 lots of alfalfa hay and cubes that were used in studies with cattle at maintenance (11 lots), cattle at production levels (four lots), sheep at maintenance (17 lots) and sheep at production levels (20 lots).

Regarding TDN, Garrett said it is interesting that TDN use has persisted to this day since digestible energy is more highly related to ADF than TDN was. However, our independent efforts with this data set to recreate equation 7 were not successful, although the TDN prediction equation based on the 11 lots of hay fed to cattle at maintenance is very close to equation 7.

So, what can be concluded about the origin of equation 7, later referred to, variably, as the "WRRP 109 equation," the "western states equation" and the "California alfalfa TDN equation"?

In order:

1. It is extremely unlikely that the exact data set used to develop equation 7 will ever be identified.

2. It is barely short of a certainty that equation 7 was based on the alfalfa digestibility data from cattle at maintenance developed by Garrett and co-workers at UC-Davis in the 1980s. It seems extremely unlikely that any of Garrett's sheep data were used, since equations to predict TDN based on ADF from the sheep data create very different TDN prediction equations.

3. The actual TDN values based on the digestibility studies developed by Garrett were based on the proximate system of analysis rather than the detergent system of analysis.

4. Comparison of TDN values calculated from MCF (equation 1) and ADF (equation 7) assayed on the same alfalfa hay sample will differ because the MCF calculation is based on data developed from sheep fed at maintenance (equation 1), whereas values based on ADF were developed based on cattle fed at maintenance (equation 7).

Implications

The exact (data) origin of the current California alfalfa hay TDN equation (equation 7), which is widely used to predict the TDN level of alfalfa hays in order to determine their appropriate price relative to feeding quality, will likely never be known with certainty. However, it is almost certainly an equation based on feeding studies with cattle fed at maintenance intake levels completed in the 1980s at UC-Davis.

As such, it is the only TDN (or feed energy) prediction equation used commercially in the U.S. that is directly based on data developed from live animal studies.

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