Developments in Equine Nutrition: Comparing the Beginning and End of This Century

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**ABSTRACT** In the first part of this century, there was little advancement in horse nutrition and little research was undertaken. However, in the last few years, there has been a great increase in interest in this whole area. This review surveys some of the more recent developments and how they have influenced feeding practices and also compares these with those feeding practices found at the start of this century. The review concentrates on the nutrition of the adult horse in work, exploring in particular what they are fed and how the nutrient value of these feeds is evaluated. *J. Nutr. 128: 2698S–2703S, 1998.*

**KEY WORDS:** horses nutrition historical review feeding practices

Research in the field of domestic animal and farm animal nutrition increased markedly in the period following the world wars, whereas that of the horse decreased. This was due to the decline in the use of the horse for transportation, as an agricultural animal and as a source of power. In a 1958 review (Squibb 1958), it was stated that there had been little advancement in knowledge of horse nutrition over the previous 50 years, resulting in little change in feeding practices from the early 1900s. This review noted that there were only six references on horse nutrition published in the Journal of Animal Science during the period 1942–1958. However, since that time, the horse has been used increasingly for pleasure and leisure purposes, and more recently, there has been a great expansion in the number and popularity of various equine-oriented courses at universities and colleges throughout the world. There has also been an increase in the amount of equine nutrition research being conducted. In a 1985 review (Hintz 1985), it was reported that from 1961 to 1983 at least 60 papers related to equine nutrition were published in the Journal of Animal Science. From 1989 to 1995, not only were nearly 20 references on this topic published in this journal, but there were also published proceedings of several European Equine Nutrition Conferences, the Biannual Equine Nutritional and Physiology Society meetings and many other relevant papers in the expanding number of equine journals.

There has in fact been so much new information produced on various aspects of horse nutrition over the last few years that it would be very difficult to summarize it all. This review therefore provides an overview of some key developments in performance horse nutrition and will look in particular at how these may have influenced feeding practices, and how such practices may have changed from those used at the turn of the century. As a main point of comparison, this review uses a book originally published in 1908 and prepared in the Veterinary Department for the war office (Anon 1908) and an Animal Nutrition and Veterinary Dietetics book published in 1927 (Linton 1927).

**WHAT WE FEED: THEN AND NOW**

What horses were fed at the start of this century obviously depended to a certain extent, as it does today, on where they lived and what feedstuffs were available. In 1908, many of the feedstuffs listed as being suitable feedstuffs for horses would be fed today, e.g., lucerne, oats, maize, barley and linseed, although soy has tended to replace linseed as one of the major protein sources for horses. The 1927 dietetic book states that in the United Kingdom, “custom has decreed that the staple diet of working horses should consist of hay and oats supplemented or substituted by straw, maize, beans or dried grains.” In the U.S., although oats were very popular and often the preferred feed, in 1912 more corn (9.3 million metric tons: 27% of the corn crop) than oats (4.1 million metric tons: 47% of the oat crop) was eaten by horses and mules (Murray 1914). Today, the grains most commonly fed to horses are still oats and corn with some barley and maize, although oat production in certain areas of the U.S. is on the decline (Hintz et al. 1997) and may affect horse feeding in the future. There were, however, some feeds listed in 1908, including kulthi, gram, moth, urad and mung (Indian beans/peas), that would be considered unusual in a modern day equine nutrition book such as Lewis (1995), and which perhaps reflected the distribution of this manual. The 1908 publication also stated (Anon 1908) that “meat was utilised successfully during the siege of Metz by being cut into small pieces and rolled in bran, and Norwegian stock of all kinds is accustomed to consume a soup made from boiled fish when mixed with other food.” Although the use of meat would be frowned upon altogether today,

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Icelandic ponies apparently may still be fed herring in the winter. It has been reported that 5–10% white fish meal in a cheap feed or milk replacer is quite satisfactory for foals and should be a good safe feed (Frape 1986); however, the feeding of animal-derived feed to a herbivore such as the horse is not a common (or recommended) practice.

Although the basic types of grain fed to horses may be identical between 1908 and today (oats, barley and corn), there are differences in how they might be presented to horses. In 1908, it was appreciated that crushing, soaking, boiling or parching certain grains, in particular corn and barley, helped improve the digestibility of these grains. It was also suggested that “bruising” or “crushing” improved the digestibility, if not the storage of oats. Recent work, conducted mainly in Germany (Meyer et al. 1993 and 1995), looked at the effects of processing on prececal starch digestibility. Considerable individual variability in prececal starch digestion was shown to be a result in part of chewing activity and amylase activity (Kienzle 1994, Meyer et al. 1995). In general, processing had a result in part of chewing activity and amylase activity.

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One of the major differences one would notice between the list of feedstuffs considered suitable for horses at the turn of the century and that today would be the current inclusion of supplementary fat in the diets of many horses, especially competition horses. The increased interest in fat supplementation developed as a result of work in the mid-1970s (Slade et al. 1975) that suggested that horses fed a diet containing 12% fat (9% added corn oil) and ridden 67 km over mountainous terrain for 8–10 h performed better and had higher blood glucose concentrations at the end of the ride than did horses fed the control diet (3% fat). Although it is appreciated that horses can digest and utilize different types of dietary fat (Potter et al. 1992), there is little information available concerning lipid metabolism in the horse. In some ways, the horse differs from other animals; for example, adult horses do not appear to have any chylomicron lipoproteins (Watson 1991) and the activities of lipoprotein lipase and carnitine palmitoyl transferase are much lower in horses than in humans (Scholte et al. 1991, Watson et al. 1992). Fat-supplemented diets (up to 20% of the total diet) can result in various effects on a range of physiologic and metabolic parameters as well as on athletic performance, in part because the various studies have been carried out on horses that differ in breed, age, body condition and training regimens as well as in diet, and the amount and type of fat fed (Harris 1997, Potter et al. 1992).

There is, however, no doubt that supplementary fat has an important role to play in the nutrition of horses today (Harris 1997, Hintz et al. 1997). Due to its energy density, the amount of feed that an individual horse requires to provide a sufficient energy intake can be reduced, which can be an advantage, especially in hard working animals in which appetite is often depressed. The amount of carbohydrate required can be reduced and/or an adequate fiber intake can be maintained if supplementary fat is fed, thereby decreasing the possibility of behavioral, digestive and metabolic disturbances occurring as a result of nutrient imbalance. Fat is less thermogenic than digestible carbohydrates or fermentable fiber and may help reduce bowel ballast and water intake (Kronfeld 1996).

One of the other major differences in the use of feeding materials is the common use of manufactured commercial feeds today. In 1908 “compressed food cakes consisting of a mix of oats, beans, corn, bran and sometimes chaff” were mentioned as possible feeds, but it was recommended that they be broken up before being fed damp (Anon 1908). The few manufactured feeds available at the start of this century tended to be expensive and contained poor quality ingredients such as ground corn stalks and sawdust (Hintz 1985). In 1927 (Linton 1927) it was appreciated that for convenience “prepared chop” could be purchased. This was reported to contain mainly cereal straw, bruised oats (of indeterminable quality), broken maize, kibbled locust beans and other beans, but it was recommended that “horse owners should buy and mix the food for the horses themselves, then they know exactly what their animals are getting and that the food is of good quality.” Pelleted feeds were being fed as early as 1917, but their popularity did not dramatically increase until the 1960s. Increased competition, improved knowledge as well as more ethical companies and government regulations have resulted in a large industry, producing mainly high quality pelleted and coarse mix feeds (sweet feeds), often tailored for the different types or uses of the horse (Breuer 1997, Harris et al. 1995, Hintz et al. 1997, Lewis 1995). More recently, extruded feeds have been introduced, which may help improve feed utilization in certain horses and may help reduce the incidence of digestive disturbances under certain management systems (Breuer 1997, Hintz et al. 1997).

**MINERAL AND VITAMIN SUPPLEMENTATION**

At the start of this century, as discussed later, very little was known about the importance of even the macrominerals; the role of trace elements had not been established and the work on vitamins was about to start. In 1908 (Anon 1908), it was stated that “the addition of salt to horse's food is not a necessity, they may be kept in the best condition without it, all the salt they actually require for the body's nourishment being contained in their food.” No mention of salt could be found in the 1927 Animal Nutrition book (Linton 1927). Today, perhaps because of the increased demands placed on our horses (especially our competition horses), supplementary salt is considered to be an important part of the performance horse's diet.

Today it is known that horse sweat is hypertonic to plasma with respect to sodium and chloride and that, depending on many factors, including the horse’s fitness, the environmental conditions plus the speed and duration of exercise, the amount of sweat produced will vary and therefore sodium requirements will vary (Table 1). However, because the sodium and chloride content of many “traditional” (home-mixed) as well as commercially prepared diets often will not meet these requirements, additional supplementation is usually recommended for those animals in work. The need for such supplementation was highlighted in some recent work from Canada (Cutcheon and Geor 1996). These researchers used especially designed sealed polythene pouches for sweat collection to assess the concentration of various electrolytes in sweat as well as the sweating rate during exercise tests carried out on a high speed...
treadmill. In this study, the horses [mean body weight (BW)]
455 ± 12 kg] undertook an exercise test designed to simulate
the cross-country phase of a 3-d event under either cool/dry
(CD) or hot/humid (HH) conditions. Under the CD condi-
tions a mean of ≈12 L of sweat was produced by the horses
with an average sodium and chloride content of 2.9 and 5.2
g/L, respectively. Under HH conditions, a mean of nearly 20 L
of sweat was produced with an average Na and Cl content of
3.2 and 5.7 g/L, respectively. The conclusions included the
comments that “it is important to recognise that, in the
case of sweat was produced with an average Na and Cl content of
2.9 and 5.2
g/L, respectively. Under HH conditions, a mean of nearly 20 L
of sweat was produced with an average Na and Cl content of
3.2 and 5.7 g/L, respectively. The conclusions included the
comments that “it is important to recognise that, in the
context of the diet maintained during this study, almost 80%
of the sodium was provided as part of the salt supplement.
Without this supplementary sodium, the cumulative losses
associated with regular training may have exceeded dietary
intake even in CD . . . “Supplementation of the diet is rec-
ommended even when training is undertaken in cool climates
. . . demonstrate the necessity for ion supplementation, in
particular sodium in hot ambient conditions.”

In a recent study (Pagan et al. 1998), the voluntary salt and
total sodium intakes were measured over a 4-mo period in a
group of horses fed either forage alone or a mixture of forage
and grain; the horses were exercised daily on a treadmill or
turned out daily during the initial 3-wk adaptation period and
then hand walked twice daily during the 7-d complete collec-
tion digestion trial. Salt was offered free choice to the horses
in 1-kg blocks. Although the exercised horses receiving the
mixed diets ingested sufficient sodium to meet their estimated
requirements, those consuming the forage did not. This could
mean that the actual sodium requirement was lower when the
forage only diet was consumed. Perhaps these horses were able
to conserve sodium more effectively, or the dietary sodium was
more available, or they required less. Alternatively, unlike
commonly held beliefs, they did not voluntarily consume
sufficient sodium from a salt block to meet their requirements.
Much more work is required in this whole area of electrolyte
supplementation.

HOW CAN THE NUTRIENT VALUE OF THE
FEED BE EVALUATED?

Looking at the list of nutrients said to be available from
feeds for horses in the 1908 manual (Anon 1908), it is appar-
tent that although the fundamentals might have been appre-
ciated, very little detail was available. The main categories or
groups of the constituents of all foods as given in 1908 are
illustrated in Table 2 together with the values given for oats
and meadow hay. A comparison with the “equivalent” values
given for the same feedstuffs in 1927 and 1989 is also provided.
It was appreciated in 1908 that overlap was possible between
certain groups, i.e., if the flesh-making elements were fed in
excess, they could be used for energy, although this was not
their essential function. Equality the fat-heat-energy—produc-
ing elements could under certain conditions be used to put
weight on. However, the fibrous and woody elements were
considered to be comparatively indigestible and were “never-
thless found to be necessary as providing the bulk so essential
to the rations of herbivorous animals.” Today it is well appre-
ciated that fiber and fiber fermentation play a very important
role in digestion of many animals including the horse. In 1908,
although it was appreciated that mineral elements of lime
were needed, especially for young growing animals, the importance
of “vitamins” and the trace elements was not appreciated. By
1927 (Linton 1927), calcium, sodium, potassium, magnesium, iron,
phosphorus, chlorine, sulfur and iodine were known to be
important, and it was appreciated that other trace elements
were also important “but little is as yet known of their func-
tion.” This book states that “vitamins, or accessory food factors
as many prefer to call them, are substances which, in view of
the results of recent research work, we may assume to be
definite chemical entities . . . they have a profound influence
on the tissues of the body . . . at least five definite vitamins so
far recognised. These have been denoted by the letters “A,” “B,” “C,” “D” and “E.” Selenium was not recognized as an
essential nutrient until the 1950s. Vitamin B-12 was not
identified until the 1940s (Hintz 1985).

Today, although we can provide much more detail on the
composition of feedstuffs, especially the vitamins, minerals,
trace elements and the amino acid profile, the actual analysis
of equine feedstuffs does not appear superficially to have altered
much, as shown in Table 2. The one major difference
between 1908/27 and today would be the starch and sugar/
nonstructural carbohydrate (NSC) content of the feeds, espe-
cially the meadow hay. This most likely reflects the way in
which these values were determined and our changing under-
standing of the role of fiber. In 1908, it appears that the starch,
and sugar content was determined according to Equation 1 as
follows: Starch and sugar content = 100 – fiber-making group
(% – fat (%) – bone-making elements (%) – woody fiber
(% – water (%). Today because it is appreciated that the
crude fiber (woody fiber) analysis does not determine all of the
fermentable fiber presented in feedstuffs, NSC content would
normally be determined according to Equation 2 as follows:
NSC = 100 – crude protein (%) – fat (%) – ash (%) –
neutral detergent fiber (NDF) (%) – water (%). However, not
everyone is satisfied with using NDF and Equation 2 to deter-
mine the hydrolyzable carbohydrate content of horse feed.
This highlights one of the fundamental problems still facing
equine nutritionists today, i.e., “how best to define fiber.” In
fact, there is still considerable international and interspecies
confusion concerning carbohydrate nomenclature, including
that of fiber. Ideally, as far as the horse is concerned, we have
to appreciate which method or methods for fiber analysis
provide an accurate guide concerning where and to what
extent the fiber is degraded and which end products are pro-
duced. This will provide more information on the nutrient
value of the fiber to horses under a variety of circumstances.
At the moment, declaration of crude fiber is still a legal require-
ment for UK horse feeds, for example, despite the fact that the
method is crude and imprecise. Work is in progress in a

TABLE 1

A guide to sodium (Na) requirements for a 500-kg horse

<table>
<thead>
<tr>
<th>Level of exercise (work)</th>
<th>Na(^2)</th>
<th>Sweat</th>
</tr>
</thead>
<tbody>
<tr>
<td>g/d</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>1 (light)</td>
<td>23</td>
<td>2.5–5</td>
</tr>
<tr>
<td>2 (moderate)</td>
<td>37</td>
<td>5–10</td>
</tr>
<tr>
<td>3 (heavy)</td>
<td>70</td>
<td>10–25</td>
</tr>
<tr>
<td>4 (very heavy)</td>
<td>96</td>
<td>&gt;25</td>
</tr>
</tbody>
</table>

1 Source: Harris et al (1995)
2 Sweat Na concentration taken as ≈3.1 g/L
Maintenance Na requirements ≈ 20 mg/(kg body weight · d).

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Looking at the list of nutrients said to be available from
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tent that although the fundamentals might have been appre-
number of institutes throughout the world to evaluate this area in more depth. Some very recent work being carried out in Edinburgh, UK involves both in vivo and in vitro techniques for evaluating fiber degradation profiles. It is hoped that these profiles, together with mean retention times under differing dietary managements, will eventually allow the prediction of the feed value of different fibers. This work has already confirmed that dietary fiber is not degraded solely in the large intestine of the horse but that a variable proportion will be digested prececially, depending on the feedstuff and the retention time within each compartment of the gastrointestinal tract (Hyslop et al. 1997, Longland et al. 1997, Moore-Colyer et al. 1997). These researchers also suggest that, in the future, non-starch polysaccharide determinations might provide a better indication of the energy value of a fibrous feedstuff.

This leads to the question of how best to express the energy content of feedstuffs for horses. This is important because the need for the diet to fulfill energy requirements is fundamental. In the 1908 manual (Anon 1908), a guide was given only with respect to how much should be fed, with no indication concerning adjustments for different body weights, breeds or how to judge work intensity (see Table 3). However, this manual was designed perhaps for a more consistently managed and exercised group of horses compared with today’s “pleasure” horse, which may be asked, for example, to sprint maximally and repetitively over short distances or to work at a submaximal pace over several days. In addition, the 1908 manual could not be considered a nutrition book, but was designed as a practical guide for those caring for and relying on horses. In the 1927 nutrition book (Linton 1927), a large number of ways of expressing the energy content of a feed were discussed including kilocalories, maintenance starch equivalent, production starch equivalent, food units, metabolizable energy and net energy. This author preferred starch equivalents and based energy requirements on the weight of the horse and fundamentally the number of hours worked (see Harris 1997). With the increased understanding of the role of fiber has come the appreciation that the DE system of assessing feeds for horses tends to overestimate the energy potential of a high fiber feed compared with a highly hydrolyzable feed. This is because fiber produces predominately short-chain volatile fatty acids that are not used as efficiently as glucose to provide mechanical energy.

Today there is still confusion over how we should define the energy content of feeds: should it be joules or calories or HFU/UFC (horse feed unit/une unit fouragire cheval)? Should it be metabolizable energy (ME), digestible energy (DE), net energy (NE), total digestible nutrients (TDN) or what? Should it be based on body weight or metabolic body weight (see Harris 1997). With the increased understanding of the role of fiber has come the appreciation that the DE system of assessing feeds for horses tends to overestimate the energy potential of a high fiber feed compared with a highly hydrolyzable feed. This is because fiber produces predominately short-chain volatile fatty acids that are not used as efficiently as glucose to provide mechanical energy.

The following tables (2 and 3) provide a comparison of the nutrient composition of two feedstuffs as given in 1908, 1927, and 1989.

### Table 2
Basic nutrient composition of two feedstuffs as given in 1908, 1927 and 1989

<table>
<thead>
<tr>
<th></th>
<th>1908 (Anon 1908)</th>
<th>1927 (Linton 1927)</th>
<th>1989 (NRC 1989)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flesh-making group</td>
<td>Fat-heat-energy group</td>
<td>Fat-heat-energy group</td>
</tr>
<tr>
<td>Oats</td>
<td>11.3</td>
<td>57.3</td>
<td>5.4</td>
</tr>
<tr>
<td>Meadow hay</td>
<td>9.2</td>
<td>42.9</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Protein (crude)</td>
<td>Soluble carbohydrates</td>
<td>Fat</td>
</tr>
<tr>
<td>Oats</td>
<td>10</td>
<td>58</td>
<td>5</td>
</tr>
<tr>
<td>Meadow Hay</td>
<td>8</td>
<td>41</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Protein (crude)</td>
<td>Non-structural carbohydrate (NSC)</td>
<td>Fat</td>
</tr>
<tr>
<td>Oats</td>
<td>11.6</td>
<td>46</td>
<td>4.6</td>
</tr>
<tr>
<td>Meadow Hay</td>
<td>8.6</td>
<td>17</td>
<td>2.3</td>
</tr>
</tbody>
</table>

1. Based on the use of Equation 2 in text.

### Table 3
Feeding recommendations in 1908 (Anon 1908)

<table>
<thead>
<tr>
<th>Work intensity</th>
<th>Hard</th>
<th>Moderate</th>
<th>Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weight of feed recommended, lbs&lt;sup&gt;2&lt;/sup&gt;</td>
<td>24–34</td>
<td>20–24</td>
<td>15–18</td>
</tr>
<tr>
<td>Approx. amount or proportion of cereals</td>
<td>50%</td>
<td>50%</td>
<td>5–6lbs</td>
</tr>
<tr>
<td>Remainder of diet forage (hay/bulk), lb</td>
<td>12–17</td>
<td>10–14</td>
<td>10–12</td>
</tr>
</tbody>
</table>

1. Suggested should feed either one of the following: 1) cereals 3–4 times a day (mixed with chaff), Hay small amounts in the morning. More at midday but most at evening stalls; or 2) whole of hay intake chaffed and mixed with the cereal and supplied almost continuously throughout the day using a nosebag.
2. 2.2 lb = 1 kg.
TABLE 4

<table>
<thead>
<tr>
<th>Maintenance starch equivalent (metabolizable energy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For a 1000-lb horse = 13,000 kcal (based on Linton’s work in 1917) = 7.5 lbs maintenance starch equivalent ± 0.5 lb of maintenance starch equivalent for every 100 lbs above/below 1000 lbs body weight (BW).</td>
</tr>
</tbody>
</table>

Production starch equivalent (net energy)

| For a 1000-lb horse at rest = 5 lbs production starch equivalent ± 0.3 lb for every 100 lbs above/below 1000 lb BW. |
| Exercise = rest + 1 lb of production starch equivalent for every hour of work NB. |

2.2 lbs = 1 kg, 4.184 MJ = 1 Mcal

WHAT OF THE FUTURE?

There are certainly still many challenges facing equine nutritionists, in particular understanding the potentially differing nutritional needs of the competition horse in the various disciplines from rodeo to 3-d eventing. It is hoped that the results of the work on fiber degradation together with a better understanding of the NE system, an appreciation of the effects of type of feed and time of feeding on digestibility in various segments of the gastrointestinal tract and an understanding of how the end products arising from the digestion of these different feeds are metabolized under different circumstances, will enable us to be in a better position to modify the diet to maximize performance while minimizing risks due to nutrient imbalances.

LITERATURE CITED


the area of NE requirements of the horse. This work has been carried out in particular in France at the Institute National de la Recherche Agronomique. The French NE system was developed to allow for the differences in utilization of the ME available from different feeds, depending on the proportion of the end products of digestion produced and the biochemical pathways used by these end products to produce mechanical energy (Martin-Rosset et al. 1994, Vermorel et al. 1984). The NE system does have the advantage of allowing for the differences in energy available for use from different feedstuffs; however, it relies on the fact that maintenance requirements for energy account for the largest part of the total energy requirement and that the NE value (2250 kcal) of 1 kg of standard barley (87% dry matter basis) in a horse is the same for maintenance as for work. Because of the increased heat production associated with work, this may not be a valid assumption (Harris 1997, Kronfeld 1996). This is an area that will promote much discussion over the next few years.

Equations for energy requirements provided today range from determining the duration of exercise at each particular speed (Lewis 1995, Martin-Rosset et al. 1994) to an incremental factor used to multiply maintenance needs according to whether the workload can be considered to be light, moderate or hard (NRC 1989) as outlined in Harris (1997). In 1927 (Linton 1927), it was stated that “one must remember that the only satisfactory method of feeding working horses is for the stable manager to study the needs of each individual horse and the capabilities of the drivers.” It has also been pointed out that “on a purely practical basis it is appreciated that horses fed insufficient energy sources to meet their requirements will lose weight” (Harris 1997). This author therefore agrees with Hintz and Cymbaluk’s comments (1994) that there is “relatively little advantage in spending more time and resources on further refining the energy requirement equations. It would be more beneficial to carry out studies on factors that influence energy metabolism and the effects of dietary manipulation on energy utilisation.” However, improved understanding and awareness of the confidence intervals for DE requirements at various life stages and work loads would be highly desirable.


