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J.D. Pagan

GERMAN FEEDING STANDARDS

MANFRED COENEN
School for Veterinary Medicine Hannover, Germany

Data about energy and nutrient requirements as well as feeding recommendations for the German horse industry are published by a particular committee set up by the German Society for Nutritional Physiology (GESELLSCHAFT für ERNÄHRUNGSPHYSIOLOGIE [GEH], 1994). Based on reviewed international literature, the tables cover energy, protein, macrominerals (Ca, P, Mg, Na, K, Cl) and trace elements (Cu, Zn, Fe, Mn, Se, I, Co) as well as vitamins (A, D, E, K, B_1, B_2, biotin, folic acid) for maintenance, exercise, reproduction and growth. The following description includes the current data about the requirement and recommendations in horse feeding as published in 1994 by the GEH. However, in some cases additional information published after 1994 may offer the opportunity for reassessing the requirements or to express more precise recommendations. Although this is an essential aspect in the discussion of a new edition of the feeding standards by NRC as well as anybody else, the presented calculations and tables are based on the latest official publication.

Energy and Protein

Maintenance

Digestible energy is still in use for horses comparable to most other countries (for France see Martin-Rosset, 2000). Digestible crude protein is established for protein requirement calculations.

The range of maintenance energy requirements is 0.48-0.62 MJ DE/kg $BW^{0.75}$ x d^{-1}, the standard value is 0.6 MJ DE/kg $BW^{0.75}$ x d^{-1} (143 kcal/kg $BW^{0.75}$ x d^{-1}). The differences to NRC levels are presented in Figure 1.

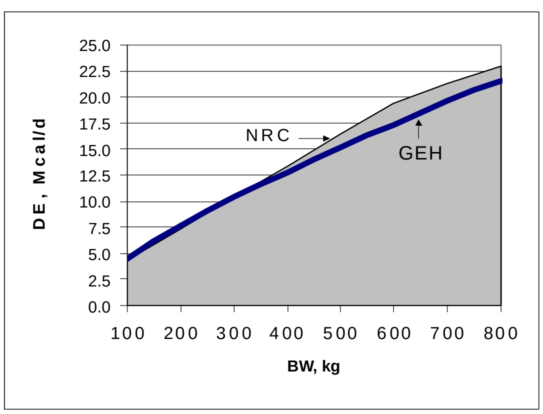


Figure 1. Digestible energy (DE, kcal/d) requirement for different body weights (BW, kg).

The endogenous N-losses and a utilization of digestible crude protein (DCP) of 80% (including a safety margin) yield 0.3 g DCP/kg $BW^{0.75}$ x d^{-1} (Figure 2). There are small differences between GEH and NRC values, if the latter are calculated by 0.6 g DCP/kg BW. The approximation of 40 g CP/kcal DE results in a bigger difference, with NRC data higher compared to those from GEH (see Table 1).

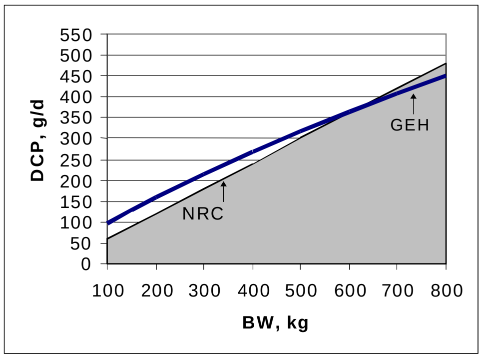


Figure 2. Digestible crude protein (DCP, g/d) requirement for different body weights (BW, kg).

Exercise

The DE required to produce kinetic energy is highly variable. Despite various influences like type of exercise, environment, capacity of the horse etc., in agreement with the NRC the following equation is used to derive the exercise- related DE requirement: DE (kJ/kg BW x h^{-1})=($e^{3.02+0.0065Y}$ - 13.92) x 0.441 (MJ instead of Mcal is used in Europe; 4.186 is the factor to convert Mcal to MJ).

For practical considerations it is crucial to have precise information about the exercise load on the one hand and not fail to recognize variable influences on the calculated requirement on the other hand. Particularly for horse keepers less experienced in animal production, a score system for evaluating the degree of exercise would be helpful. As a common practice low, medium or high intensity exercise creates an increase in relation to maintenance of 1.25, 1.25-1.5 and 1.5-2, respectively. These factors are also used by NRC.

In general, it is claimed that working muscle does not require additional protein. The elevated feed intake (increase in endogenous N-losses) and amino acid breakdown for energy metabolism and finally N-losses via sweat may change the DCP requirement. But as the DCP:DE ratio (g:MJ) in most feedstuffs is >5:1 (= >209 g DCP:1 Mcal), a sufficient DCP intake can be assumed even if the factorial approach may underestimate the DCP requirement. On the other hand, a protein supply approaching threefold the maintenance requirement is unfavorable. We recommend to keep the intake of DCP < 2 g/kg BW. Calculations for a 500 kg mature horse are presented in Table 1, comparing the data according to GEH and NRC, respectively.

Reproduction

The nonlinear curve for fetal growth reflects the accretion of energy and nutrients occurring mainly in the last months of pregnancy (Figure 3). From the growth curve and the body composition of the fetus, the energy and nutrient deposition as percentages of the total amount at birth can be calculated (Table 2). The estimation of a foal's birth weight is done by a regression equation (birth weight, kg = 0.45 * kg mare's $BW^{0.75}$), although this equation results in an over- and underestimation, respectively, of foals in small and large breeds, it is a helpful

Table 1. Daily energy and nutrient requirements for a 500 kg horse (GEH, 1994 vs. NRC, 1989).

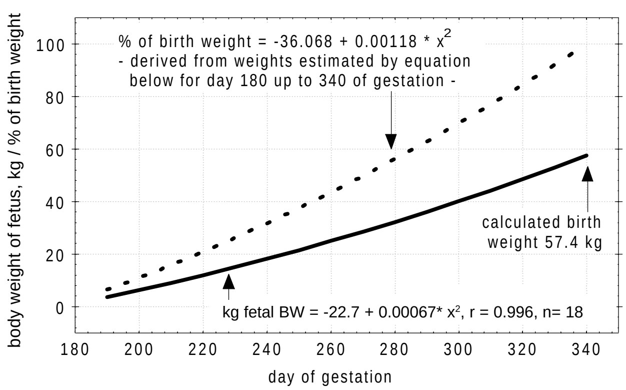
BW, kg	DE, Mcal	DCP, g	Ca, g	P, g	Mg, g	Na, g	K, g	Cl, g
Maintenance, 500 kg BW								
GEH	15.2	317	25	15	10	10	25	40
NRC	16.2	361[1]	25	18	9.4	-	31.2	-
Exercise a) 60 min, 250 m/min								
GEH	19.8	595	26	15	11	28	35	68
NRC	20.5	451	25	18	9.4	-	31.2	-
Exercise b) 60 min, 250 m/min + 15 min 400 m/min + 5 min 600 m/min								
GEH	27.7	581	28	15	12	57	52	115
NRC	32.8	722	30	21	11.3	-	37.4	-
Reproduction, aa) pregnancy 8th month								
GEH	18.9	450	33	19	10	12	26	41
NRC								
Reproduction, ab) pregnancy 9th 10th month								
GEH	19.8	505	38	22	10	12	27	41
NRC	18.2-18.5	448	35	26	8.7	-	29.7	-
Reproduction, ac) pregnancy 11th month								
GEH	21.0	560	39	23	10	12	27	41
NRC	19.7	476	37	28	9.4	-	31.5	-
Reproduction, b) lactation, 3rd month								
GEH	29.6	720	55	42	13	14	45	36
NRC	28.3	785	56	36	10.9	-	46	-
Growth 3rd 6th month								
GEH	15.1	580	37	27	5	6	13	20
NRC	14.4	396	34	19	3.7	-	11.3	-
Growth 7th-12th month								
GEH	15.8	540	30	21	7	7	16	26
NRC	15.0-17.2	413-473	29-36	16-20	4-4.3	-	13	-
Growth 13. -18. month								
GEH	16.2	485	30	20	8	8	19	31
NRC	18.9-21.3	468-526	29-34	16-19	5.6	-	18	-
Growth 19.-24. month								
GEH	16.7	445	29	19	9	9	22	34
NRC	19.8	491	27	15	6.4	-	21.1	-
Growth 25.-36. month								
GEH	17.7	415	28	18	10	10	24	38
NRC	18.8	400	24	13	7.0	-	23.1	-

[1] Assuming a crude protein digestibility of 55% accordingly (NRC, 1989).

Table 2. Intrauterine fetal growth, energy and nutrient accretion.

	Accretion/month in % of total at birth				
pregnancy, month	fetal BW	energy, protein	Ca, P	Mg, K	Na, Cl
up to 7^{th}	17	10.5	10	15	16
8	18	14	14	15	21
9	19	21.5	22	21	19
10	23	23	36	22	28
11	23	31	18	27	16

Figure 3. Body weight (y) of the fetus in horses depending on day of gestation (x)



tool to predict energy and nutrient accretion during the last month of gestation. The pregnancy related requirement is calculated by the following equations: MJ DE/day = 0.004851 x a x $BW^{0.75}$; DCP, g/day = 0.06055 x a x $BW^{0.75}$; a is the relative accretion in each month of pregnancy as described in Table 2. A sufficient body condition is essential for breeding mares, and the plane of nutrition is important because accretion occurs not only in the pregnant uterus but also in maternal tissues.

To enable the mare to realize energy and protein deposition in maternal tissues, the additional requirement is calculated by: MJ DE/day= BW x 0.0164; g DCP/day = BW x 0.085. The requirement during lactation depends on milk yield (kg milk/kg $BW^{0.75}$: 1st month 0.14, 2nd month 0.17 and 5th month 0.12) and milk composition (NRC, 1989). The utilization of DCP and DE for milk production is set at 50 and 66%, respectively. Results of calculations for the requirements of pregnant mares are presented in Table 1.

Growth

A summary of data taken from the literature yields a model to predict a foal's actual BW in relation to mature BW depending on age; the regression equation (BW % = log (mature BW, kg) + 35469 x log (0.3345 x age, month + 1.1114); r = 0.989) describes the nonlinear growth curve which on average results in 72-57% of mature BW for a yearling (Figure 4).

The composition of the weight gain in the foal is calculated by use of the NRC (1978) equations for fat and protein (body fat % = 0.1388 x relative BW + 1.111; body protein % = 0.22 x (100 - body fat) and completed for macro-elements by literature data (Table 3).

The utilization of DE for growth is set at 60% as in other species, while for DCP, 50% is assumed for the 3rd - 6th month and 35% for older foals. Further information on amino acid turnover would present a more precise figure, taking into account what protein quality is needed. For a 6-month-old foal and a yearling, respectively, 2.3 and 1.88 g of lysine are recommended. Adapted from pigs the S-containing amino acids and threonine should be 0.6 in relation to lysine (=1).

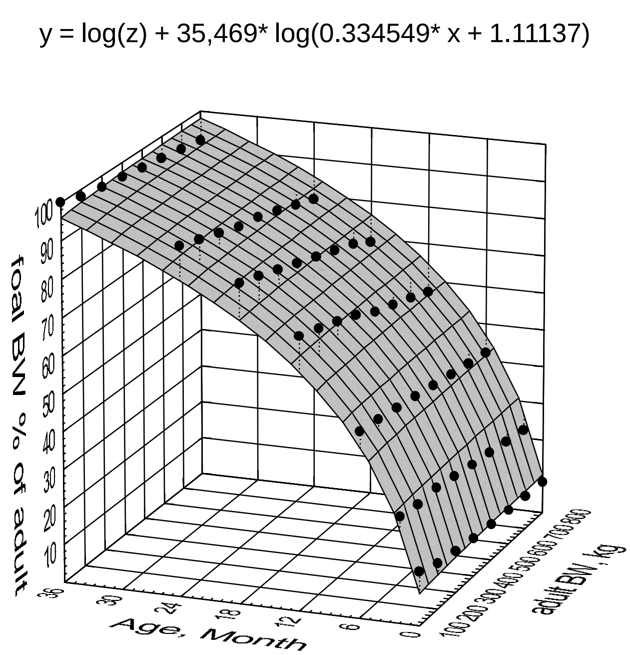


Figure 4. Body weight of foals (y, % of mature BW) depending on age (x, month) and mature body weight (z, kg).

Table 3. Estimated composition of foal's weight gain (per kg; mature BW 600 kg).

<table>
<tr><td>age</td><td>protein</td><td>fat</td><td>energy</td><td>Ca</td><td>P</td><td>Mg</td><td>Na</td><td>K</td><td>Cl</td></tr>
<tr><td>month</td><td colspan="2">g</td><td>Mcal</td><td colspan="6">g</td></tr>
<tr><td>3- 6</td><td>197</td><td>106</td><td>2.126</td><td>18</td><td>9</td><td>0.5</td><td>1.5</td><td>2.0</td><td>1.2</td></tr>
<tr><td>7-12</td><td>186</td><td>157</td><td>2.556</td><td>17</td><td>8</td><td>0.4</td><td>1.6</td><td>1.8</td><td>1.2</td></tr>
<tr><td>13-18</td><td>176</td><td>199</td><td>2.891</td><td rowspan="3">15</td><td rowspan="3">8</td><td rowspan="3">0.4</td><td rowspan="3">1.7</td><td rowspan="3">1.8</td><td rowspan="3">1.2</td></tr>
<tr><td>19-24</td><td>170</td><td>229</td><td>3.153</td></tr>
<tr><td>25-36</td><td>165</td><td>257</td><td>3.392</td></tr>
</table>

Table 4. Growth rate (GR, g/d) and growth related daily requirements for digestible energy (DE) and digestible protein (DCP) in foals.

age	200[1]			400[1]			600[1]		
month	GR	DE	DCP	GR	DE	DCP	GR	DE	DCP
	g	Mcal	g	g	Mcal	g	g	Mcal	g
3 -6	344	1.28	134	656	2.37	256	984	3.49	388
7-12	242	0.99	126	440	1.93	230	560	2.38	298
13-18	132	0.68	64.6	264	1.33	132	429	2.07	216
19-24	87	0.48	41.1	175	0.94	84.0	295	1.55	143
25-36	44	0.26	20.0	110	0.69	50.9	181	1.02	85.4

[1] Mature body weight (kg)

For the derivation of complete requirements, the higher energy requirement for maintenance compared to adults is taken into account (month [M] 3rd-6th: 0.21; M 7th-12th: 0.167; M 13th-18th: 0.151; M 19th-36th: 0.143 Mcal/kg $BW^{0.75}$ x d^{-1}). For foals kept outside or in groups an extra 20% is added. The recommended relation DCP:DE Mcal of 20.9:1 is used to calculate maintenance requirements for DCP in foals.

Macroelements

Endogenous losses and assumed utilization are the basic data for calculation of macroelement requirements (Table 5). The utilization of calcium can be higher than 60% if the Ca intake is low. The utilization of phosphorus is rather low, recognizing the amount of P in concentrates which is mainly in the form of phytate-phosphorus. The principle to combine endogenous losses with utilization to calculate requirements fails in the case of chloride. Fecal losses are low and nearly completely independent of Cl intake. Intake covering endogenous losses is nearly sufficient to avoid metabolic alkalosis, the typical effect of Cl depletion in horses as in other animals, but an increase in pH and bicarbonate in blood is still present. At 80 mg/kg BW x d^{-1} normochloremia as well as no influence on acid-base balance can be expected; therefore requirement calculations are based on these data.

Table 5. Endogenous losses, utilization and derived daily requirement for macroelements.

		Ca	P	Mg	Na	K	Cl
endogenous losses	mg/kg BW x d^{-1}	30	12	7	18	40	5
utilization	%	60[1]	40[2]	35	90	80	100
maintenance requirement	mg/kg BW x d^{-1}	50	30	20	20	50	80[3]

[1] Lower if P intake is high
[2] Higher for P from inorganic sources, lower for P in phytate
[3] Less than 80 mg C1/kg BW x d^{-1} and even balancing endogenous losses is not sufficient to prevent changes in acid-base balance.

Table 6. Sweat composition.

element	g/l	element	mg/1
Na	3.1	P	<10
K	1.6	Zn	11
Cl	5.5	Fe	5
Ca	0.12	Cu	0.3
Mg	0.05	Se	traces

Table 7. Mean mineral accretion in fetus (F) and fetus plus adnexes (F+A) in 9th-11th month of gestation (mg/kg BW x d^{-1}).

	mature body weight, kg							
	200		400		600		800	
element	F	F+A	F	F+A	F	F+A	F	F+A
Ca	18.1	19.9	15.2	16.7	13.7	15.1	12.7	14.0
P	9.6	10.6	8.1	8.9	7.3	8.0	6.8	7.5
Mg	0.36	0.40	0.31	0.34	0.28	0.31	0.26	0.29
Na	1.6	3.2	1.3	2.6	1.2	2.4	1.1	2.2
K	1.7	3.4	1.5	3.0	1.3	2.6	1.2	2.5
Cl	1.0	2.0	0.8	1.6	0.8	1.6	0.7	1.4

The sweat volume and sweat composition (Table 6) and mineral accretion in fetus and adnexes (Table 7) determine exercise- and pregnancy-related requirements, respectively. The same utilization is taken into account as for maintenance requirements. Although the development of the fetus is nonlinear, formulation of the pregnancy-related requirement is based on the average mineral accretion in the fetus plus adnexes for the 9th through the 11th month of gestation. By recognizing the adnexes, the net accretion in the fetus is elevated by 10% for Ca, P and Mg and by 50 % for the electrolytes. Finally the composition of foal's weight gain and growth rate (Tables 3 and 4) makes it possible to calculate the requirement for growing horses. The results for a 500 kg horse are included in Table 1.

Trace Elements

In general there is a lack of precise information on the trace element requirements in horses. The current recommendations are in part taken from other species. The usual dimension is mg/kg dry matter (DM), assuming a mean DM intake of 2 kg/ 100 kg BW x d^{-1}.

There are comparable recommendations for growing, breeding and exercising horses (Table 8). The rather high iron (Fe) accretion during pregnancy (75-185 µg/kg BW x $d^{-1)}$ as well as Fe output by milk contribute to levels of 80-100 mg/kg DM. The higher demand for copper (Cu) in foals compared to other horses is reflected by 12 mg Cu/kg DM.

Vitamins

Similar to trace elements, the database for vitamin requirement is incomplete; therefore the recommendations are assumptions and partly based on observations in practice (Table 8). For the fat-soluble vitamins, GEH recommends a broad range for horses. In part there is a higher intake proposed for exercising horses (Vitamins E, B_1). The results from experiments adding ß-carotene are controversial; therefore no clear level can be expressed as a special carotene requirement. Although in some cases supplemental vitamins or vitamin-like substances may be of benefit (folic acid - exercise, ascorbic acid - aged horses, carnitine - exercise), the experimental results do not provide rationale for clear recommendations.

Table 8. Recommendations for trace elements and vitamins in horse feeding.

		maintenance and exercise	breeding horses	foals
iron (Fe)	mg/kg DM	60 80	80	80 – 100
copper (Cu)	mg/kg DM	7 – 10	8 10	10 12
zinc (Zn)	mg/kg DM		50	
manganese (Mn)	mg/kg DM		40	
cobalt (Co)	mg/kg DM		0.05 0.1	
selenium (Se)	mg/kg DM		0.15	
iodine (I)	mg/kg DM	0.1 0.2		
vitamin A	IE/kg BW x d^{-1}	75	100 – 150	150 200
vitamin D	IE/kg BW x d^{-1}	5 10	15	15 20
vitamin E	mg/kg BW x d^{-1}	1 2[1]	1	1
vitamin B_1	mg/kg DM		3[2]	
vitamin B_2	mg/kg DM		2.5	
biotin	mg/kg DM		0.05	

[1]For strenous exercise 4 mg/kg BW x d^{-1}
[2]For strenous exercise 5 mg/kg DM

Table 9. Mean dry matter (DM) intake (kg/100 kg BW x d^{-1}).

BW, kg	maintenance		exercise		gestation		lactation		Growth, month of age					
- mature -									3	6	7	12	13	24
200	1.3	1.6	1.8	2.9	1.9	2.1	2.4	3.0	2.8	3.2	2.6	3.0	2.1	2.5
400	1.2	1.4	1.5	2.4	1.6	1.8	2.0	2.5	2.0	2.5	1.8	2.2	1.6	1.8
600	1.1	1.3	1.4	2.2	1.4	1.6	1.8	2.3	1.9	2.2	1.8	2.0	1.5	1.7
800	1.0	1.2	1.3	1.5	1.3	1.5	1.7	1.5	1.6	1.8	1.6	1.8	1.3	1.5

Feed and Water Intake

The average DM intake varies between 1.3 and 3.2 kg/100 kg BW x d^{-1}. The different values are summarized in Table 9. The mean water consumption is set at 3-3.5 l/kg DM (liters/100 kg BW x d^{-1}, foals 7-10, maintenance 3-5, lactating mares 8, exercise 3-10). However, environment, interindividual variation, and feed type can give reason for remarkable differences. In consequence, the best way to supply fresh water is freely, indoors as well as outdoors.

Basic Limits for Ration Design

To create a ration means to fulfill the following characteristics:

a) covering requirement
b) keep total DM within the margins for DM intake
c) have a ration which takes into account natural equine eating behavior
d) combine feeds in a compatible ration
e) keep the ration in a reasonable economical frame

The aspects related to a and b are described earlier in this paper. With regard to the natural behavior (~12-13 h/d spent on feed intake) we recommend 1 kg, but at least 0.5 kg hay or an alternate roughage per 100 kg BW x d^{-1}. Beside the horse's activity related to feed intake, the saliva production during chewing (mainly a function of chewing time/g feed) is a further reason to require a specific amount of roughage. Compared to grass or hay, the intake of concentrates results in lower saliva production, accelerated gastric fill without balanced gastric emptying and a rather high dry matter percentage in gastric contents (>30%). To prevent disturbances by this situation, the maximum amount of concentrate is 0.5 kg/100 kg BW x $meal^{-1}$; that means in cases of high energy requirement, 3 or more meals/day are necessary for a safe feeding system.

Selected Aspects for "Brain Storming"

Although nutrient requirements are closely examined before a new edition of feeding standards is published, some further points should be underlined. A system to predict the energy content of individual feedstuffs by chemical composition is an essential instrument in order to convert the knowledge about requirements into feeding practice. But there is a certain influence of the whole ration on the feeding value of a single component of the ration. A reasonable prediction (as well as an agreement as to what kind of calculation anybody should use) of feeding value for the whole ration and the isolated feed would offer remarkable benefit, particularly on the market of mixed feeds.

The described classes of exercise (low, medium and high) in terms of the x-fold of maintenance requirement are a rough but helpful approach to project energy and nutrient requirements for exercise. But they consider the intensity of exercise from the standpoint of requirement. In practice, however, horse keepers need help adapting feeding level to exercise intensity. This requires evaluation of requirement data in relation to duration and speed of exercise. This is very important because many people assume that their horse is in hard work.

More knowledge about digestion in the small and large intestine would be of interest, in particular the digestibility of protein and amino acids. The relation of ammonia in colon draining veins to peripheral venous blood is about 10:1; that means, the liver may be loaded by ammonia as a function of protein intake, protein quality and microbial fermentation in the large intestine.

Observations on the changes in bones in young horses during the first weeks of training stimulate discussion of the mineral supply, particularly Ca intake. However, at present it seems that elevated Ca intake alone is ineffective in minimizing the risk of injury in early training.

There are different results dealing with the anion-cation balance (focused on exercising horses). Possibly they can be introduced in the recommendation for electrolyte supply. The rather high potassium concentration in roughage from intensively used meadows as well as the possible link between glucose uptake by the muscle and the electrolyte homeostasis substantiate the interest in the effects of electrolyte balance in feed on the acid base balance in the horse.

Recent information on selenium in horses indicates that a low selenium intake is not simply related to muscle problems and that the selenium requirement may be overestimated by the current data. The big variation in blood selenium under identical feeding conditions poses the question for the optimal Se intake and the suitable tool for assessment of Se ingestion.

In general the vitamin intake is above the requirement if concentrates are in use. One question reflects a possible interaction between vitamin A and vitamin E in the case of vitamin A excess. A second one is related to the requirement of vitamin D. Some experimental data indicate a certain degree of independence of vitamin D intake for the horse. In consequence, it is doubtful if there is a remarkable vitamin D requirement in the horse; however, the typical recommendations are higher than necessary.

In general the supply of trace elements and vitamins is in excess of requirement in many cases. Limits for a reasonable intake would complete the formulation of recommendations.

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