
VOLUME 62 2002

Effects of age, live weight and dry matter intake on total tract nutrient digestibility in adult mares

P.C.H. MOREL*
Institute of Food, Nutrition and Human Health, Massey University, Private Bag 11-222, Palmerston North 4442, New Zealand
*Corresponding author: p.c.morel@massey.ac.nz

ABSTRACT

The effects of age, live weight (LW) and dry matter intake (DMI) on the total tract digestibility of dry matter (DDM), organic matter (DOM), energy (DE), nitrogen (DN), neutral detergent fibre (DNDF), acid detergent fibre (DADF) and minerals (DCa, DK, DMg, DNa, DP and DS) were investigated in adult thoroughbred mares. Twenty mares, aged between 7 and 16 years (mean = 11.9; standard deviation ± 3.1) and weighing 508 to 650 kg (559.5 ± 36.7 kg) were offered 13 kg of feed per day consisting of 9 kg meadow hay, 3 kg barley and 1 kg lucerne chaff. Total faeces were collected over six days following a 20 day adaptation period. The average digestibility values were DDM: 0.59 ± 0.04; DOM: 0.63 ± 0.03; DN: 0.54 ± 0.08; DNDF: 0.44 ± 0.04, DADF: 0.38 ± 0.06, DE: 0.59 ± 0.04; DCa: 0.48 ± 0.08; DK: 0.68 ± 0.07; DMg: 0.27 ± 0.11; DNa: 0.63 ± 0.13 DP: 0.17 ± 0.11; and DS: 0.59 ± 0.05. Age was only related to DS. DMI (9.16 kg ± 1.1 kg) was negatively correlated ($P < 0.05$) with DDM, DOM and DE while LW was positively correlated ($P < 0.05$) with DDM, OM, DN, DNDF, DADF and DE. Mineral digestibility was not affected by LW or DMI. It is concluded that feed allowances should be adjusted for LW and/or DMI when a given amount of digestible nutrients are provided.

Keywords: horse; age; live weight; dry matter intake; digestibility.

INTRODUCTION

Nutrient digestibility in horses can be affected by animal and dietary factors such as, age, live weight, breed, feed intake and feed/forage quality. However the effects of those factors on digestibility are not always systematic. For example, higher organic matter digestibility has been reported in ponies which are lighter than horses (Slade & Hintz, 1969; Uden & van Soest, 1982), and higher organic and dry matter digestibilities have been reported for heavy mares fed *ad libitum* when compared with lighter horses (Martin-Rosset *et al.,* 1990).

A negative relationship between dry matter intake (DMI) and dry matter digestibility has been observed across and within forages (Edouard *et al.,* 2008). Similarly, in ponies, a decreased dry matter digestibility, obtained by diluting a concentrate diet with hard wood, resulted in an increase in dry matter intake (Laut *et al*., 1985). It is also postulated that horses are able to increase DMI as the quality of the forage decreases (Vernet *et al*., 1995). However, no differences in dry matter or organic matter digestibility were observed when a barley/hay diet was fed at maintenance level or *ad libitum* to light or heavy horses (Martin-Rosset *et al*. 1990) or at 1.06 or 1.26 times maintenance energy requirement to sport horses (Vermorel *et al*., 1997a). The aim of the present study was to investigate the effects of age, live weight and dry matter intake on total tract nutrient digestibility in thoroughbred mares.

MATERIAL AND METHODS

A total of 20 adult thoroughbred mares aged between 7 and 16 years (Mean = 11.9 ± 3.1 (standard deviation)) and weighing between 508 and 650 kg (559.5 ± 36.7 kg), were individually penned in a bare paddock. The pens were fenced with plastic electric tape, and the paddock had previously been freed of plant materials with herbicide treatment (Roundup®, Monsanto, St. Louis, Missouri, USA).

All mares were offered 13 kg per day of a ration consisting of 9 kg meadow hay, 3 kg ground barley and 1 kg lucerne chaff. The horses were acclimated to the diet for 20 days before the start of the six day total faecal collection period as recommended by Martin-Rosset *et al.* (1984). The horses were weighed at the beginning of the acclimatisation period (LW). The weights of hay, barley and lucerne chaff fed to the animal were recorded daily as well as the weight of hay refusal. No barley or chaff refusals were observed. Daily dry matter intake (DMI) and DMI per kg metabolic weight (DMI75 = DMI divided by $LW^{0.75}$) during the collection period were calculated.

During the collection period, samples of hay, barley and lucerne chaff were collected daily, bulked by ingredient, sub-sampled and submitted for chemical analysis. Samples of hay refusal were collected daily for the six day collection period. They were also bulked together, sub-sampled, and submitted for chemical analysis. The faeces were weighed daily and a sub-sample (1 kg) was kept frozen for further processing. The frozen daily sub-samples were then thawed, bulked together by horse and sub-sampled. The bulked faecal sub-samples were freeze dried and submitted for chemical analysis.

Hay, barley, lucerne chaff, hay refusals and faecal samples were chemically analysed for dry matter (DM), organic matter (OM), nitrogen (N), neutral detergent fibre (NDF), acid detergent fibre (ADF), gross energy (GE), calcium (Ca), potassium (K), magnesium (Mg), sodium (Na) phosphorus (P), sulphur (S), and manganese (Mn). All analyses were conducted in duplicate.

TABLE 1: Chemical composition of the feed ingredients on an "as fed" basis.

Component	Hay	Barley	Lucerne	Estimate of mixed diet
Gross nutrient				
Dry matter (g/kg)	941	870	944	925
Organic matter (g/kg)	926	980	911	937
Nitrogen (g/kg)	12	16	28	14
Neutral detergent fibre (g/kg)	616	173	408	498
Acid detergent fibre (g/kg)	370	54	290	291
Gross energy (MJ/kg)	17.1	16.2	17.7	16.9
Mineral				
Ca (mg/kg)	4,452	699	12,804	4,228
K (mg/kg)	9,334	3,593	17,432	8,632
Mg (mg/kg)	2,208	807	1,749	1,849
Na (mg/kg)	3,380	224	508	2,430
P (mg/kg)	1,384	2,089	2,006	1,595
S (mg/kg)	1,417	851	2478	1,368

DM and OM content were determined by the method of AOAC (1990). N content was determined by the Kjeldhal method (AOAC, 1990) on a Kjeltech 10030 auto-analyser (Tecator, Höganäs, Sweden). NDF and ADF contents were determined using the method described by Robertson and van Soest (1981). GE was determined by the method of AOAC (1990) using an adiabatic bomb calorimeter (Gallenkamp and Co. Ltd., London, England). The mineral elements (Ca, K, Mg, Na, P, S) were determined by plasma emission spectrometry at AgResearch Grasslands, Palmerston North, New Zealand). Briefly, 0.5 g of a ground, dry sample was digested in 10mL of concentrated nitric acid. The procedure involved adding the nitric acid, leaving overnight for 12 to16 hours, refluxing at 120 to150°C for three to four hours, then heating strongly at 250 to 300°C to remove the nitric acid until a residue was left. On cooling, the residue was dissolved in 10mL 2M hydrochloric acid. The minerals were then determined by ICP/AES (inductively coupled plasma, atomic emission spectrometry) along with the appropriate standards and blanks.

The apparent digestibility coefficient for DM, OM, N, NDF, ADF, GE and minerals were calculated as in Equation 1. These coefficients are underestimating the true digestibility as endogenous losses are not taken into account.

Relationships between digestibility coefficient and age, live weight or dry matter intake were investigated using correlation and multiple regression methods (proc COR and proc REG, SAS 2008).

The experiment was conducted in accordance with the Massey University Animal Ethics Committee and the New Zealand Code of Practice for the Care and Use of Animals for Scientific Purposes.

RESULTS

The analyses of the feedstuffs used in the study are given in Table 1.

During the trial, the horses always consumed all of the barley and chaff offered, but did not consume all of the hay provided. The percentage of hay refusal ranged between horses from 12.5% to 56.5% (31.4 ± 13.3%). On a dry matter basis the amount of hay eaten by the horses varied between 3.6 kg/d and 7.2 kg/d (5.6 ± 1.1 kg/d). Thus, the variation in DMI (9.16 ± 1.1 kg) was only caused by the variation in hay intake. The dry matter intake per kg metabolic live weight ranged between 58 and 97 g DM/ $kg^{0.75}$ (80 ± 11 g DM/$kg^{0.75}$).

The gross nutrient and mineral digestibility coefficients are presented in Table 2.

The correlation coefficients between age, LW, DMI and DMI75 and digestibility coefficients are

EQUATION 1: Calculation of apparent digestibility.

$$\text{Apparent digestibility of Y (\%)} = \frac{[\text{Total Y intake (Barley + Lucerne + Hay)}] - [\text{Total Y in hay refusals}] - [\text{Total Y in feaces}]}{[\text{Total Y intake (Barley + Lucerne + Hay)}]}$$

where Y is: Dry matter, Organic matter, Gross energy, N, Neutral detergent fibre, Acid detergent fibre, Ca, K, Mg, Na, P or S.

TABLE 2: Mean ± standard deviation for gross nutrient and mineral digestibility coefficients

Component	Digestibility coefficient
Gross nutrient	
Dry matter	0.59 ± 0.04
Organic matter	0.63 ± 0.03
Nitrogen	0.54 ± 0.08
Neutral detergent fibre	0.44 ± 0.04
Acid detergent fibre	0.38 ± 0.06
Energy	0.59 ± 0.04
Mineral	
Ca	0.48 ± 0.08
K	0.68 ± 0.07
Mg	0.27 ± 0.11
Na	0.63 ± 0.13
P	0.17 ± 0.11
S	0.59 ± 0.05

presented in Table 3. Age was only related to sulphur digestibility ($P < 0.05$). Live weight was positively correlated with DDM, DOM, DN, DNDF, DADF, DE and DK ($P < 0.05$). DMI and DMI75 were negatively correlated with DDM ($P < 0.001$), with DOM ($P < 0.01$ and $P < 0.001$) and with DE ($P < 0.01$ and $P < 0.001$). DMI were not related to protein digestion, fibre digestion (NDF or ADF) or mineral digestion. The correlation coefficients between age, LW, and DMI were not different from zero ($P > 0.05$).

DE was highly correlated with DOM digestibility ($r = 0.98$), and the following equation can be used to predict it, as OM is easier to measure that GE.

DE (%) = -8.75 + 1.07 DOM (%) (Coefficient of determination (R^2) = 0.96, Standard error of estimation (SEE) = 0.72, $P < 0.0001$).

The digestibility coefficients for DDM, DOM and DE increased with a reduction in DMI (kg/d) and an increase in LW (kg) as indicated by the multiple regressions shown in Table 4. The digestibility coefficients for DN, DNDF, DADF and DK increased with an increase in LW (kg).

TABLE 3: Correlation coefficient between age, live weight (LW), dry matter intake (DMI), dry matter intake per kg metabolic live weight (DMI75) and digestibility coefficients.

Component	Age	LW	DMI	DMI75
Gross nutrient				
Dry matter (g/kg)	0.28	0.60**[1]	-0.69***	-0.76***
Organic matter (g/kg)	0.30	0.64**	-0.67**	-0.76***
Nitrogen (g/kg)	0.25	0.62**	-0.21	-0.36
Neutral detergent fibre (g/kg)	0.11	0.53*	-0.19	-0.31
Acid detergent fibre (g/kg)	0.04	0.48*	-0.02	-0.15
Gross energy (MJ/kg)	0.23	0.62**	-0.61**	-0.70***
Mineral				
Ca (mg/kg)	-0.01	0.01	0.10	0.08
K (mg/kg)	-0.14	0.50*	-0.22	-0.32
Mg (mg/kg)	0.03	0.16	0.08	0.02
Na (mg/kg)	0.18	0.15	-0.23	-0.22
P (mg/kg)	0.14	0.15	-0.34	-0.33
S (mg/kg)	0.46*	0.20	-0.19	-0.22

DISCUSSION

The digestibility coefficients for DM (0.59), OM (0.63), N (0.54), NDF (0.44), ADF (0.38) and GE (0.59), measured in this study for a mixed diet are at the low end of the range of values reported in the literature for hay/barley/maize mix diets: DM (0.57 to 0.68), OM (0.59 to 0.70), N(0.58 to 0.75), NDF(0.44 to 0.55), ADF(0.40 to 0.49) and GE(0.55 to 0.64) (Martin-Rosset & Dulphy, 1987; Vermorel *et al.,* 1997a, 1997b;).

The digestibility coefficients for Ca (0.48), K (0.68), Mg (0.27), Na (0.63), P (0.17) and S (0.59) measured in the present study are slightly lower than values reported for 300 kg yearlings (Grace *et al.,* 2002a & 2003) and 560 kg lactating mares (Grace *et al.,* 2002b) kept on pasture in New Zealand. These were Ca (0.58 to 0.75), K (0.73 to 0.76), Mg (0.43 to 0.63), Na (0.75 to 0.78), P (0.07 to 0.43) and S (0.72) but are comparable to the values for horses fed mixed diets reported by van Doorn *et al.* (2004): Ca (0.26 to 0.48), P (0.02 to 0.15) and Mg (0.29 to 0.41).

In the horse, as the NDF content of the diet increases the digestibility decreases (Duncan *et al.* 1990; Edouard *et al.* 2008). This could explain why the digestibility values measured in this study are on the low side of published data. The mixed diet had a relatively high content of NDF (538 g/kg DM). Using the equations published by Duncan *et al.* (1990) and Edouard *et al.* (2008) the predicted DDM of 0.58 was close to the observed DDM of 0.59 measured in the present study.

With the exception of sulphur digestibility, differences in age between 7 and 16 years, did not affect the digestibility of the diet. In the literature, to the knowledge of the author, no data have been reported on the effect of age on nutrient digestibility in adult horses.

In this study, the mineral digestibility coefficients were not influenced by DMI or LW, thus suggesting that mineral digestion in horses is mainly driven by feed factors.

TABLE 4: Calculation of apparent digestibility.

DDM= 0.534 – 0.0179 DMI + 0.040 LW (R^2 = 0.62, SEE = 0.023, P <0.001)
DOM = 0.531 – 0.0159 DMI + 0.00043 LW (R^2 = 0.64, SEE = 0.021, P <0.001)
DGE = 0.456 – 0.0151 DMI + 0.00047 LW (R^2 = 0.57, SEE = 0.026, P <0.001)
DN = -0.221 + 0.00135 LW (R^2 = 0.38, SEE = 0.066, P <0.01)
DNDF = 0.095 + 0.00062 LW (R^2 = 0.28, SEE = 0.038, P <0.05)
DADF = -0.031 + 0.00073 LW (R^2 = 0.24, SEE = 0.050, P <0.05)
DK = 0.163 + 0.0009 LW (R^2 = 0.25, SEE = 0.059, P <0.05)

where DDM = Dry matter digestibility; DOM = Organic matter digestibility; DE = Digestibility of gross energy; DN = Digestibility of nitrogen; DNDF = Digestibility of neutral detergent fibre; DADF = Digestibility of acid detergent fibre; DK = Digestibility of potassium; DMI = Dry matter intake; LW = Live weight; SEE = Standard error of estimation.

The results of the multiple regression analysis show that the digestibility coefficients for DDM, DOM and DE increase with either a reduction in DMI (kg/d) or an increase in LW (kg). According to Martin-Rosset and Dulphy (1987), as the interactions between forage and concentrate are negligible, the diet digestibility is the weighted sum of the digestibility of the forage and the concentrate. Given that, in this study, the difference in dry matter intake is only caused by the difference in hay intake, it is possible that the effect of dry matter intake on DDM, DOM and DE was caused by the lower digestibility of hay when compared to barley and chaff. The slope of a linear regression between daily gross energy intake from hay (GEHi, MJ/d)) and the daily digestible energy intake from the diet (DEi, MJ/d)) represents the energy digestibility coefficient of hay and the intercept is the amount of digestible energy supplied by the barley/lucerne chaff concentrate. The energy digestibility coefficient of the concentrate can then be calculated by the intercept by the amount of gross energy provided by the concentrate (66.1 MJ/d).

The linear regression is:

DEi (MJ/d) = 58.1 + 0.395 GEHi (R^2 = 0.72, SEE = 4.79)

The estimated energy digestibility coefficients were 0.395 for hay and 0.880 (58.1/66.1) for the barley/lucerne chaff mix.

The DE value obtained for hay is plausible when compared to a range of values reported by Vermorel *et al.* (1997a) and Bergero *et al.* (2004) for adult horses (0.40 to 0.52).

However, a DE value of 0.88 for a barley/lucerne chaff mix seems unrealistically high. DE coefficients have been reported as 0.80 and 0.55 for barley and lucerne, respectively (NRC, 1989). Therefore, it is possible that in an adult horse, dry matter intake does have a negative effect on DDM, DOM and DE. In the literature, no difference in DDM, DOM, and DE have been reported when mixed diets were fed to groups of adults horse at different levels of maintenance (Martin-Rosset & Dulphy, 1987; Martin-Rosset *et al.,* 1990; Vermorel *et al.,* 1997a,b), but on an individual basis a negative relationship between DMI and DDM has been reported (Edouard *et al.,* 2008). Overall however, it is still not clear which parameter is the main driving force; are the horses adjusting the DMI depending on the DDM of the diet, or does DDM changes as DMI changes?

As live weight increases DDM, DOM, DN, DNDF, DADF and DE increased, which agrees with the results of Martin-Rosset *et al.* (1990) who reported higher organic and dry matter digestibility for heavy, compared with light mares. However, the effect of individual live weight on digestibility coefficients for a given class of horse, have not been reported. In other monogastric species, such as pigs, an improvement in digestibility has been reported as the animals get heavier (Noblet *et al.,* 1994).

CONCLUSION

In adult horses mineral digestion is not affected by animal factors such as age, dry matter intake and live weight, but dry matter, organic matter and energy digestibilities are influenced by both dry matter intake and live weight. Therefore, assuming that the feed digestible energy content is fixed in adult horses, this will result in underfeeding in light horses and overfeeding in heavy horses. The same comment applies when the ration is formulated to meet protein requirements, as protein digestibility decreases as live weight increases. It is concluded that the feed allowance should be adjusted for both DMI and LW when a given amount of digestible energy or protein is to be provided to meet the animal's requirements.

ACKNOWLEDGEMENTS

Funding for this work was provided by Alltech Inc. The skilled assistance of the technical staff at Massey University is greatly appreciated: David Moore, Hillary Shaw, Sue Skinner and Yvette Cottam for the conduct of the trial and the care of the horses and the staff at the Institute of Food, Nutrition and Human Health Nutrition laboratory for the chemical analysis. Thanks are extended to Dr. Neville Grace at AgResearch for the mineral analysis.

REFERENCES

AOAC. 1990: Official methods for analysis, 15th Edition. Association of Official Analytical Chemists, Arlington, Virginia, USA.

Bergero, D.; Miraglia, N.; Abba, C.; Polidori, M. 2004: Apparent digestibility of Mediterranean forage determined by total collection of feaces and acid-insoluble ash as internal marker. *Livestock Production Science* **85**: 235-238.

Duncan, P.; Foose, T.J.; Gordon, I.J.; Gakahu, C.G.; Lloyd, M. 1990: Comparative nutrient extraction from forages by grazing bovids and equids: a test of the nutritional model of equid/bovid competition and coexistence. *Oecologia* **84**: 411-418.

Edouard, N.; Fleurance, G.; Martin-Rosset, W,; Duncan, P.; Dulphy, P.J.; Grange, S.; Baumont, R.; Dubroeucq, H.; Perex-Barberia F.J.; Gordon, I.J. 2008: Voluntary intake and digestibility in horses: effect of forage quality with emphasis on individual variability. *Animal* **2**: 1526-1533.

Grace, N.D.; Gee, E.K.; Firth, E.C.; Shaw, H.L. 2002a: Digestible energy intake, dry matter digestibility and mineral status of grazing New Zealand Thoroughbred yearlings. *New Zealand Veterinary Journal* **50**: 63-69.

Grace, N.D.; Shaw, H.L.; Gee, E.K.; Firth, E.C. 2002b: Determination of the digestible energy intake and apparent absorption of macro element in pasture-fed lactating Thoroughbred mares. *New Zealand Veterinary Journal* **50**: 182-185.

Grace, N.D.; Rogers, C.W.; Firth, E.C.; Faram, T.L.; Shaw, H.L. 2003: Digestible energy intake, dry matter digestibility and effect of increased calcium intake on bone parameters of grazing Thoroughbred weanlings in New Zealand. *New Zealand Veterinary Journal* **51**: 165-173.

Laut, J.E.; Houpt, K.A.; Hintz, H.F.; Houpt, T.R. 1985: The effect of caloric dilution on meal patterns and food intake of ponies. *Physiology and Behavior* **35**: 549-554.

Marin-Rosset, W.; Dulphy, J.P. 1987: Digestibility interaction between forage and concentrate in horses: influence of feeding level – comparison with sheep. *Livestock Production Science* **17**: 263-276.

Martin-Rosset, W.; Andrieu, J.; Vermorel, M.; Dulphy, J.P. 1984: Valeur Nutritive des aliments pour le cheval. *In*: Le Cheval, Reproduction, Sélection, Alimentation, Exploitation. Jarrige, R.; Martin-Rosset, W. eds. INRA, Paris, France. p. 209-238.

Martin-Rosset, W.; Doreau, M.; Boulot, S.;Miraglia, N. 1990: Influence of level of feeding and physiological state on diet digestibility in light and heavy breed horses. *Livestock Production Science* **25**: 257-264.

Noblet, J.; Shi, X.S.; Dubois, S. 1994: Effect of body weight on net energy value of feeds for growing pigs. *Journal of Animal Science* **72**: 648–657.

NRC. 1989: National Research Council. Nutrient requierements of horses. Fifth Edition. Revised. National Academy of Sciences, Washington, DC, USA.

Robertson, J.B.; Van Soest, P.J. 1981: The detergent system of analysis and its application to human foods. *In*: The Analysis of Dietary Fibre in Food. James,W.P.T.; Theander, O. eds. Marcel Dekker Inc., New York, USA. p. 123–158.

SAS. 2008 SAS/STAT Software. Release 9.13. SAS Institute, Cary, North Carolina, USA.

Slade, L.M.; Hintz,H.F. 1969: Comparison of digestion in horses, ponies, rabbits and guinea pigs. *Journal of Animal Science* **28**: 842-843.

Udén, P.; Van Soest, P.J. 1982: Comparison of timothy (*Phleum pratense*) fibre by ruminants, equines and rabbits. *British Journal of Nutrition* **47**: 267-272.

Van Doorn, D.A.; Everts, H.; Wouterse, H.; Beyne, A.C. 2004. The apparent digestibility of phytate phosphorus and the influence of supplemental phytase in horses. *Journal of Animal Science* **82**: 1756-1763.

Vermorel, M.; Martin-Rosset, W.; Vernet, J. 1997a: Energy utilisation of twelve forages or mixed diets for maintenance by sport horses. *Livestock Production Science* **47**: 157-167.

Vermorel, M.; Vernet, J.; Martin-Rosset, W. 1997b: Digestive and energy utilisation of two diets by ponies and horses. *Livestock Production Science* **51**: 13-19.

Vernet,J.; Vermorel, M.; Martin-Rosset, W. 1995: Energy cost of eating long hay, straw and peletted food in sport horses. *Animal Science* **47**: 581-588.