**Supplementary Material**

**Title: Review of feeding conserved forage to horses: recent advances and recommendations**

**Authors:** P.A. Harris 1, A.D. Ellis 2, M.J. Fradinho 3, A. Jansson 4, V. Julliand 5, N. Luthersson 6, A.S. Santos 7 and I. Vervuert 8.

1 *Equine Studies Group, WALTHAM Centre for Pet Nutrition, Leics LE14 4RT, UK*

*2 UNEQUI, Research~Education~Innovation, Southwell, Nottinghamshire, NG25, UK*

*3 CIISA, Faculdade de Medicina Veterinária, Universidade de Lisboa, Av. Universidade Técnica, 1300-477 Lisboa, Portugal*

*4 Dept of Anatomy, Physiology and Biochemistry, Swedish University of Agricultural Sciences, 750 07 Uppsala, Sweden.*

*5AgroSup Dijon, 21079 Dijon Cedex, France*

*6 Hestedoktoren I/S, Bukkerupvej 195, 4360 Kr. Eskilstrup Denmark*

*7  Department of Veterinary Medicine, Escola Universitária Vasco da Gama, 3020-210 Coimbra / CITAB-UTAD – Center for Research and Technology of Agro-Environmental and Biological Sciences, Vila Real, PA Box 1013, 5001- 801 Vila Real, Portugal*

*8 Institute of Animal Nutrition, Nutrition Diseases and Dietetics, Faculty of Veterinary Medicine, University of Leipzig, An den Tierkliniken 9, D-04103 Leipzig, Germany.*

**Corresponding Author**: Pat Harris. E-mail: pat.harris@effem.com

**Supplementary Material S1**

**References from Main text from 2009 and before**

Argenzio, RA, Southworth V and Stevens CE 1974. Sites of organic acid production and absorption in the equine gastrointestinal tract. American Journal of Physiology 226, 1043-1050.

Bélanger G and McQueen RE 1997. Leaf and stem nutritive value of timothy cultivars differing in maturity. Can. J. Plant Sci 77, 237-245.

Boswinkel MA, Ellis AD. and Sloet van Oldruitenborgh-Oosterbaan MM 2007. The influence of low versus high fibre haylage diets in combination with training or pasture rest on equine gastric ulceration syndrome (EGUS). Pferdeheilkunde 23, 123-130.

Buxton DR 1996. Quality-related characteristics of forages as influenced by plant environment and agronomic factors. Animal Feed Science and Technology 59, 37-49.

Cohen ND, Gibbs PG and Woods AM 1999. Dietary and other management factors associated with colic in horses. Journal of the American Veterinary Medical Association 215, 53-60.

Cohen ND, Toby E, Roussel AJ, Murphey EL and Wang N 2006. Are feeding practices associated with duodenitis‐proximal jejunitis? Equine Veterinary Journal *38*, 526-531.

Cohen ND, Vontur CA and Rakestraw PC 2000. Risk factors for enterolithiasis among horses in Texas. Journal of the American Veterinary Medical Association 216, 1787-1794.

Connysson M, Muhonen S, Lindberg J E, Essén-Gustavsson B, Nyman G, Nostell K and Jansson A 2006. Effects on exercise response, fluid and acid-base balance of protein intake from forage-only diets in Standardbred horses. Equine Veterinary Journal Suppl. 36, 648-653

Cookson WR, Rowarth JS and Cameron KC 2000. The response of a perennial ryegrass (*Lolium perenne L*.) seed crop to nitrogen fertilizer application in the absence of moisture stress. Grass and Forage Science 55, 314-325.

Couetil LL and Ward MP 2003. Analysis of risk factors for recurrent airway obstruction in North American horses: 1444 cases (1990-1999). Journal of American Veterinary Medicine Association 223, 1645-1650.

Crozier JA, Allen V G, Jack NE, Fontenot JP and Cochran MA 1997. Digestibility, apparent mineral absorption, and voluntary intake by horses fed alfalfa, tall fescue, and caucasian bluestem. Journal of Animal Science *75*, 1651-1658

Cymbaluk NF, Christison GI, and Leach DH 1989. Nutrient utilization by limit-and ad libitum-fed growing horses. Journal of Animal Science 67, 414-425.

De Fombelle A, Varloud M, Goacher AG, Jacotot E, Philippeau C, Drogoul C and Julliand V 2003. Characterization of the microbial and biochemical profile of the different segments of the digestive tract in horses given two distinct diets. Animal Science77, 293-304.

[Divers TJ](http://www.ncbi.nlm.nih.gov/pubmed/?term=Divers%20TJ%5BAuthor%5D&cauthor=true&cauthor_uid=3512502), [Bartholomew RC](http://www.ncbi.nlm.nih.gov/pubmed/?term=Bartholomew%20RC%5BAuthor%5D&cauthor=true&cauthor_uid=3512502), [Messick JB](http://www.ncbi.nlm.nih.gov/pubmed/?term=Messick%20JB%5BAuthor%5D&cauthor=true&cauthor_uid=3512502), [Whitlock RH](http://www.ncbi.nlm.nih.gov/pubmed/?term=Whitlock%20RH%5BAuthor%5D&cauthor=true&cauthor_uid=3512502) and [Sweeney RW](http://www.ncbi.nlm.nih.gov/pubmed/?term=Sweeney%20RW%5BAuthor%5D&cauthor=true&cauthor_uid=3512502) 1986. Clostridium botulinum type B toxicosis in a herd of cattle and a group of mules. Journal of American Veterinary Medical Association 188, 382-6.

Drogoul C, Pocet C and Tisserand JL 2000. Feeding ground and pelleted hay rather than chopped hay to ponies: 1. Consequences for in vivo digestibility and rate of passage of digesta. Animal Feed Science Technology 87, 117-130.

Dürr L. 2004. Silage effluent production from round baled grass silage. Proceedings of the 20th General meeting of the European Grassland Federation 21-24 June 2004 Luzern, Switzerland, p. 894-896.

Edouard N, Fleurance G, Martin-Rosset W, Duncan P, Dulphy JP, Grange S and Gordon IJ 2008 . Voluntary intake and digestibility in horses: effect of forage quality with emphasis on individual variability. Animal 2, 1526-1533.

Ellis AD and Hill J 2002. Feed factors affecting intake behaviour and water intake in horses. 53rd Annual Meeting of the European Association of Animal Science, 1-4 September 2002, Cairo, Egypt. 259.

Ellis AD, Thomas S, Arkell K and Harris P 2005. Adding chopped straw to concentrate feed: The effect of inclusion rate and particle length on intake behaviour of horses. Proceedings of the Equine Nutrition Conference 1-2 October 2005 Hannover, Germany, 35 -37.

Ellis AD, Visser CK, Van Reenen CG 2006. Effect of a high concentrate versus high fibre diet on behaviour and welfare in horses, Proceedings of the 40th International Congress of the ISAE, 8-12th August 2006, Bristol, UK p.42.

Ellis WC, Wylie MJ and Matis JH 1988. Dietary-Digestive interactions determining the feeding value of forages and roughages. In Feed Science (ed. ER Orskov), pp 177-179. Elsevier, Amsterdam, the Netherlands.

Field M and Wilman D 1996. pH in relation to dry matter content in clamped and baled grass
silages harvested in England and Wales, Proceedings of the XIth International Silage Conference, 8-11th September, 1996, Aberystwyth, Wales, UK p . 126-127.

Galey FD 2001. Botulism in the horse. Veterinary Clinic North American Equine Practice 17, 579-88.

Gordon CH, Derbyshire JC, Wiseman HG, Kane EA and Melin CG 1961. Preservation and feeding value of alfalfa stored as hay, haylage and direct cut silage. Journal of Dairy Science. 44, 1299-1311.

Hassel DM, Rakestraw PC, Gardner IA, Spier SJ and Snyder JR 2004. Dietary risk factors and colonic pH and mineral concentrations in horses with enterolithiasis. Journal of veterinary internal medicine *18*, 346-349.

Henneke DR and Callaham JW 2009. Ad Libitum Concentrate Intake in Horses, Journal of Equine Veterinary Science 29, 425-427.

Hillyer MH, Taylor FG, Proudman CJ, Edwards GB, Smith JE and French NP 2002. Case control study to identify risk factors for simple colonic obstruction and distension colic in horses. Equine veterinary journal 34, 455-463.

Hotschkiss JW, Reid SW and Christley R 2006. Construction and validation of a risk-screening questionnaire for the investigation of recurrent airway obstruction in epidemiological studies of horse populations in Great Britain. Preventive veterinary medicine 75, 8-21.

Hudson JM, Cohen ND, Gibbs PG, and Thompson JA2001. Feeding practices associated with colic in horses. Journal of the American Veterinary Medical Association 219, 1419-1425

Hughes BO and Duncan IJH 1988. The notion of ethological ‘need’, models of motivation and animal welfare. Animal Behaviour 36, 1696–1707.

Hunt LM, Valberg SJ, Steffenhagen K and McCue ME 2008. An epidemiological study of myopathies in warmblood horses. Equine Veterinary Journal 40, 171-176.

Husted L, Sanchez LC, Olsen SN, Baptiste KE and Merritt AM 2008. Effect of paddock vs. stall housing on 24 hour gastric pH with the proximal and ventral equine stomach. Equine Veterinary Journal 40, 337–341.

Jacobsson F 2002. Paketensilering som belyser inverkan av sträckfilmens kvalitet vid inplastning med 6 och 8 lager sträckfilm. BSc Thesis. Dept of Biosystems and Techonology, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Jouany JP, Medina B, Bertin G and Julliand V 2009. Effect of live yeast culture supplementation on hindgut microbial communities and their polysaccharidase and glycoside hydrolase activities in horses fed a high-fiber or high-starch diet. Journal of animal science 87, 2844-2852.

[Keles G](http://apps.webofknowledge.com/OneClickSearch.do?product=UA&search_mode=OneClickSearch&excludeEventConfig=ExcludeIfFromFullRecPage&SID=X1lwKkXsvEPTaKWOLi7&field=AU&value=Keles,%20G), [O'Kiely P](http://apps.webofknowledge.com/OneClickSearch.do?product=UA&search_mode=OneClickSearch&SID=X1lwKkXsvEPTaKWOLi7&field=AU&value=O'Kiely,%20P&ut=12831470&pos=%7b2%7d&excludeEventConfig=ExcludeIfFromFullRecPage), [Lenehan JJ](http://apps.webofknowledge.com/OneClickSearch.do?product=UA&search_mode=OneClickSearch&SID=X1lwKkXsvEPTaKWOLi7&field=AU&value=Lenehan,%20JJ&ut=12811500&pos=%7b2%7d&excludeEventConfig=ExcludeIfFromFullRecPage) and [Forristal PD](http://apps.webofknowledge.com/OneClickSearch.do?product=UA&search_mode=OneClickSearch&SID=X1lwKkXsvEPTaKWOLi7&field=AU&value=Forristal,%20PD&ut=11359345&pos=%7b2%7d&excludeEventConfig=ExcludeIfFromFullRecPage) 2009. Conservation characteristics of baled grass silages differing in duration of wilting, bale density and number of layers of plastic stretch-film. Irish Journal of Agricultural and Food Research 48, 21-34.

La Casha PA, Brady HA, Allen VG, Richardson CR and Pond KR 1999. Voluntary intake, digestibility, and subsequent selection of Matua Bromegrass, Coastal Bermudagrass, and Alfalfa Hays by yearling horses. Journal of Animal Science.77, 2766–2773.

Lemann D 1971. Verlustvorgänge und Schimmelbildung beir der Trocknung und lagerung von Halmfutter. Landtechnische Forschung 19, 180-187.

Little D and Blikslager AT 2002. Factors associated with development of ileal impaction in horses with surgical colic. 78 cases (1986-2000). Equine Veterinary Journal 34, 464-468.

Luthersson N, Hou Nielsen K, Harris P and Parkin T 2009. Risk factors associated with equine gastric ulceration syndrome (EGUS) in 201 horses in Denmark. Equine Veterinary Journal 41, 625-630.

MacLeay JM, Valberg SJ, Pagan JD, Xue JL, De La Corte FD and Roberts J 2000. Effect of ration and exercise on plasma creatine kinase activity and lactate concentration in Thoroughbred horses with recurrent exertional rhabdomyolysis. American Journal of Veterinary Research 61, 1390-1395.

McBride SD and Hemmings A 2005. Altered mesoaccumbens and nigro-striatal dopamine physiology is associated with stereotypy development in a non-rodent species. Behavioural brain research 159, 113-118.

McDonald P, Edwards RA, Greenhalgh JFD and Morgan CA 2002. Animal Nutrition. 6th edition. pp. 518-522. Pearson Prentice Hall, Essex England.

[McGechan](http://www.sciencedirect.com/science/article/pii/S0021863489800678) MB 1989. A review of losses arising during conservation of grass forage: Part 1, field losses. [Journal of Agricultural Engineering Research](http://www.sciencedirect.com/science/journal/00218634) 44, 1-21.

[McGechan](http://www.sciencedirect.com/science/article/pii/S0021863489800678) MB 1990. A review of losses arising during conservation of grass forage: Part 2, storage losses. [Journal of Agricultural Engineering Research](http://www.sciencedirect.com/science/journal/00218634) 45, 1-30.

McGorum BC and Pirie RS 2008. A Review of recurrent airway obstruction and summer pasture associated obstructive pulmonary disease. Ippalogia 19, 11-19.

McGreevy PD, Cripps PJ, French NP, Green LE, Nicol CJ 1995 Management factors associated with stereotypic and redirected behaviour in the Thoroughbred horse. Equine Veterinary Journal 27, 86-91.

McKenzie EC, Valberg SJ, Godden SM, Pagan JD, MacLeay JM, Geor RJ and Carlson GP 2003. Effect of dietary starch, fat and bicarbonate content on exercise responses and serum creatine kinase activity in equine recurrent exertional rhabdomyolysis. Journal of Veterinary Internal Medicine 17, 693-701.

Mihin AM 1940. The role of moisture in the preparation of silages. Feeding of farm animals and fodder production, 233-242.

Miyaji M, Ueda K, Nakatsuji H, Tomioka T, Kobayashi Y, Hata H, and Kondo S (2008). Mean retention time of digesta in the different segments of the equine hindgut. Animal Science Journal *79*, 89-96.

Morrison FB 1956. Feeds and feeding. A handbook for the student and stockman. 22nd ed. The Morrison Publishing Company, Ithaca. New York, USA

Muhonen S, Connysson M, Lindberg JE, Julliand V, Bertilsson J and Jansson A 2008a. Effects of crude protein intake from grass silage-only diets on the equine colon ecosystem after an abrupt feed change. Journal of Animal Science 86, 3465-3472.

Muhonen S, Lindberg JE, Bertilsson J and Jansson A 2008b. Effects on fluid balance and exercise response in Standardbred horses feed silage, haylage and hay. Comparative Exercise Physiology 5*, 133-142.*

Muhonen S 2008. [Metabolism and hindgut ecosystem in forage fed sedentary and athletic horses.](http://pub.epsilon.slu.se/1821/) PhD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Muhonen S, Julliand V, Lindberg JE, Bertilsson J and Jansson A 2009. Effects on the equine colon ecosystem of feeding silage or haylage after an abrupt change from hay. Journal of Animal Science87**,** 2291-2298**.**

Müller C 2005. Fermentation patterns of small-bale silage and haylage produced as a feed for
horses. Grass and Forage Science 60, 109-118.

Müller C 2007. [Wrapped forages for horses.](http://pub.epsilon.slu.se/1442/) PhD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

[Myllykoski J](http://www.ncbi.nlm.nih.gov/pubmed/?term=Myllykoski%20J%5BAuthor%5D&cauthor=true&cauthor_uid=18606025), [Lindström M](http://www.ncbi.nlm.nih.gov/pubmed/?term=Lindstr%C3%B6m%20M%5BAuthor%5D&cauthor=true&cauthor_uid=18606025), [Keto-Timonen R](http://www.ncbi.nlm.nih.gov/pubmed/?term=Keto-Timonen%20R%5BAuthor%5D&cauthor=true&cauthor_uid=18606025), [Söderholm H](http://www.ncbi.nlm.nih.gov/pubmed/?term=S%C3%B6derholm%20H%5BAuthor%5D&cauthor=true&cauthor_uid=18606025), [Jakala J](http://www.ncbi.nlm.nih.gov/pubmed/?term=Jakala%20J%5BAuthor%5D&cauthor=true&cauthor_uid=18606025), [Kallio H](http://www.ncbi.nlm.nih.gov/pubmed/?term=Kallio%20H%5BAuthor%5D&cauthor=true&cauthor_uid=18606025), [Sukura A](http://www.ncbi.nlm.nih.gov/pubmed/?term=Sukura%20A%5BAuthor%5D&cauthor=true&cauthor_uid=18606025), and [Korkeala H](http://www.ncbi.nlm.nih.gov/pubmed/?term=Korkeala%20H%5BAuthor%5D&cauthor=true&cauthor_uid=18606025) 2009. Type C bovine botulism outbreak due to carcass contaminated non-acidified silage. Epidemiology and Infection 137, 284-93.

Nicol CJ, Davidson HPB, Harris PA., Waters AJ and Wilson AD 2002. Study of cri-biting and gastric inflammation and ulceration in young horses. The Veterinary Record 151, 658-662.

Pauly T 1999. Heterogeneity and hygienic quality of grass silage. PhD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Pirie RS, Collie DDS, Dixon PM and McGorum BC 2003. Inhaled endotoxin and organic dust particulates have synergistic proinflammatory effects in equine heaves (organic dust-induced asthma). Clinical & Experimental Allergy 33, 676-683.

Pirie TS, Collie DDS, Dixon PM and McGorum BC 2002. Evaluation of nebulised hay dust suspensions (HDS) for the diagnosis and investigation of heaves. 2: Effects of inhaled HDS on control and heaves horses. Equine Veterinary Journal 34, 337-342.Ragnarsson S 2009. Digestibility and metabolism in Icelandic horses fed forage-only diets.PhD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Ragnarsson S and Lindberg JE 2008. Nutritional value of timothy haylage in Icelandic horses. Livestock Science 113, 202-208.

Raymond SL, Heiskanen M, Smith TK, Reiman M, Laitinen S and Clarke AF 2000. An investigation of the concentrate of selected Fusarium mycotoxins and the degree of mold contamination of field-dried hay. Journal of Equine Veterinary Science 20, 616-21.

Richards N, Hinch GN and Rowe JB. 200. The effect of current grain feeding practices on hindgut starch fermentation and acidosis in the Australian racing Thoroughbred. Australian Veterinary Journal 84, 402-407.

[Ricketts SW](http://www.ncbi.nlm.nih.gov/pubmed/?term=Ricketts%20SW%5BAuthor%5D&cauthor=true&cauthor_uid=6394315), [Greet TR](http://www.ncbi.nlm.nih.gov/pubmed/?term=Greet%20TR%5BAuthor%5D&cauthor=true&cauthor_uid=6394315), [Glyn PJ](http://www.ncbi.nlm.nih.gov/pubmed/?term=Glyn%20PJ%5BAuthor%5D&cauthor=true&cauthor_uid=6394315), [Ginnett CD](http://www.ncbi.nlm.nih.gov/pubmed/?term=Ginnett%20CD%5BAuthor%5D&cauthor=true&cauthor_uid=6394315), [McAllister EP](http://www.ncbi.nlm.nih.gov/pubmed/?term=McAllister%20EP%5BAuthor%5D&cauthor=true&cauthor_uid=6394315), [McCaig J](http://www.ncbi.nlm.nih.gov/pubmed/?term=McCaig%20J%5BAuthor%5D&cauthor=true&cauthor_uid=6394315), [Skinner PH](http://www.ncbi.nlm.nih.gov/pubmed/?term=Skinner%20PH%5BAuthor%5D&cauthor=true&cauthor_uid=6394315), [Webbon PM](http://www.ncbi.nlm.nih.gov/pubmed/?term=Webbon%20PM%5BAuthor%5D&cauthor=true&cauthor_uid=6394315), [Frape DL](http://www.ncbi.nlm.nih.gov/pubmed/?term=Frape%20DL%5BAuthor%5D&cauthor=true&cauthor_uid=6394315), [Smith GR](http://www.ncbi.nlm.nih.gov/pubmed/?term=Smith%20GR%5BAuthor%5D&cauthor=true&cauthor_uid=6394315) and Murray LG 1984. Thirteen cases of botulism in horses fed big bale silage. Equine Veterinary Journal 16, 515-8.

Ringler JE, Hayes S, Brummer M, McCown SM, Parks AG and Lawrence LM. 2009. Comparison of in vivo digestibility estimates obtained from weanling and mature horses receiving the same diet. Journal of Equine Veterinary Science, 29, 347-348.

Rotz CA 2003. How to maintain forage quality during harvest and storage. Advanced Dairy Technology 15, 227-239.

[Sarkijärvi S,](http://apps.webofknowledge.com/OneClickSearch.do?product=CABI&search_mode=OneClickSearch&colName=CABI&SID=Y2hM9TLWr169iBxTw5s&field=AU&value=Sarkijarvi,%20S.&ut=CABI:20123129396&pos=1&excludeEventConfig=ExcludeIfFromFullRecPage)  [Sormunen-Cristian R,](http://apps.webofknowledge.com/OneClickSearch.do?product=CABI&search_mode=OneClickSearch&colName=CABI&SID=Y2hM9TLWr169iBxTw5s&field=AU&value=Sormunen-Cristian,%20R.&ut=CABI:20123129396&pos=1&excludeEventConfig=ExcludeIfFromFullRecPage) [Heikkila T,](http://apps.webofknowledge.com/OneClickSearch.do?product=CABI&search_mode=OneClickSearch&colName=CABI&SID=Y2hM9TLWr169iBxTw5s&field=AU&value=Heikkila,%20T.&ut=CABI:20123129396&pos=1&excludeEventConfig=ExcludeIfFromFullRecPage)  [Rinne M and](http://apps.webofknowledge.com/OneClickSearch.do?product=CABI&search_mode=OneClickSearch&colName=CABI&SID=Y2hM9TLWr169iBxTw5s&field=AU&value=Rinne,%20M.&ut=CABI:20123129396&pos=1&excludeEventConfig=ExcludeIfFromFullRecPage)  [Saastamoinen M](http://apps.webofknowledge.com/OneClickSearch.do?product=CABI&search_mode=OneClickSearch&colName=CABI&SID=Y2hM9TLWr169iBxTw5s&field=AU&value=Saastamoinen,%20M.&ut=CABI:20123129396&pos=1&excludeEventConfig=ExcludeIfFromFullRecPage) 2012. Effect of grass species and cutting time on *in vivo* digestibility of silage by horses and sheep. Livestock Science144, 230-239.

Souris A, Kaczensky P, Julliard R and Walzer C 2007. Time budget-, behavioral synchrony- and body score development of a newly released Przewalski's horse group Equus ferus przewalskii, in the Great Gobi B strictly protected area in SW Mongolia. Applied Animal Behaviour Science 107, 307-21.

Spörndly R 2003. Feed tables for ruminants. Report 257, Department of Animal nutrition and management, Swedish Univ. of Agric. Sci., Uppsala, Sweden.

Stewart J 1838. Stable economy: **a treatise on the management of horses,** in relation to stabling, grooming, feeding, watering, and working. W. Blackwell, Edinburgh, UK.

Sturgeon LS, Baker LA, Pipkin JL, Haliburton JC, and Chirase NK 2000. The digestibility and mineral availability of matua, Bermuda grass, and alfalfa hay in mature horses. Journal of Equine Veterinary Science 20, 45-48.

Tinker MK, White NA, Lessard P, Thatcher CD, Pelzer KD, Davis B and Carmel DK 1997. A prospective study of equine colic risk factors. Equine Veterinary Journal 29, 454-458.

UK Animal Welfare Act 2006, DEFRA; http://www.defra.gov.uk/animalh/welfare/act/index.htm

Valentine BA, Van Saun RJ, Thompson KN and Hintz HF 2001. Role of dietary carbohydrate and fat in horses with equine polysaccharide storage myopathy. J. of American Veterinary Medicine Association 219, 1537-1544

Van Dierendonck MC, Bandi N, Batdorj D, Dugerlham S and Munkhtsog B 1996. Behavioural observations of reintroduced Takhi or Przewalski horses (Equus Ferus Przewalskii) in Mongolia. Applied Animal Behaviour Science 50, 95-114.

Van Soest PJ 1994. Nutritional ecology of the ruminant. 2nd edition. Comstock Publishing Associates, Cornell University Press, Ithaca and London.

Weissbach F 1996. New Developments in Crop Conservation. Proceedings *of* the Xlth International Silage Conference 8th - 11th September 1996, University of Wales, Aberystwyth, pp1-25

Wichert B, Nater S, Wittenbrink MM, Wolf P, Meyer K, Wanner M 2008. Judgement of hygienic quality of roughage in horse stables in Switzerland. Journal of Animal Physiology Animal Nutrition 92, 432-437.

[Wichtel JJ](http://www.ncbi.nlm.nih.gov/pubmed/?term=Wichtel%20JJ%5BAuthor%5D&cauthor=true&cauthor_uid=1917659) and [Whitlock RH](http://www.ncbi.nlm.nih.gov/pubmed/?term=Whitlock%20RH%5BAuthor%5D&cauthor=true&cauthor_uid=1917659) 1991. Botulism associated with feeding alfalfa hay to horses. Journal of American Veterinary Medical Association 199, 471-2.

Wilkinson JM, Wilson RF and Barry TF 1976. Factors affecting the nutritive value of silage. Outlook on Agriculture 9, 3-8

Willing B, Vörös S, Roos S, Jones A, Jansson A and Lindberg JE 2009. Changes in faecal bacteria associated with concentrate and forage-only diets fed to horses in training. Equine Veterinary Journal 41, 908-914.

Wollanke B 2004. Botulism in 16 horses and ponies. Praktischer Tierarzt 85, 252-261.

S 1 – *Example of the range in chemical composition of forages produced and fed to horses in some European regions*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **European****Region** | **Forage** **type** | **Botanical composition** | **DM****(%)** | **CP (%DM)** | **Fibre** |
| **CF****(%DM)** | **NDF****(%DM)** |  **ADF****(%DM)** |
| Nordic andBalticcountries (a) | Hay | Grasses | 85 - 88 | 6.3 - 18 | 31 - 36 | 61 - 63 |  |
| Haylage | Grasses | 43\* - 85 | 6.1 - 20 | 26 - 35 | 50 - 64 | 27 - 41 |
| Silage | Grasses | 25 – 55\* | 10 - 16 | 26 - 37 | 54 - 63 | 29 - 34 |
| Straw | Cereal | 85 | 3.0 | 45 |  |  |
|  |  |  |  |  |  |  |  |
| Central Europe countries (b) | Hay | Grasses | 84 - 86 | 4.8 – 19 | 24 - 38 | 54 - 72 | 27 - 40 |
| Mixed i, iii | 85 - 94 | 6.3 - 20 | 25 - 46 | 53 - 75 | 28 - 53 |
| Haylage | Grasses | 55 - 82 | 6.1 - 16 | 24 - 35 | 55 - 74 | 31 - 48 |
| Mixed i | 55 | 9.6 - 21 | 27 - 35 | 53 - 60 | 30 - 37 |
| Silage | Grasses | 34 - 44 | 9.1 - 19 | 24 - 33 | 48 - 63 | 28 - 35 |
| Mixed i | 34 | 12 - 21 | 25 - 33 | 51 - 59 | 28 - 35 |
| Maize | 30 - 35 | 6.9 - 7.7 | 20 - 21 | 44 - 47 | 22 - 23 |
| Straw | Cereal | 84 - 90 | 3.2 - 4.9 | 40 - 45 | 76 - 80 | 47 - 50 |
|  |  |  |  |  |  |  |  |
| Southern countries (c) | Hay | Grasses ii | 84 - 95 | 5.2 - 8.9 | 26 - 37 | 59 - 68 | 32 - 43 |
| Mixed iii | 83 - 90 | 6.2 - 8.9 | 32 - 38 | 61 - 66 | 38 - 45 |
| Haylage | Grasses  | 59 - 65 | 8.3 - 16 | 27 - 31 |  |  |
| Mixed i  | 59 | 9.4 |  | 61 | 38 |
| Silage | Maize | 31 - 36 | 6.5 - 8.9 | 19 - 28 | 39 - 53 | 21 - 32 |
| Straw | Cereal | 85 - 91 | 2.7 - 5.5 | 36 - 44 | 75 - 77 | 46 – 53 |

\* NB from our consensus definition the forages included here as haylages with a DM <50% would be considered silages and DM >50% haylages.

iMeadow or permanent pasture; ii Oats hay included; iii Meadow hay and consociations of grass x legume hay.

DM: Dry matter; CP: Crude Protein; CF: Crude Fibre; NDF: Neutral detergent fibre; ADF: Acid Detergent Fibre

Adapted from:

(a) Finland, Sweden, Iceland, Denmark, Estonia

References: Särkijärvi *et al*., 2008; MTT, 2010; Saastamoinen and Hellämäki, 2012; Müller and Udén, 2007; Jansson and Lindberg, 2012; Ragnarsson and Lindberg, 2008; 2010; Luthersson, personal data; Kaldmäe *et al*., 2012a; 2012b.

(b) Netherlands, Germany, UK, France

References: CVB, 2010; LUFA Nordwest, personal data; HorseHage, 2014; Tinsley *et al*., 2014; Dulphy *et al*., 1997a; Julliand, personal data; INRA, 2011.

(c) Italy, Spain, Portugal

References: Peiretti *et al*., 2001; Bergero *et al*., 2002; Bergero *et al*., 2005; Bergero and Peiretti, 2011; Clotet, personal data; Casamiglia *et al*., 2004; Dentinho *et al*., 2014; Fradinho *et al*., 2013; INIAV, not published.

S2. *Summary of voluntary intake behaviour of horses fed various diets ad libitum with feed intake time over 24 hours (ADF – Acid detergent fibre; Wet Matter – WM; Dry Matter-DM; ± s.d. STB – Standardbred, TB - Thoroughbred)*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Reference** | **Horses/****Ponies** | **Feed (24 hr observations unless stated otherwise)** | **WM intake 500 kg horse** | **Average DM Intake** in %BW | **Intake\* Rate** min/kg | **Mean Intake Time** hrs/24hrs |
| Vulink (2001)  | Wild Konik  | Nature Reserve, NL,  |  |  |  | 13 ± 2.0 |
| Van Dierendonck *et al.* (1996) | Przewalsky | Mongolia steppe grass (18 hrs) |  |  |  | 12 ± 3.6 |
| Magnusson *et al*.(1994) | Icelandic  | Iceland Grass Plains  |  |  |  | 14 ± 2.5 |
| Berger *et al.*(1999) | Przewalsky | Nature Reserve, D  |  |  |  | 11 ± 4.4 |
| Ferreira *et al*. (2013)Osoro *et al*. (2015) | Galiciano | Western Asturias, June, Heathland,Sep |  | 5.32.7 | 2211 | 12 ± 0,8 |
|  ***Mean Free-ranging, semi-feral horses on grass*** |  |  |  | **12.4 ±2.7** |
| Houbiers and Smolders (1990) | 12 TB Trotters | Fresh cut summer grass (long DM 16%)  | 80 | 2.1 | 10 | 13.37 |
|  |  | Fresh cut spring grass(short DM 14%)  | 84 | 2.3 | 8 | 11.16 |
|  | 12 Warmblood | Fresh cut summer grass (long DM 16%)  | 85 | 2.1 | 10 | 14.15 |
|  |  | Fresh cut spring grass(short DM 14%) | 90 | 2.4 | 8 | 11.95 |
| Chenost and Martin-Rosset (1985) | TB | Fresh cut hybrid ryegrass (DM 20%) | 52 | 2.6 | 12 | 10.36 |
| Dulphy *et al*. (1997a) | Light horses | Fresh forages (n=16) | 63 | 2 | 10 | 10.57 |
| ***Mean Barn/Stabled horses with cut Fresh Forages/Grass (DM 14 – 20%)*** | **75.6** | **2.3** | **9.67** | **12 ± 1.5** |
| Bergero *et al*. (2002) Haylages (some nearly silages) | Ponies Rest | Early cut (DM 56%) | 19 | 2.7 | 30 | 9.36 |
| Light Work | Late cut (DM 63%) | 17 | 2.8 | 30 | 8.52 |
| Med. Work | Late cut (DM 65%) | 19 | 3.1 | 30 | 9.3 |
|  **Mean Stabled, Haylages (DM 56-65%)** | **23.2** | **2.8** | **30** | **9 ± 0.5** |
| Martin-Rosset and Dulphy (1987) | Heavy H.Yearlings | Hay medium quality | 12 | 2 | 40 | 7.75 |
| Vermorel *et al.* (1997) | STB | Hay late cut  | 10 | 1.7 | 40 | 6.42 |
|  |  | Hay medium | 11 | 1.9 | 40 | 7.05 |
| Dulphy *et al.* (1997b) | Light horses | Lucerne hay ( n=12) | 13 | 2.2 | 45 | 9.55 |
|  from various authors |  | Grass hay (n=38) | 13 | 2.2 | 35 | 7.42 |
|  |  | Straws (n=6)# | 7 | 1.3 | 50 | 5.88 |
| Pearson *et al.* (2001) | Ponies | Oat straw | 12 | 2.2 | 45 | 9 |
| Staniar *et al.* (2014) | Quarter H. | Teff Hay (40% ADF)# | 9.1 | 1.7 | 45 | 7 |
|  **Stabled: Mean Hays (DM 85%)** | **12 ± 1.4** | **2.0 ±0.2** | **40 ± 5** | **8 ±1.3** |
| **Stabled: Mean Straws/High ADF\*\* (DM 88% +)** | **10 ± 3.5** | **1.7 ±0.6** | **48±2.2** | **7.3 ± 4.1** |
| Argo *et al.* (2002) | Welsh  | Total Chaff-Pellet Mix | 21 | 3.2 | 25 | 8.61 |
|  | Ponies | As above – pelleted | 25 | 4.4 | 18 | 7.43 |
|  | Day 26 | Max intake pelleted  | 28 | 4.9 | 18 | 8.4 |
| Dugdale *et al.* (2011) | Fat Ponies | Complete Chaff Diet | 12 | 2.3 | 60 | 11.6 |
|  **Mean Concentrate: minimum 50% Chaff Diets**  | **16.5** | **2.75** | **25-60** | **10 ± 1.8** |
|  **Mean Concentrate: Pellets**  | **26.4** | **4.64** | **18** | **8 ± 0.7** |

\*Feed Intake Time as per author or estimated according to Ellis, 2010

# High ADF content: only volume limiting forage - if overruled by intake behaviour can lead to compaction colics

**References for Table S1 and S2**

Argo CMcG, Cox JE, Lockyer C and Fuller Z 2002. Adaptive changes in the appetite, growth and feeding behaviour of pony mares offered ad libitum access to a complete diet in either a pelleted or chaff-based form. Animal Science 74, 517-528.

Berger A, Scheibe K, Eichhorn K, Scheibe A and Streich J 1999. Diurnal and ultradian rhythms of behaviour in a mare group of Przewalski horse (Equus ferus przewalskii), measured through one year under semi-reserve conditions, Applied Animal Behaviour Science 64, 1-17.

Bergero D and Peiretti PG 2011. Intake and Apparent Digestibility of Permanent Meadow Hay and Haylage in Ponies. Journal of Equine Veterinary Science 31, 67-71.

Bergero D, Meineri G, Miraglia N and Peiretti PG 2005. Apparent digestibility of hays in horses determined by total collection of faeces and using internal marker methods. Journal of Food, Agriculture & Environment3, 199-202.

Bergero D, Peiretti PG and Cola E 2002. Intake and apparent digestibility of perennial ryegrass haylages fed to ponies either at maintenance or at work, Livestock Production Science 77, 325-329.

Casamiglia S, Ferret A and Bach A 2004. Tablas FEDNA de valor nutritivo de Forrajes y Subproductos fibrosos húmedos. Fundación para el Desarrollo de la Nutrición Animal. Madrid. Retrieved on 19 Abril 2014, from [*http://www.fundationfedna.org/forrajes/introducci%C3%B3n-forrajes*](http://www.fundationfedna.org/forrajes/introducci%C3%B3n-forrajes)

Chenost M and Martin-Rosset W 1985. Comparaison entre espèces (mouton, cheval, bovin) de la digestibilité et des quantités ingérées des fourrages verts. Annales de Zootechnique, 34, 291-312.

CVB. 2010. Tabellenboek Veevoeding. CVB Reeks 49. Productschap Diervoeder, Den Hag. The Netherlands.

Dentinho MT, Batista JG, Jorge HD, Bessa RJB and Moreira O 2014. Composição química e valor nutritivo de alimentos para animais. INIAV. Retrieved on 27 June 2014, from[*http://www.iniav.pt/gca/index.php?id=1451*](http://www.iniav.pt/gca/index.php?id=1451)

Dugdale A, Curtis G, Cripps P, Harris P and Argo C 2011. Effects of season and body condition on appetite, body mass and body composition in ad libitum fed pony mares. Veterinary Journal 190, 329-337.

Dulphy JP, Martin-Rosset W, Dubroeucq H and Jailler M 1997a. Evaluation of voluntary intake of forage trough-fed to light horses. Comparison with sheep. Factors of variation and prediction, Livestock Production Science 52, 97-104.

Dulphy JP, Martin-Rosset W, Dubroeucq H, Ballet JM, Detour A and Jailler M 1997b. Compared feeding patterns in ad libitum intake of dry forages by horses and sheep. Livestock Production Science 52, 49-56.

Ellis AD 2010. Biological basis of behaviour and Feed Intake in horses, In The impact of Nutrition on the Health and Welfare of Horses (ed. AD Ellis, AC Longland, M Coenen and N Miraglia), pp 53-74. EAAP Publication No. 128, Wageningen Academic Publishers, Wageningen, the Netherlands

Ferreira LMM, Celaya R, Santos AS, Garcia U, Rosa Garcia R, Rodrigues MAM and Osoro K 2013. Foraging behaviour of equines grazing on partially improved heathlands. In Forages and grazing in horse nutrition (ed. M Saastamoinen, MJ Fradinho, AS Santos and N Miraglia) pp 227-230. EAAP publ No. 132, Wageningen Academic Publishers, Wageningen, the Netherlands.

Fradinho MJ, Bessa RJB, Martin-Rosset W, Ferreira-Dias G and Caldeira RM 2013. Nutritional status of *Lusitano* broodmares on extensive feeding systems: body condition, live weight and metabolic indicators. Italian Journal of Animal Science 12, 71.

HorseHage 2014. Typical Analysis charts. Retrieved on 27 June 2014, from [*http://www.horsehageforage.co.uk/WP/?page\_id=108*](http://www.horsehageforage.co.uk/WP/?page_id=108)

Houbiers HJ and Smolders EA 1990. Opname van vers gras van verschillende opbrengsten (Intake of fresh grass from various harvests). In Praktijkonderzoek Paardenonderzoek 1990 (Equine Research 1990) Proefstation voor de Rundveehouderij, Schapenhouderij and Paardenhouderij (PR), Lelystad, The Netherlands

INRA, 2011. Alimentation des chevaux – Tables des apports alimentaires INRA 2011. Martin-Rosset, W. (coord.). Éditions Quae – IFCE

Jansson A and Lindberg JE 2012. A forage-only diet alters the metabolic response of horses in training. Animal 6, 1939–1946.

Kaldmäe H, Olt A, Kass M and Ots M 2012a. Quality of hay and silage at Estonian riding stables. In: *Grassland - a European Resource?* (ed. P Golinski, M Warda and P Stypinski) pp 364 - 366. EGF publication Nº 17. Grassland Science in Europe Oficyna Wydawnicza Garmond, Poznan, Poland.

Kaldmäe H, Rebase C, Olt A and Ots M 2012b. Hobuste silo toiteväärtusest ja kvaliteedist. Agraarteadus XXIII , 38 - 42.

Magnusson J and Thorhallsdottir AG 1994. Horse grazing in northern Iceland – behaviour and habitat selection. Livestock Production Science 40, 77-86.

Martin-Rosset W and Dulphy JP 1987. Digestibility interactions between forages and concentrates in horses: Influence of feeding level - Comparison with sheep. Livestock Production Science 17, 263-276.

MTT 2010. Feedtables for horses. MTT Agrifood Research Finland. Retrieved on 28 June 2014, from [*https://portal.mtt.fi/portal/page/portal/Rehutaulukot/feed\_tables\_english/feed\_tables*](https://portal.mtt.fi/portal/page/portal/Rehutaulukot/feed_tables_english/feed_tables)

Müller CE and Udén P 2007. Preference of horses for grass conserved as hay, haylage or silage. Animal Feed Science and Technology 132, 66–78.

Osoro K, Ferreira LMM, García U, Martinez A, Celaya R 2015. Forage intake, digestibility and performance of cattle, horses, sheep and goats grazing together on an improved heathland. Animal Production Science,doi:10.1071/AN15153, Published online by CSIRO Publishing 22 September 2015.

Pearson RA, Archibald R F and Muirhead RH 2001. Comparison of the effect of forage type and level of feeding on the digestibility and gastrointestinal mean retention time of dry forages given to cattle, sheep, ponies and donkeys. British Journal of Nutrition 95, 88-98

Peiretti P, Mimosi A, Fortina R, Bergero D and Ladetto G 2001. Caratteristiche degli insilati aziendali. L ’ Informatore Agrario 27, 37-40.

Ragnarsson S and JE Lindberg 2008. Nutritional value of timothy haylage in Icelandic horses. Livestock science 113, 202-208.

Ragnarsson S and JE Lindberg 2010. Nutritional value of mixed grass haylage in Icelandic horses. Livestock Science 131, 83-87.

Saastamoinen MT and Hellämäki M 2012. Forage analyses as a base of feeding of horses. In Forages and grazing in horse nutrition (ed. M Saastamoinen, MJ Fradinho, AS Santos and N Miraglia) 305-314. EAAP publication No. 132, Wageningen Academic Publishers,

 Wageningen, the Netherlands.

Sarkijärvi S, Sormunen-Cristian R, Heikkilä T, Komppa J, Rinne M, Saastamoinen M and Jauhiainen L 2008. Effect of grass species and time of cutting on in vivo digestibility in horses and sheep. In Nutrition of the exercising horse. (ed. MT Saastamoinen and W Martin-Rosset), pp. 351-354. EAAP Publication No. 125, Wageningen Academic Publishers, Wageningen, The Netherlands

Staniar WB, Bussard JR, Repard NM, Hall MH and Burk AO 2014. Voluntary intake and digestibility of teff hay fed to horses. Journal of Animal Science 88, 3296-3303.

Tinsley SL, Brigden CV, Barfoot C and Harris PA 2014. Nutrient values of forage grown inthe UK in 2012 -2013. Proceedings of the 7th European Workshop on Equine Nutrition,

September 29th - October 2nd 2014, Leipzig, Germany, pp 82-83.

Van Dierendonck MC, Bandi N, Batdorj D, Dugerlham S and Munkhtsog B 1996. Behavioural

 observations of reintroduced Takhi or Przewalski horses (Equus Ferus Przewalskii) in

 Mongolia. Applied Animal Behaviour Science 50, 95-114.

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

Vulink JT, Cornelissen P, Drost HJ and Prins HHT 2001. Hindgut fermentation is not an evolutionary dead end: comparative feeding ecology of cattle and horses pp 87-103. In: Hungry Herds: Management of temperate lowland wetlands by grazing (ed. JT Vulink) Rijksuniversiteit Groningen, The Netherlands.