Recent studies into the efficacy of Haygain hay steamers

HAYGAIN
hay steamers

Experiment 1.

James, R. and Moore-Colyer, M.J.S. (2010) The effect of steam treatment on the total viable count, mould and yeast numbers in hay using the Haygain steamer *European Workshop for Equine Nutrition, Cirencester,* Sept 2010. The Impact of nutrition on the health and welfare of horses. EAAP publication No. 128. Ed Ellis, A., Longland, A.C., Coenen, M and Miraglia, N.p 128-132

Introduction: It is widely recognised that even good quality hay can contain a wide range of fungal spores, bacteria and mite faeces all of which can initiate the debilitating condition Recurrent Airways Disorder (RAO) in horses (McGorum *et al.,* 1993), and Farmers Lung in humans (Kotimaa *et al.,* 1991). This study sought to determine the effect of steaming at high temperatures in the Haygain HG 1000 steamer on the microbial content of hay.

Method: A 1g sample was taken from 5 different regions of an intact dry bale of hay. 79 ml of maximum recovery diluting (MRD) solution was added to the sample and the mixture was stomached for 2 minutes whereupon it underwent a series of dilutions which were used to inoculate petri-films specifically designed to grow bacteria, yeasts and fungi. Films were incubated for 3-7 days at 33oC for TVC and 20oC for yeasts and fungi. The intact bale was then steamed for 50 minutes in the HG 1000 and the above procedure repeated. This was repeated with 5 separate bales of hay. Colony numbers were counted and the difference between the dry and steamed hay was determined using the Wilcoxon signed rank test.

Results: As shown in Table 1 highly significant ($P<0.008$) reductions in colonies of bacteria (TVC), fungi and yeasts were seen in the steamed hay compared with the dry hay, indicating that steaming kills most of these potentially harmful microorganisms.

Table 1. Microbial colony numbers in dry and hay steamed for 50 minutes in the Haygain steamer.

Microorganism	Dry hay	Steamed Hay	Sig
TVC	381573	4453	0.008
Fungi	1.85 x108	0	0.008
Yeast	6893333	0	0.008

Conclusions: The results of this experiment clearly showed that steaming for 50 minutes in the HG 1000 produced hay devoid of fungi or yeast and with an 86% reduction in bacterial contamination. Horses are therefore consuming clean fodder when eating hay steamed in the HG 1000.

Experiment 2

James, R. and Moore-Colyer, M.J.S. (2013) Hay for horses: The nutrient content of hay before and after steam treatment in a commercial hay steamer. *Proceedings of British Society of Animal Science Conference,* Nottingham April 2013.

Introduction: Previous work has shown that soaking can reduce the nutrient content of hay (Moore-Colyer, 1996; Warr and Petch, 1992), whereas steaming 5 kg hay nets did not cause nutrient depletion (Blackman and Moore-Colyer, 1998). This study sought to determine the extent of nutrient loss from complete bales of hay when steamed for 50 minutes at high temperatures in the HG 1000.

Method: Samples from 5 areas of each bale, were taken from 30 different bales of hay from all over the UK. The same bales were then steamed for 50 minutes in a Haygain steamer and another 30 samples taken, using the same procedure. Samples were immediately stored in a freezer before being dried in a force-draught oven at approx 60oC whereupon they were analysed for total nitrogen by use of the Leco
FP428 nitrogen determinator; sodium, potassium, calcium and magnesium by ICP- AES; phosphorous by colorimetry, water soluble carbohydrates by an automated anthrone method and trace elements by ICP-AES.

Results Nutrient losses are detailed in Table 1 below.

Table 1. Nutrient content of 30 different samples of hay before and after steaming for 50 minutes in the HG 1000

Nutrient (units)	Dry (mean)	Steamed (mean)	Standard error of mean	Significance (P)
N (%)	1.12	1.19	0.025	0.014
Ca (%)	0.39	0.41	0.027	0.428
K (%)	1.36	1.50	0.068	0.041
Mg (%)	0.12	0.12	0.007	0.407
Na (%)	0.13	0.15	0.025	0.465
P (%)	0.15	0.16	0.008	0.276
WSC (%)	12.6	10.3	0.827	0.009
Cu (mg/kg)	46.5	61.3	15.32	0.341
Mn (mg/kg)	108	124	18.03	0.390
Fe (mg/kg)	288	121	120.3	0.174
Zn (mg/kg)	17.5	23.5	1.54	0.001

Conclusions: Steaming for 50 minutes in the HG 1000 had no effect on Ca, Mg, Na, P, Cu, Mn or Fe. The only nutrient to be lost as a result of steaming was WSC which showed a 2.3% loss. This is probably due to partial heat-induced break down of the cellular structure of the hay, allowing nutrient leaching. The loss of WSC would account for the small proportional increases noted in N, K and Zn. The small but significant reduction in WSC may also make this hay a useful fodder when fed to ponies pre-disposed to laminitis.

Experiment 3

Stockdale, C and Moore-Colyer, M.J.S (2010) Steaming hay for horses: The effect of three different treatments on the respirable particle numbers in hay treated in the Haygain steamer. *European Workshop for Equine Nutrition*, Cirencester, Sept 2010. The Impact of nutrition on the health and welfare of horses. EAAP publication No. 128. Ed Ellis, A., Longland, A.C., Coenen, M and Miraglia, N. p136-138

Introduction: It is widely known that even good quality hay contains a high number of respirable particles (those < 5 µm in diameter) and that these particles can initiate the debilitating condition Recurrent Airways Obstruction (RAO) that causes respiratory distress, coughing and nasal discharge. This study sought to determine the efficacy of the HG 1000 steamer at reducing respirable particle numbers in 4 different hays, representing typical hay fed to horses across the UK.

Method: Two replicate bales of hay from four different sources (n= 8) were subjected to 3 treatments: dry, 50 minutes steam in the HG 1000 + shaken immediately, and 50 minutes steam and left to dry for 24 hours before shaking. Respirable particle (RP) numbers were measured from a 5 kg sample by shaking vigorously under a cyclone air sampler for 3 minutes. Differences in respirable particle numbers were determined using analysis of variance and lsd test = t (error df) x s.e.d.

Results : *Table 1. Mean Respirable particle numbers (/kg hay / litre of air) from 2 replicates of four different dry hays*

	Hay 1	Hay 2	Hay 3	Hay 4	s.e.d	Sig
RP numbers	51254^{c}	28506^{b}	12327^{a}	10711^{a}	3897.3	0.005

abc Values in the same row not sharing common superscripts differ significantly (P<0.05).

Table 1 shows that significant differences (P<0.05) exist between respirable particle numbers in hays from different areas of the UK. These differences are most likely due to weather conditions during conservation and the dry matter of the hay when stored.

Table 2. Respirable particle numbers (/kg hay/litre of air) detected in dry, steamed and steamed +24 hours in 4 different hay

	Dry hay	Steamed Hay	Steamed Hay + 24 hours	s.e.d	Sig
RP numbers	25699a	1586b	5398b	1937.5	0.001

Table 2 demonstrates that steaming a wide range of hays for 50 minutes in the HG 1000 significantly (P<0.001) reduced the respirable particle numbers by 94% compared with dry hay.

Moreover steaming the hay and leaving it to rest for 24 hours did not significantly increase the respirable challenge indicating that even after being left for 24 hours steamed hay reduced the respirable challenge to the horse by 79%.

Conclusions: Steaming in the HG 1000 was an effective method for reducing respirable particles numbers in all hays, whether only slightly dusty (hay 4) or highly contaminated (hay 1).

Experiment 4

In vitro fermentation of dry hay and hay steamed for 50 minutes in the HG 1000 Haygain steamer

Introduction: Steaming is a commonly used method by which to cook vegetables, increasing their digestibility and palatability, while conserving their nutrient content. This study sought to determine if steaming hay in the HG 1000 would influence the *in vitro* degradation of hay for horses.

Method: 6 hay samples (3 dry and 3 steamed) were fermented *in vitro* using equine faeces as the microbial inoculum in the gas production technique of Theodorou *et al*. (1994). Gas volume and pressure readings were taken using a pressure transducer over a 65-hour incubation at 370C.

Results:

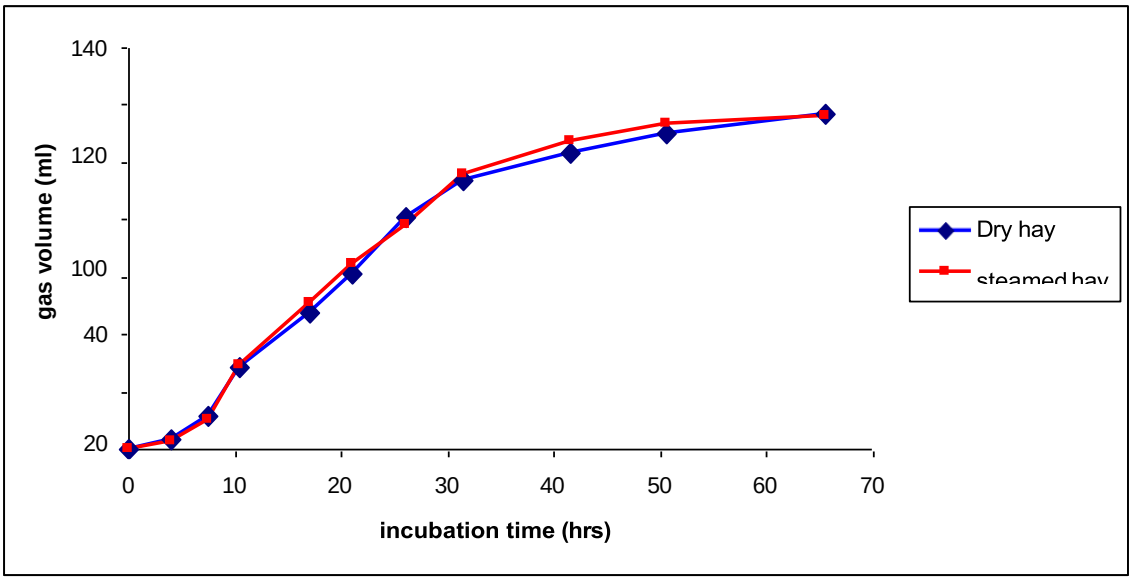


Figure 1. Cumulative gas production profiles for dry hay and hay steamed for 50 minutes in the Haygain steamer

Conclusions: As indicated in Fig 1. No significant differences were detected between gas production profiles from dry and steamed hay showing that despite the small reduction in WSC noted in Experiment 2, steaming did not effect the potential degradability of hay in the hind gut of horses.

Experiment 5

Moore-Colyer, M.J.S. and Payne, V. (2012) Palatability and ingestion behaviour of 6 polo ponies offered a choice of dry, soaked and steamed hay for 1 hour on three separate occasions. *Advances in Animal Biosciences. Healthy Food from Healthy Animals.* Vol 3 part 1. 127

Introduction: Steaming has been shown to be an effective alternative to soaking for reducing respirable particles in fodder (Stockdale and Moore-Colyer, 2010).
However, to date no information is available on the palatability of steamed vs soaked vs dry hay. The current trial sought to determine the palatability of dry, steamed and soaked hay when offered to 6 Polo ponies for 1 hour, previously fed haylage in a repeated measures design experiment.

Methodology Replicate bales of hay were taken from first cut Timothy and Meadow Fescue hay which had been barn-stored for 6 months. Bales were divided into 2. One half was steamed in the HG 600 while 2 x 1 kg hay nets were taken from the other half for the dry and soaked treatments. Six Polo ponies were offered 1 kg each of the dry, soaked and steamed hay simultaneously. The hay was placed on the floor in 3 different corners of a rubber-matted stable, where water was available *ad libitum.* In order to eliminate positional preferences, the experiment was repeated 3 times for each horse with the position of each of the hays being rotated between the 3 corners of the stable. Data was subjected to a repeated measures analysis of variance (Genstat 12). Observations were recorded on the first choice of forage eaten for a consecutive 5 minutes.

Results:

Table 1. Average amount of forage consumed in kg (on 95% DM basis) when offered to 6 polo ponies on 3 separate occasions.

	Steamed	Soaked	Dry	Sed	Sig
Kg of Hay consumed	0.867c	0.050a	0.183b	0.0246	***

abc Values in the same row not sharing common superscripts differ significantly (P<0.001)

Conclusions: The results from this experiment clearly demonstrate that horses preferred to consume steamed hay to dry or soaked hay when offered free-choice in a stable environment. Observations of choice of feed revealed that steamed hay once tasted was always the first consumed. Some horses did nibble some dry hay, but quickly returned to the steamed hay until it was all consumed whereupon they then chose to eat the dry hay.

Experiment 6

Moore-Colyer, M.J.S and Fillery, B.G. (2012) The Effect of three different treatments on the respirable particle content, total viable count and mould concentrations in hay for horses. 6th *European Workshop for Equine Nutrition*, Lisbon, Portugal, June. 101- 106.

Introduction: Many horse owners soak hay to reduce airborne particles, but soaking is laborious, leaches nutrients (Moore-Colyer, 1996) and the resulting post-soak liquor is an environmental pollutant (Warr and Petch, 1992). In contrast, steaming hay in the HG 1000 has been shown by Stockdale and Moore-Colyer (2010) to reduce respirable particle numbers by 91% and fungal colony numbers by 98% (James and Moore- Colyer, 2010). However, the HG 1000 is too big for many owners and accordingly Propress Equine Ltd has produced the HG 600, a smaller version which steams half a bale and works on the same principles as the HG 1000.
This study sought to compare the efficacy of the smaller steaming chamber in the HG 600, at reducing respirable particle numbers, bacteria, and mould concentrations in five bales of poor-quality perennial rye grass (*Lolium perenne)* hay and to compare steaming with dry hay and hay soaked in water for 10 minutes.

Method: Five replicate bales of barn-stored *Lolium perenne* hay made in Hungerford, June 2011, were treated as follows: Half was steamed for 40 minutes in HG 600. Two 4-6kg hay nets were weighed from the other half. One net was soaked in tap water (150C) for 10 minutes then drained for 10 minutes. Post treatment 1g from dry, soaked and steamed hay were weighed into separate stomacher bags with 79 ml of maximum recovery solution and processed for 2 minutes. Sequential dilutions were prepared down to 10 -4. Two x 1 ml from each were placed onto 2 x 3 M TM petrifilms, (3M Microbiology, St Paul, MN 55144-1000), and incubated for 3-5 days at 20oC (mould films) and 320C (bacteria), before counting using a standard colony counter. RP were determined according to the method of Moore-Colyer, (1996). Differences between treatments were determined using ANOVA on log transformed data.

Results: Table 1. *Geometric mean numbers of respirable particle (RP), total bacterial colonies (TVC) and mould colonies (Mould) from 5 bales of hay steamed for 40 minutes in the HG 600 (steamed), soaked for 10 minutes in water (wet) and dry hay (dry).*

	Dry	Wet	Steamed	s.e.d	Sig
RP (/l air/kg DM)	1327^{a}	0^{b}	1.47^{b}	1.719	P<0.001
TVC /g	$21,877,616^{a}$	$37,153,522^{a}$	$83,176^{b}$	2.55	P<0.001
Mould /g	$1,174,897^{a}$	$316,227^{a}$	$1,072^{b}$	1.97	P<0.001

abc Values in the same row not sharing common superscripts differ significantly (P<0.001)

Conclusions: Steaming in the HG 600 was the most effective treatment for reducing RP, mould and TVC concentrations. Soaking reduced RP but increased TVC and thus cannot be recommended as a treatment for improving the hygienic quality of hay.

Experiment 7

Leggatt, P. and Moore-Colyer, M.J.S (2013). The effect of steam treatment on the bacteria yeast and mould concentrations in haylage for horses. *Proceedings of British Society of Animal Science Conference,* Nottingham April 2013. p 103

Introduction: An increasing number of horse owners choose to feed haylage to their stabled horses. Good quality haylage if well conserved has a high nutrient value and low dust content and can make excellent long forage for performance horses.
However, as conservation of haylage is more dependent on air-tight storage than lactic acid fermentation (Muller, 2005), once opened it must be used within 5 days.
Exposure to air causes rapid bacterial and fungal growth rendering the forage unpalatable and potentially hazardous to feed. Previous work has shown that steaming hay in the Haygain range of steamers has reduced bacteria and fungi concentrations by >95% (James and Moore-Colyer, 2010; Moore-Colyer and Fillery, 2012) and so this study sought to determine if similar reductions in microbial concentrations could be achieved when steaming haylage.

Method: Five bales of commercially produced *Lolium perenne* haylage were randomly selected from a farm in Gloucestershire. Each bale was divided into 4 equal portions. Portion 1 was tested immediately, portion 2 left for 4 days then tested.
Portion 3 and 4 were steamed in the HG 600 (Haygain Ltd). Portion 3 was tested immediately post steaming and portion 4 was left for 4 days before testing. All 4 portions underwent the following procedure. One gram was weighed into separate stomacher bags with 79 ml of maximum recovery solution and processed for 2 minutes. Sequential dilutions were prepared down to 10 -4. Two x 1 ml from each were placed onto 2 x 3 M TM petrifilms, (3M Microbiology, St Paul, MN 55144- 1000), and incubated for 3-5 days at 20oC (mould films) and 2- 3 days at 320C (bacteria), before counting using a standard colony counter. Differences between treatments were determined using ANOVA on log transformed data.

Results: *Total bacterial counts (TVC) and fungi in fresh haylage, haylage opened for 4 days, freshly steamed haylage and steamed haylage left open for 4 days*

CFU	**Fresh**	**Fresh + 4 days**	**Steamed**	**Steamed + 4 days**	**s.e.d**
Fungi /g	420	2786	12	128	
Log fungi	2.48c	3.38d	0.45a	1.58b	0.304
TVC/g	41,600	114,000	10	304	
Log TVC	4.556c	5.048c	0.823a	2.092b	0.2701

abc Values in the same row not sharing letters differ significantly (P<0.05)

Conclusions: TVC and mould concentrations increase by 64 and 75% respectively in haylage opened for 4 days. Steaming significantly reduced microbial growth and this reduction was

maintained (99 and 70% lower respectively than freshly opened haylage) after 4 days aerobic exposure.

Experiment 8

Blumerich, C.A., Buechner-Maxwell, V.A., Scrratt, W.K., Wilson, K.E., Ricco, C., Becvarova, I., Hodgson, J. and Were, S. (2012) Comparison of airway response of Recurrent Airway Obstruction affected horses fed steamed versus noon-steamed hay. *Proceedings of the Annual ACVIM Conference, 2012.*

Introduction: Recurrent Airway Obstruction (RAO)-affected horses experience bronchoconstriction and airway inflammation in response to inhalation of aerosolized irritants including hay molds. Steaming hay reduces fungal content, but the effect on the antigenic potential of hay has not been investigated. The aims of this experiment were to test the hypothesis that RAO-affected horses develop less clinical disease when fed steamed versus non-steamed hay and this reduction coincides with decreased hay fungal content.

Method: Six RAO-affected horses in clinical remission were divided into two groups and fed *ad libitum* steamed or non-steamed alfalfa hay for 10 days using a two-way cross-over design. All horses had *ad libitum* access to water and a mineral lick throughout the duration of the trial. Hay was steamed using the HG 1000 (Haygain Ltd). Clinical assessment was performed daily. Full assessment performed on days 1, 5 and 10, included upper airway endoscopy, assignment of mucous scores and measurement of maximal change in pleural pressure. Bronchial fluid sampling and cytology were performed on days 1 and 10. Hay core samples were collected pre- and post-steaming and cultured to determine fungal and bacterial concentrations. Differences between treatments were determined using repeated measures ANOVA, mixed model ANOVA, Wilcoxon rank-sum and Wilcoxon two sample tests.

Results: Steaming significantly decreased the number of fungi colony forming units in hay. Horses fed non-steamed hay experienced a significant increase in clinical score ($p<0.0001$) and a trend towards total airway neutrophilia ($p=.0834$) during the feeding period, while parameters were unchanged in horses fed steamed hay.

Conclusions: These results indicate that steaming reduces the RAO-affected horse's response to hay which coincides with a reduction in viable fungal content of hay.

Experiment 9

Brookes, R and Lambert, P (2012) Investigations into the bacteria (TVC) and fungi concentrations and palatability of hay steamed in the HG600 and left for up to 24 hours before testing. *BSc thesis, Royal Agricultural College, 2012.*

Introduction: Horse owners that wish to restrict hay intake due to adiposity, or those owning only 1 horse, are unable to feed all the treated hay immediately post steaming. While previous research (Stockdale and Moore-Colyer, 2010) has shown that the reduction of respirable particles is maintained 24 hours post-steaming, no information is available on the effect of time on the bacteria and mould concentrations in hay left for up to 10 hours post steaming. Furthermore although Moore-Colyer and Payne (2012) reported increased intakes by horses fed steamed hay compared with either dry or soaked hay, there is no information available on the palatability of steamed hay when left to dry-out for up to 24 hours. These studies addressed the hypothesis that hay steamed and left for up to 24 hours would be less palatable and have significantly more bacteria and mould than hay tested immediately post-steaming.

Methodology: Five bales of perennial rye grass/timothy mix hay, harvested from a permanent pasture near Hungerford, UK in 2011 were used in each study. In study1 each replicate bale was steamed in the HG 600 for 50 minutes and organised so that 1 kg of hay that had been steamed 24, 8, 2 and 0 hours could be offered simultaneously in 4 corners of rubber-matted stabling to 3 horses. In order to eliminate positional preferences, the experiment was repeated 4 times for each horse with the position of each of the hays being rotated between the 4 corners of the stable.
The amount of hay consumed and the foraging behaviour of the horses was noted for 1 hour. Data was subjected to a repeated measures analysis of variance (Genstat 12).

In study 2 five bales of the same hay was steamed in the HG 600 and tested for TVC and mould concentrations 0, 2, 6 and 10 hours post-steaming. Each replicate sample was subjected to the following treatment. One gram was weighed into separate stomacher bags with 79 ml of maximum recovery solution and processed for 2 minutes. Sequential dilutions were prepared down to 10 -4. Two x 1 ml from each were placed onto 2 x 3 M TM petrifilms, (3M Microbiology, St Paul, MN 55144- 1000), and incubated for 3-5 days at 20oC (mould films) and 2- 3 days at 320C (bacteria), before counting using a standard colony counter. Differences between treatments were determined using ANOVA on log transformed data (Genstst 12).

Results study 1: *Palatability of hay steamed in HG 600 for 50 minutes and fed 0, 2, 8 and 24 hours post steaming*

Hours fed post-steaming	**0**	**2**	**8**	**24**	**s.e.d**	**Sig**
Amount consumed /hr in kg	0.260	0.300	0.307	0.273	0.1000	NS

Study 2: *Fungi and bacteria in hay steamed in the HG 600 for 50 minutes and tested at 0, 2, 6 and 10 hours post-steaming*

CFU	Dry	0	2	6	10	s.e.d
Fungi /g	30,530	3.3	2	10	2	
Log Fungi	4.11a	0.26b	0.20b	0.56b	0.20b	0.429
TVC/g	243,400	193.3	438	44	87,126	
Log TVC	4.91a	1.60b	1.40b	1.05b	2.44b	0.899

ab Values in the same row not showing common letters differ significantly (P<0.05)

Conclusions: Hay steamed in the HG 600 and left for up to 24 hours was equally palatable to freshly steamed hay when offered free-choice to stabled horses. Steaming reduced (P<0.05) the TVC and fungi concentrations compared with dry hay and this reduction was maintained for up to 10 hours post steaming. Results from these studies show that hay steamed in the HG 600 steamer maintains low TVC and mould concentration for up to 10 hours post steaming and retains its palatability for up to 24 hours. Horse owners can therefore steam hay and feed it 10-24 hours later without compromising the hygienic quality nor palatability of the fodder.

Experiment 10

Brown, E., Tracey, S and Gowers, I. (2013) An investigation to determine the palatability of steamed hay, dry hay and haylage. *Proceedings of British Society of Animal Science Conference,* Nottingham April 2013. p 104

Introduction: In recent years, hay has been replaced by haylage in the diets of stabled horses. Haylage is reported to be highly palatable but can be too high in nutrients for some horses. Hay is more suitable fodder for many horses but can be dusty and induce respiratory disorders. Steamed hay is dust free and has been shown by Payne and Moore-Colyer (2011) to be more palatable than dry and soaked hay. The aim of this study was to determine which fodder, dry hay, steamed hay or haylage was the preferred fodder for stabled horses.

Method: Seven horses stabled at Writtle College Lordships Stud were simultaneously offered 3 hay nets containing either dry hay, haylage or hay that had been steamed for 50 minutes in the HG 600 steamer. Intake was determined by the weight difference in forage, before and after the one hour feeding period. Observations were taken for the first five minutes of each period to record the first, second and third choices of forage. Analysis of variance (ANOVA) followed by a Bonferroni post hoc test were used to determine differences in intake between the 3 forages and Chi squared test to determine differences in first choice of forage.

Results: The overall trial results demonstrated a significantly greater (P=0.003) consumption of steamed hay (6.72kg ± 1.17 s.e) compared to haylage (2.04 kg ± 0.36 s.e.). However, there was no significant difference between steamed hay and dry hay or between haylage and dry hay. The Chi-squared goodness of fit test showed steamed hay to be chosen most often as the first forage to be consumed, followed by haylage and then dry hay (P = 0.003).

Conclusion: The results of this experiment demonstrate that steamed hay was the first fodder chosen by horses and they went on to consumed more steamed hay than either haylage or dry hay within the 1 hour feeding period. Steamed hay is therefore a hygienically clean and palatable fodder for stabled horses.

Experiment 11

Taylor, J. and Moore-Colyer, M.J.S. (2013). The effect of five different wetting treatments on the microbial concentration in hay for horses. *Proceedings of the European Equine Health and Nutrition Congress.* Ghent, Belgium March 2013.

Introduction: Poor forage hygiene has long been associated with gastrointestinal tract (GIT) and respiratory disorders in horses. The purpose of this study was to establish the efficacy of five different treatments commonly adopted by horse owners to reduce bacteria, yeast and moulds concentrations within randomly selected UK hay.

Methodology: Ten bales of hay were subjected to five different treatments; dry, soaked for 10 minutes in fresh tap water, steamed for 50 minutes in the HG 600 (Haygain) steamer, steamed for 50 minutes in a home steamer and steamed for 50 minutes by pouring a kettle of hot water over hay in a bag. The aerobic bacteria, yeast and mould were cultured according to the technique of Moore-Colyer and Fillery (2012).

Results: *The effect of five different treatments on the yeast mould and bacteria contents (cfu/g) in hay for horses.*

(Log 10) cfu/g	**Dry**	**HG 600**	**Kettle**	**soaked**	**Homemade steamer**	**s.e.d**	**Sig**
Yeast and mould	5.75d	0.7a	3.47bc	4.41cd	2.92	0.673	0.001
% reduction		88	40	24	50		
bacteria	6.60c	2.84a	5.00bc	6.00b	4.28ab	1.007	0.003
% reduction		58	25	10	36		

Conclusions: The use of steam was seen to be an effective method for reducing mould counts within hay; however hay steamed in a specifically designed steamer (HG 600), is the most effective way to reduce both mould and bacteria contents thus producing hygienically acceptable forage for horses.

Experiment 12

Moore-Colyer MJS, Lumbis K, Longland AC, Harris PA. (2014).The effect of five different wetting treatments on the water soluble carbohydrate content and microbial concentration in hay for horses. *Plos One.*

Introduction: Ingestion of high levels of water soluble carbohydrates (WSC) by horses from either forage or cereal based feeds increases the risk metabolic disorders such as insulin resistance, equine metabolic syndrome (EMS) polysaccharide storage myopathy (PSSM) and laminitis. Hay or forage replacers with WSC level < 100g/kg DM are best for such animals. WSC levels in UK hays are commonly between 100 and 310g/kg DM. Recent research has shown that soaking hay increases the bacterial content of the fodder and this could compromise the health of the horse (Moore- Colyer and Fillery, 2013). The aim of this study was to measure the effect of soaking, steaming and a combination of both treatments on the WSC content and microbial contamination of 5 different UK hays.

Materials and Method:. Five different hays were used to determine the effect of 5 different soaking and steaming treatments on the WSC and microbial contents of UK hay. Hays were subjected to the following treatments: Dry (D), steamed for 50 minutes in the HG 600 steamer (S), soaked in water at 16oC for 9 hours (W), steamed then soaked (SW) and soaked then steamed (WS). Post treatment hays were tested for WSC, bacteria and mould. Differences between means were determined using ANOVA and least significant difference with hay (5), bale (3) and treatment (5) as fixed factors, thus n = 75.

Results: W, SW and WS treatments were all equally effective at reducing WSC with significantly ($P<0.05$) lower mean contents (79-83g/kg DM) compared with the 126 and 122 g/kg DM for D and S respectively. S and WS had significantly ($P<0.05$) less bacteria (1046 and 490 cfu/g DM) compared with W which increased cfu/g DM from 60256 in D up to 354813. Mould contents cfu/g DM were significantly ($P<0.05$) reduced by S (2) and WS (1.9) but no difference was seen between D (1148), W (692) or SW (501).

Discussion. Steaming increased the moisture content across all of the hays 2 fold and soaking by > 5 fold. The mean loss of WSC with S was only 3 % whereas soaking caused an average WSC loss of 34% (range 23% to 53%). Submerging hay in water caused rapid and extensive proliferation of bacteria up to 5 fold and this could compromise the health of the horse. S and WS on the other hand reduced ($P<0.001$) the cfu/g of bacteria by 98 – 99%. Soaking hay for 9 hours followed by steaming for 50 minutes in the Haygain steamer was the most effective method for reducing both WSC and microbial contamination in hay. Soaking or steaming + soaking lowered WSC but significantly reduced the hygienic quality of the hay which could potentially compromise the health of the horse.

Experiment 13

Moore-Colyer MJS and Auger EJ, (2014) The effect of design, and management regime on the respirable particle concentrations in 2 different types of horse stables *Proceedings of the Equi Horse Facilities Conference Lion D'Angers, France, October 2014*

Introduction: It is widely acknowledged that dust, particularly respirable particles (RP) of <5 µm in size, found in the stable environment has a major negative impact on respiratory problems in horses and can cause the debilitating allergic condition known as Recurrent Airways Disorder (RAO). The level of dust within the stable environment is influenced by the management regime, namely the choice of bedding and forage and the ventilation rate. The aim of this study was to investigate the relationship between respirable dust in the breathing zone (BZ) of the horse and the general stable zone (SZ) when horses were kept on different management regimes, in either American Barns or straight-block stables.

Methodology: Thirty eight individual stables in 10 different American barns and 34 stables in 9 different straight stable blocks were used for data collection. Samples of respirable dust (RD) were collected from the area close to the horse's nose (breathing zone - BZ) and the middle of the stable (stable zone -SZ) using a cyclone personal air sampler that captured RD on nitrocellulose membrane filter papers. Particle numbers were counted using a microscope and expressed as RP per litre of air sampled.
Management regimes were either 1, shavings and steamed hay; 2, straw and haylage; 3, straw and dry hay; 4, shavings and dry hay. An average of 8 replicate stables was sampled for each regime. Stables were sampled during quiet periods in the yards. Data were analysed using a Wilcoxon Matched-Pairs test (Genstat 15) with significant differences between means set at $P<0.05$.

Results: The lowest respirable particle concentrations (< 360 RP/l air) for both stable designs across both zones were with shavings and steamed hay. Straw and dry hay produced the most amount of dust in the SZ and the BZ of 6250 and 5079 RP/l air in American Barns respectively and was significantly greater than the 2901 and 942 RP/l air measured from the straight stables. In contrast, straw and haylage produced significantly more respirable dust in both zones in straight stables compared with American barns. Shavings and dry hay produced significantly more dust in the BZ than in the SZ in both stable types, while straw and haylage produced more dust in the SZ compared with the BZ across both stable designs.

Conclusion: Forage and bedding have major impacts on dust concentrations in horse stabling. Shavings and steamed hay produced the lowest level of respirable dust across both zones and stable types and thus is the preferred management regime for stabled horses. Feeding dry hay or bedding on straw significantly increases the dust in both zones particularly in American Barn stables and could put horses at risk of developing respiratory disorders.

Experiment 14

Moore-Colyer MJS and Taylor J, (2014) Forage in the stable – techniques for reducing the respirable challenge and microbial content in hay. *Proceedings of the Dorothy Russel Havemeyer Foundation IAD Workshop*. Cabourg. France October 2014.

Introduction: Reducing exposure to respirable (<5 um) particles (RP) from fodder is recognised to be the most effective way of combating Recurrent Airway Obstruction in stabled horses. These experiments were designed to measure the efficacy of soaking and different steaming methods at reducing the respirable particle (RP) and microbial contents in hay for horses.

Methods: Experiment 1- Eight bales of meadow hay were subjected to 5 treatments. 1. Dry; 2. Soaked for 10 minutes; 3. Steamed using HG 600 steamer; 4. Steamed in a domestic dustbin; 5. Steamed using a kettle of hot water. Post-treatment respirable particles (RP) were determined using a cyclone personal air sampler and counted using a microscope. Experiment 2: five bales of meadow hay were subjected to 3 treatments. 1. Dry; 2. Steamed in HG 600; 3. Steamed in a domestic dustbin; all treatments were carried out in simulated cold weather conditions in a walk-in cold room (i.e., 0 - 7oC). Post treatment total bacteria and mould (cfu/g) were determined by culturing on 3TM petrifilms. Differences between treatments in both experiments were determined using ANOVA and least significant difference test.

Results: Steaming in HG 600 and soaking reduced RP content by 99%. Both homemade steamers reduced RP but still contained 80% more RP than found hay steamed in the HG 600 steamer or soaked hay. Steaming hay in cold conditions in the HG 600 significantly reduced bacteria and mould by >99%. Steaming in a homemade steamer did not significantly decrease mould and increased bacteria by 2.4 fold.

Conclusions: Steaming in HG 600 is the most effective method for reducing RP and microbial contamination of hay. Incomplete steaming increased the bacteria content compromising the hygienic quality of hay.

Experiment 15

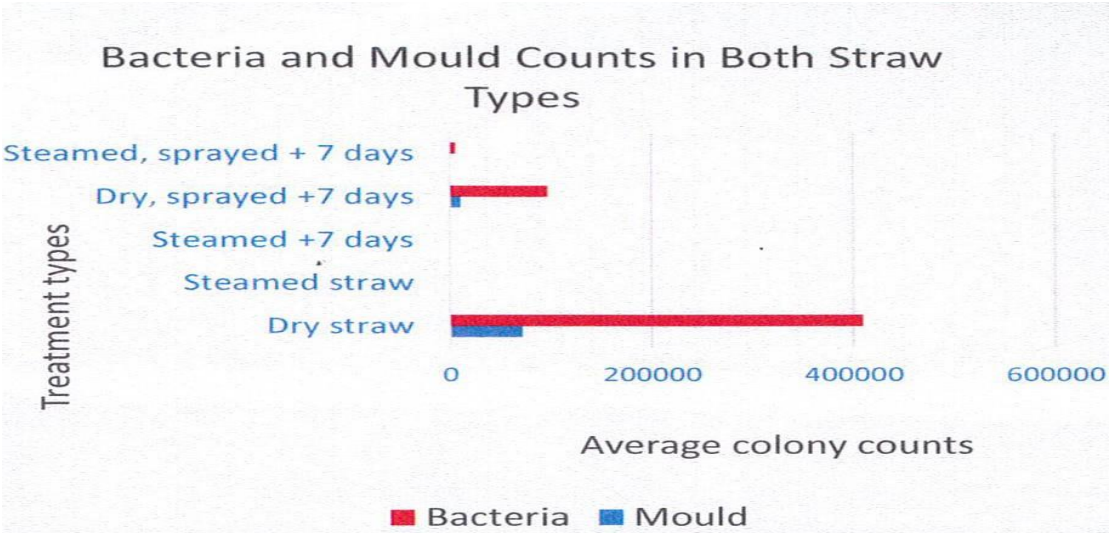
Murihead V. (2014) The effect of steam and Protek Envirocair on the respirable particle, mould and bacteria content in two types of straw bedding for horses. *BSc thesis, Royal Agricultural University, Cirencester, UK.*

Introduction: Previous work has shown that constant exposure to respirable particles (RP) from hay and straw in the stable can cause respiratory disorders in horses. Straw is cheaper than shavings and the behavioural benefits of bedding on straw are well documented (Pederson *et al.,* 2004). However, recent work (Moore-Colyer and Auger, 2014) has shown that bedding horses on straw and feeding dry hay increased the dust in the stable 17 fold, compared with a regime of steamed hay and shavings. Producing bedding for competition horses that will allow expression of normal behaviours while maintaining respiratory health is a management priority. This experiment determined the effect of steaming and applying the disinfectant Protek Envirocair on the microbial and respirable particle content of barley and wheat straw.

Methodology: Randomised block design comprising 2 straw types (barley and wheat), 3 replicates per straw type and 5 treatments was used. Replicate bales were divided into 5 and given the following treatments:1. Dry; 2. Steamed in the Haygain (HG) 600; 3. Steamed and left for 7 days; 4. Sprayed with Protek Envirocair and left for 7 days; 5. Steamed and sprayed and left for 7 days. Post-treatment RP were captured using a cyclone dust sampler and the level of bacteria and moulds determined by culturing on 3TM pertifilms for total viable count and yeast and mould. Differences between treatments were determined using ANOVA and least significant difference test.

Results: Across both straws spraying with Protek reduced bacteria content by 76% ($P<0.05$), while all treatments involving steaming reduced bacteria and mould contaminations by 99% see Figure 1 below. Steaming reduced RP content by 84%, while straw left in a stable for 7 days after steaming maintained a high reduction in RP of 76%.

Discussion: This study showed that it is possible to use straw as bedding material for performance horses provided it is properly steamed in order to reduce respirable particle content. Using treated straw may help to improve the time budgets of stabled horses allowing them to engage in natural behaviours without compromising their respiratory health.



Experiment 16

Gosling K (2014).The prevalence of human respiratory disorders in UK equine industry personnel *BSc thesis, Royal Agricultural College, Cirencester, UK*

Background: Farmers lung (hypersensitivity pneumonia) and asthma are potentially life-threatening conditions that can be brought on by exposure to respirable dust in stables. To date there is little published information on the prevalence of respiratory disorders within the UK horse owning population or on any relationships that might exist between stable management activities and the incidence of disease. The objective of this study was to determine the incidence of respiratory disorders in people working with horses and to identify if any stable management activities corresponded with respiratory disorders.

Methodology: Questionnaires were constructed using 'Survey Monkey' with access via equine forums, social media sites and e-mail. 216 equine industry personnel across the UK completed the questionnaire. The survey was divided into 3 sections; a) respondent profile and time spent at the stable; b) use of hay and straw; c) the stable environment. Responses were analysed using chi-squared (Genstat 13) on the total data set and then on the sub-set (106) of those with respiratory disorders to examine relationships between management activities and the incidence of respiratory disorders. Significance level set at $P<0.05$.

Results: 49% of the 216 respondents from across all regions of UK suffered from a respiratory disorder of which 52% had been medically diagnosed with asthma, while others suffered recurrent sneezing, coughing and blocked sinuses. There was no relationship between UK region, number of days or hours spent at the stable and the incidence of respiratory disorders. People feeding dry hay ($P<0.014$) and filling 2 or more hay nets per day ($P<0.022$), keeping over half the horses within an enclosed barn bedded on straw ($P=0.040$) and sweeping an enclosed barn twice a day ($P=0.030$) were more likely to suffer from a respiratory disorder.

Discussion: These results show that 25% of people working with horses in UK suffer from the life-threatening condition asthma. The incidence of respiratory diseases was related to stable management activities particularly feeding dry hay and filling hay nets. There are approximately 3.5 million people working in the UK equine industry, and based on these results, 1.7 million could be suffering from a respiratory disease. This study highlights the need to review horse care activities and implement dust reducing stable management regimes to reduce the incidence of respiratory disorders in people working with horses.

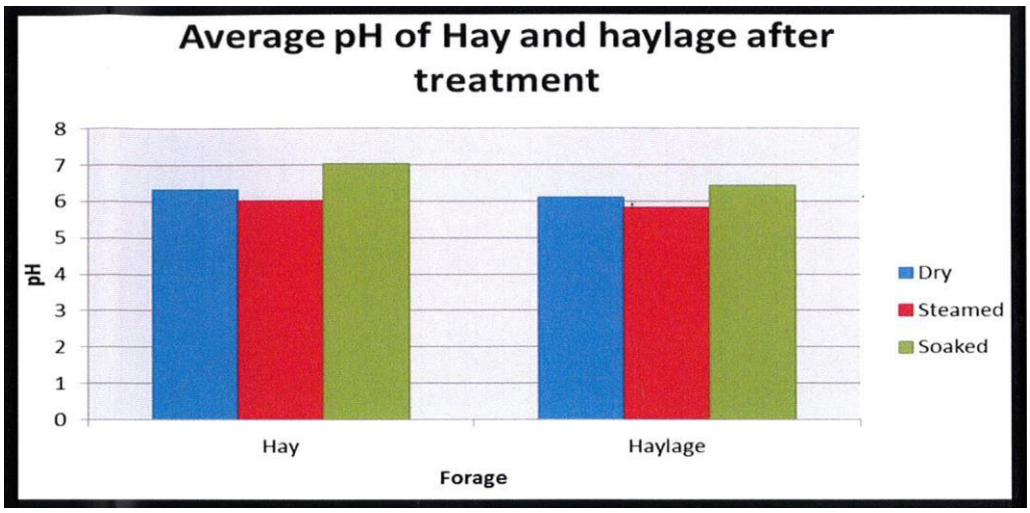
Experiment 17

Dewhurst J, (2014) The effect of soaking or steaming in the HG 600 hay steamer on the pH of hay and haylage. *BSc thesis Royal Agricultural University, Cirencester, UK.*

Introduction: The incidence of gastric ulcers (EGUS) in performance horses is high, with some disciplines e.g., racing reaching 90%. Meal feeding concentrates is a major cause of EGUS, while maintaining a constant intake of forage can help to reduce ulceration. Feeds that are alkaline in nature can help to buffer acid production and balance the negative effects of highly fermentable cereal feeds. This experiment aimed to determine whether different treatments of hay and haylage have any negative effect on the pH of the forage.

Method: Six replicate bales of meadow hay and haylage was sampled when dry, post soaking for 30 minutes in tap water, and steamed for 40 minutes in the HG 600 steamer. Post treatment samples were tested for pH by taking a 12.5g subsample and adding 162.5ml of de-ionised water. Each samples was shaken on its side for 60 minutes at 120 oscillations per minute. The pH was then taken from the solution using a pH logger.

Results: Table 1. The pH of hay and haylage after being subjected to soaking and steaming in the HG 600 steamer



Conclusions: The pH of haylage and hay were similar indicating that the haylage was late-cut high dry matter forage. There was no significant difference in pH between dry, soaked or steamed hay with pH.

Experiment 18

Moore-Colyer, M.J.S. Taylor, J. and James, R (2015). The effect of steaming and soaking on the respirable particle, bacteria, mould and nutrient content in hay for horses. *Journal of Equine Veterinary Science. Aug 2015*

Introduction: Forage is crucial for stabled horses, promoting gut health, supplying valuable nutrients, and maintaining normal feeding behaviors. Forage can contain high levels of respirable dust predisposing horses to respiratory disorders.

Method & Results: This study examined the effect of different treatments on the airborne respirable particles (ARPs), microbial and nutrient content of hay for horses in three experiments. Experiment 1a eight bales of meadow hay were subjected to five treatments n = 40: dry (D), 10-minute soak in water (W), steamed in a wheelie bin (TWB), steamed in a Haygain (HG) 600, and steamed with a kettle of boiling water (K) on ARP content. Experiment 1b microbial contamination was measured in five bales of meadow hay after treatments D, TWB, and HG in cold conditions (0–7°C) (n = 15). Experiment 2 measured the nutrient content of 30 different hays after D and HG treatments, n = 60. Data in experiments 1a and 1b were analyzed using analysis of variance and least significant difference test: hay and treatment as factors. Experiment 2 was analyzed using paired t-test with significance levels accepted $P < .05$. Results showed steaming in the HG reduced ARP and microbial contamination by 99%. TWB or K reduced ARP in hay by 88%. W, TWB, or K did not reduce microbial contamination. HG treatment preserved mineral and protein contents but reduced water-soluble carbohydrate by 18.3%.

Conclusion: Steaming using an HG steamer is a feasible long-term strategy for reducing ARP and microbial contamination, while conserving mineral and protein content in hay and is thus suitable for providing hygienically clean forage to stabled horses.