MEASURING MOISTURE CONTENT IN KERATINIZED HORNY STRUCTURES OF THE FOOT IN DOMESTICATED HORSES

Andrew Bowyer FWCF, Grad dip ELR

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Abstract

The purpose of this study is to validate a hand held commercial digital moisture meter to measure moisture content (MC) in the hoof and to develop a methodology to obtain readings in three architectural structures of the hoof; hoof wall (HW), sole and white line (WL) of domesticated horses. It is hypothesized that the moisture meter would be able to reliably measure MC in the HW, the sole and WL with the purpose of taking the instrument forward to be used in future research studies in live horses. Its proposed that the introduction of moisture meters in equine research could improve our understanding of the complexities of MC in the hoof.

Studies of feral horses have shown that there is no difference in MC of the HW in wet and dry environments. The sole has been shown to have an increased MC after hydration of samples in a laboratory environment. However, to the author's knowledge, there are no records of moisture content measurements in the WL.

MC readings were obtained using two different commercial moisture meters in twelve cadaver feet, of which six were exposed to saturation in water for three hours before measuring. Samples were then extracted from the feet and tested for the actual moisture content (AMC) using a lab oven. Data was cross examined for an accurate comparison between devices and oven results.

Results from the study indicated that MC in the equine hoof can be measured with commercial moisture meters, however readings are generally higher compared to the oven drying experiment. The study also demonstrated that saturation of the hoof resulted in a significantly increased moisture content in all three sections examined. A Bland Altman correction equation indicated that MC can most consistently be measured with Device B on Setting f in the HW, Device A in the sole, and Device B on setting h in the WL. The results of this study provide valuable information for validation of MC measurements in the feet of live horses.

Declaration

I hereby declare that the work within this Fellowship dissertation is my own. Any sources have been duly referenced and any illustrations or diagrams that are not mine are used with permission of the owner.

Table of Contents

ACKNOWLEDGMENTS I

ABSTRACT II

DECLARATION III

LIST OF ABBREVIATIONS V

INTRODUCTION 1

ANATOMY 4

MATERIALS AND METHODS 7

INSTRUMENTATION 8

- Device A 8
- Device B 8
- Moisture Probes and reading depths 9
- How to measure hoof wall width using mathematics 10
- Probe application to the foot 12

DATA COLLECTION 14

- Sample extraction to obtain AMC values 15

DATA ANALYSIS 16

RESULTS 17

- Shore hardness results 21

MOISTURE METER PERFORMANCE 22

DISCUSSION 24

CONCLUSION 27

EQUIPMENT ADDRESSES 28

REFERENCES 29

APPENDICES I

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List of Abbreviations

MC: Moisture Content

HW: Hoof Wall

WL: White Line

AMC: Actual Moisture Content

SD: Standard Deviation

WLoA: Widths of the Limits of Agreements

±: Plus/minus

Introduction

Moisture content of the equine hoof is widely discussed in professional practice between farriers, vets and horse owners. Several studies conclude that the MC has a direct effect on horn quality and mechanical stiffness of the hoof Douglas et al., (1996), Wagner et al., (2001), Li et al., (2010).

Existing research investigating MC in horn has been carried out in samples that have been extracted from the hoof capsule, saturated as an external sample. The author questions whether the horn samples tested in these studies would react to MC differently in the complete hoof capsule and considers this to be a major gap in the research.

The aim of this experimental study is to validate a hand-held moisture meter and to develop a methodology to obtain MC readings in horny structures of feet in domesticated horses. The study will be using cadaver material but the process of taking the readings will be designed so it can be taken forward and used in live horse studies for future research. It was hypothesized that the moisture meter would be able to reliably measure the MC in the HW, the sole and WL of the hoof capsule.

To the authors knowledge, there are no reports describing MC measurements taken in horn structures from an external position, as there is currently no device available to carry out these measurements. The purpose of this study is also to investigate the MC of the WL as currently there is little comparative data linking the WL to other anatomical structures of the hoof and no recorded MC values.

A comprehensive study by Hampson et al., (2012) on MC in the HW of feral horses from a desert environment and a wetland environment showed MC of the HW to be consistently the same. However, anecdotally, farriers often think of the hoof capsule as a sponge soaking up moisture from ground conditions in a domestic environment. Horses that are kept in a wet environment are trimmed and the horn cuts more easily than horses kept in dry, hot climates or on a dry wicking bedding. This suggests that moisture content has a direct effect on the hardness and mechanical stiffness of horn. Although this evidence is anecdotal, it is concluded by the practitioners that work with horses' feet and observe them changing through the seasons. Researchers have been investigating the MC of the hoof capsule for many years, some dating as far back as the early 20th century, Lungwitz (1913).

Most of the studies have focused research on the MC of the HW in the majority of cases, and not considered the MC of the other horny structures comprising the hoof capsule. More recently, studies have looked closely at the horn matrix in an attempt to identify if there is a variation in MC between the individual anatomical structures, Reilly., (2006). Douglas et al., (1996) found that in the HW, the abaxial stratum medium yielded 27.9% moisture, whilst the main body of the stratum medium contained 35.5%. A study of feral horses confirmed MC results of 29.6% and previous studies ranging from 22.7% to 36.3% Hampson et al., (2012). Hampson concluded that the wide range of MC values in previous research is most likely due to the many different methods used and these may not accurately reflect the AMC of the foot in vivo.

Reilly., (2006) looked more closely at the MC within the sole, and concluded with results indicating a MC of 33%. Hampson et al., (2012) confirmed 29.8% MC of the sole and while soaking did not affect the hydration of the HW, it did increase the MC of the sole. Additionally, Wagner et al., (2001) suggests horn samples have been proven to hydrate rapidly during short periods of exposure to saturation in a water tank with the greatest increase in hydration to the stratum medium occurring in the first 24 hours in vitro. Samples that are extracted from the hoof capsule, may hydrate at a faster rate as there would be more surface areas exposed to saturation. Therefore, this could not be a true representation of hydration levels in the hoof capsule in vivo.
There has been extensive research done in the keratinized horn from cattle. Li et al., (2010) investigated the effects of hydration on the mechanical properties of horn samples from cattle feet. They concluded MC effects the material's mechanical properties. Horn which is dehydrated and low in MC effects the mechanical stiffness and strength, which increases, however the horn material becomes brittle. The opposite effect would be horn which has a high moisture content and is saturated, causing the material to become too weak to resist high loads and deform more easily under pressure. Although this research was not performed in equine feet, cattle claws represent a keratinized structure and this work could add understanding as to why equine feet distort. It appears conceivable that MC changes

the mechanical stiffness of horn causing the hoof capsule to lose some of its architectural strength.
Hampson et al., (2012) tested the permeability and MC of horn in 100 feet from feral horse populations in five different environments; from wetlands to desert and concluded that MC of the stratum medium of the HW does not change between environments. The horses used in the study by Hampson, were culled as part of a feral horse control program. Samples of the horn were cut out of the dorsal wall with a band saw, wrapped in parafilm and frozen within two hours. The samples were then tested for MC two weeks later using a desiccator containing potassium phosphate.

Hampson et al., (2012) questioned the permeability of the stratum tectorium of the hoof wall and suggested that it is an impermeable structure. This would consequently question the advice given to horse owners to apply topical hoof dressings during the summer months in order to help keep hooves moist and supple. The treatment would be ineffective if the outer surface of the hoof capsule is impermeable. If this is the case, it indicates a distinct lack of research behind some of the manufacturer's products. An interesting finding in the study was that the MC is variable in the horn of the sole which does not have a stratum tectorium.

Within building and surveying, it is common practice to use moisture meters to measure MC of materials to assess their quality, strength and stability, Burkinshaw., (2006). It is evident from existing research, both anecdotal and evidence based that MC has an effect on the hoof capsules quality, strength and stability.

Anatomy

The hoof capsule is a highly keratinised epidermal structure, which is avascular and void of nerve endings Reilly., (2006). Keratin is the main structural protein that comprises the epidermal and dermal horn. It is present in skin, nail, hair, claw, wool, scale and horn. The tubular horn of the hoof wall and the sole is composed of hard keratin and is rich in disulphide bonds which gives it great physical strength. The WL is rich in sulfhydryl groups but poor in disulphide bonds which gives it lower physical strength but greater elasticity Pollitt.,(1996).

The horny structures of the hoof capsule comprise of three different types of horn: Tubular horn, Inter-tubular horn and Intra-tubular horn. The tubular horn in the HW runs proximodistally and parallel to the surface of hoof Thomason et al., (1992)

The HW grows distally from the highly vascular germinative layer of the coronary corium and can be classified into five layers or stratums (Figure 1).

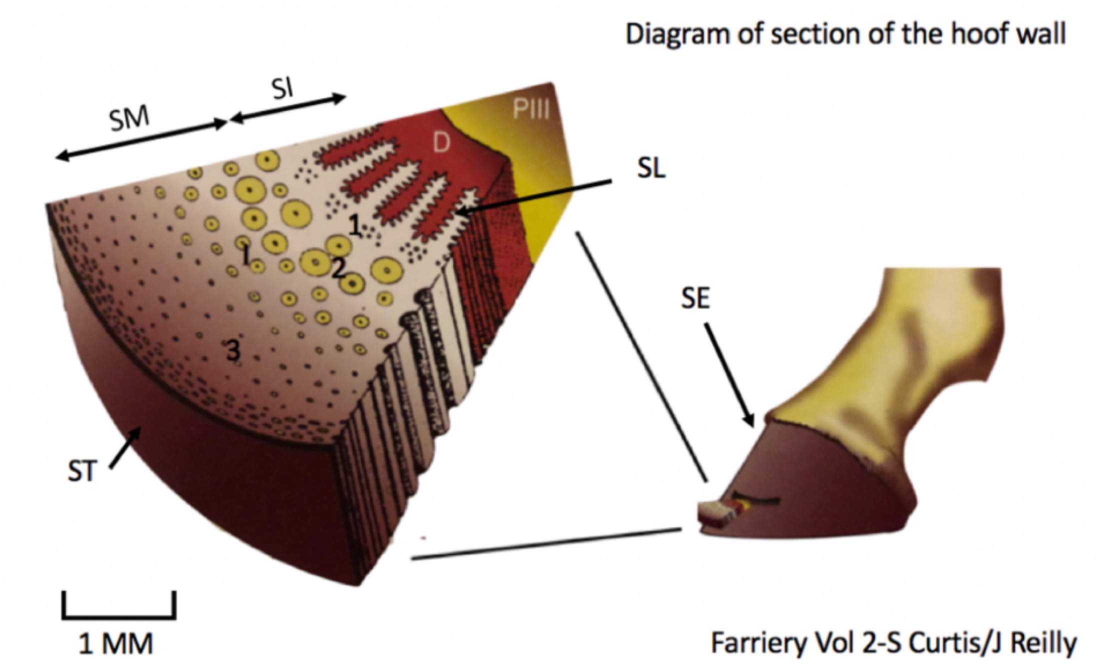


Fig 1. Diagram. Section of the hoof wall. SE: Stratum externum. ST: Stratum tectorium. SM: Stratum medium.SI: Stratum internum. SL: Stratum lamellatum. 1,2,3: horn tubules. I: Intermediate zone containing intermediate horn tubules. D: Dermis Laminal corium. P111: Distal Phalanx. *Courtesy of S Curtis*

The Stratum externum: Outer layer commonly referred to as the periople, is produced from the perioplic corium and is a continuation of the skin. The periople scales off at a variable distance down the wall to leave a thin layer of flat horn cells Reilly., (2006).

The Stratum tectorium*:* distally to the periople is very thin, glistening and varnish-like in appearance and covers the entire outer surface of the HW except where periople is present and has been removed with a rasp Lungwitz., (1913). Both the periople and the stratum tectorium have a relatively high lipid content which may play a role in controlling hydration levels, and reducing evaporative moisture loss through the HW, Reilly., (2006).

The Stratum medium*:* constitutes the main bulk of the hoof wall and is produced from the coronary corium and consists of tubular and intertubular horn. Horn tubules are smaller and more closely packed abaxially and larger and more widely spaced axially.

The Stratum internum: commonly referred to as the zona alba forms an inner non-pigmented section of the HW. The Stratum lamellatum*:* comprises of the primary and secondary epidermal lamella Reilly., (2006).

Within these strata the hoof wall has four distinct zonal variations in tubule density as see in (Figure 2). This configuration of tubules within the HW may satisfy the different mechanical demands required across the hoof wall which are modulated by moisture content Reilly., (2006).

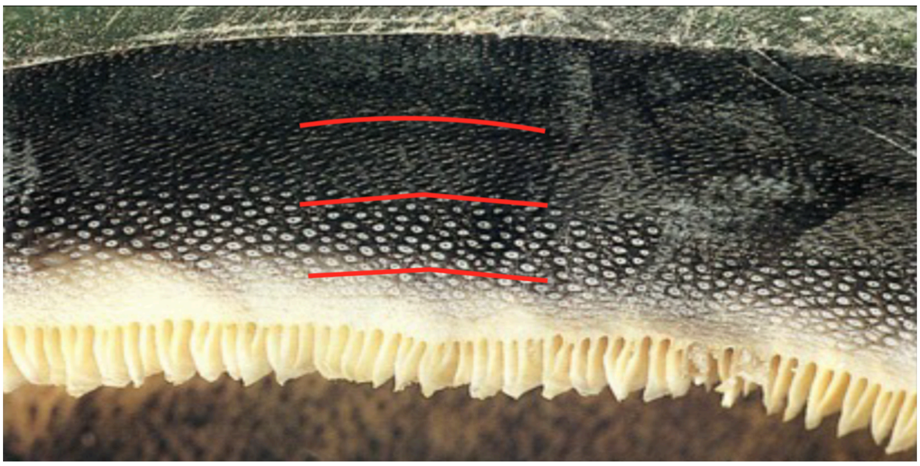


Fig 2. A Transverse section of the HW showing four distinct zones of tubular density and size. (photo from Pollitt 1995) *Courtesy of C Pollitt*

Zonation of the HW is an important factor to consider when designing the methodology and device to measure moisture content. Because of the different layers of the stratum medium, the methodology of measuring MC requires testing at a consistent depth in the hoof wall.

The sole and WL, all grow distally from their retrospective coria on the solear surface of the foot and are consistent in form Reilly., (2006). These structures will be measured vertically from the solear surface.

Materials and Methods

Twelve cadaver front limbs from six mature horses were used. The left fore was saturated to the coronary band for three hours, the right fore which was not exposed to saturation.

The horses were euthanized for reasons unrelated to this study. All horses were classified as domesticated and in work with shoes on both fore feet. All horses were predicted to of been shod within two weeks of testing and none of the feet had any excess horn. The left forelimb was marked at the fetlock with a livestock marker for identification purposes. Immediately post euthanasia, shoes were removed and the hooves cleaned of excess debris using a wire brush and immediately wrapped tightly in a water impermeable 50mm [1]Parafilm™, to eliminate natural moisture evaporation Hampson et al., (2012). Feet were tested and processed within 24 hours.

Two commercial moisture meters were used to obtain MC readings in the HW, sole and WL. Shore readings were also taken at these locations using a [2]shore durometer digital hardness tester, to see if MC affected the shore rating/hardness of horn. The left fore foot from each horse was submerged in a water tank proximal to the coronary band for three hours, the right fore foot was processed unsaturated. After the device readings had been obtained, samples were extracted from the hoof capsule and the MC was measured with an oven drying experiment to determine the AMC.

Instrumentation

The two commercial moisture meters used in the study are manufactured by the same company [3,4]Protometer. Two devices were tested because they measure MC values across a wide range of settings, thereby increasing the likelihood that horn samples would fit into one of these settings.

Device A

The [3]Protometer Digital Mini is calibrated for wood (Figure 3.a). The device also measures the MC in materials other than wood, the device displays the wood moisture equivalent (WME) value of the material. The device has one setting which returns a numerical value and is widely used in construction to take WME reading in concrete, dry wall and other materials.

Device B

The [4]Protometer Timbermaster features eight calibration settings, enabling the user to take MC readings in 150 different wood species (Figure 3.b). The eight settings ABCEFGHJ are used with the protimeter wood calibration table to identify which setting should be used with a specific wood specie. The calibration data on the table are based on standard tests by oven drying of commercial species of wood.

Surface temperature of the material can also affect the moisture reading. The device is calibrated to take material readings at 20°C. If readings are obtained where the surface temperatures are ±5°C, it can affect the MC value. A surface temperature sensor can be connected to the device to automatically correct the output value if the surface temperature over 25°C or 15°C below (Figure 3.b).

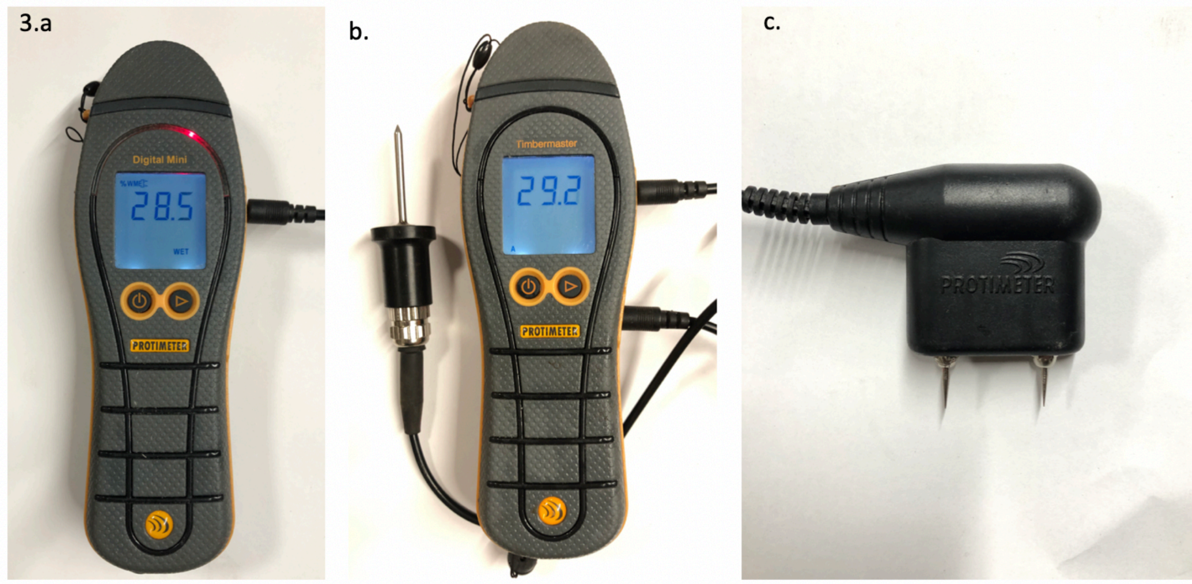


Fig.3.a device A, protimeter digital mini. 3.b device B, protimeter timbermaster and surface temperature probe. 3.c protimeter heavy duty moisture probe

Moisture Probes and reading depths

Two [5]heavy duty protometer probes were used with both devices A and B (Figure 3.c). The probes calculate an output through the device, using a small electrical field which passes between the two pin tips measuring resistance giving a MC % reading of a very specific area at the depth that the pins are inserted. The probes were modified for the study by fitting a stainless-steel casing and a thermoplastic cap to make them durable enough to be tapped into the horn with a nylon hammer. The modified probe A was used to obtain MC readings in the sole and WL, it has a smaller casing and can be easily pushed into the softer horn on the solear surface of the foot (Figure 4.a).

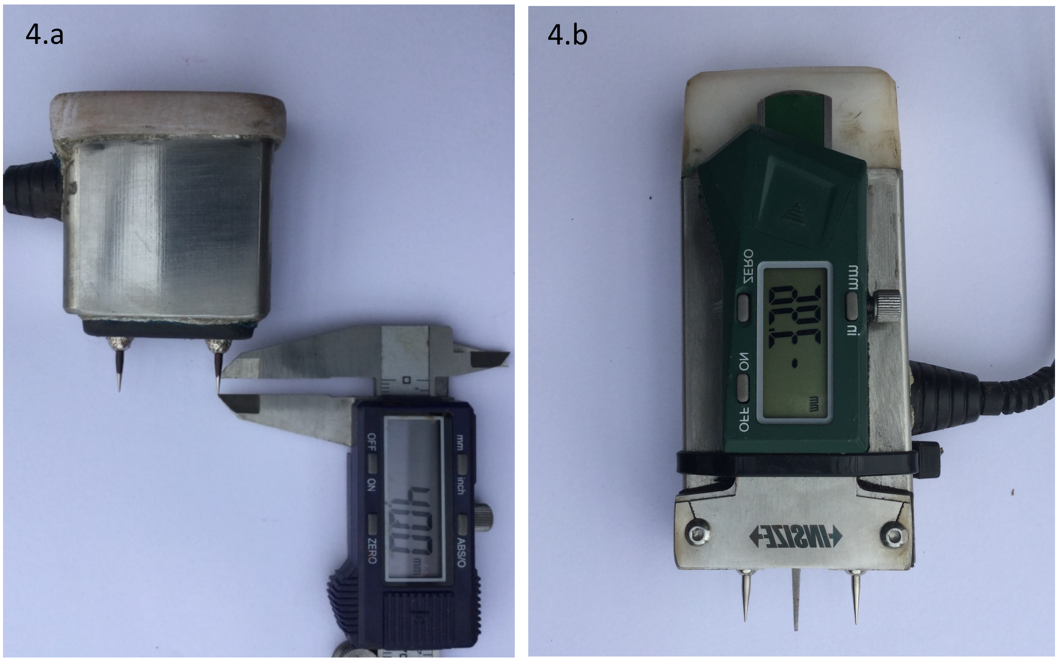


Fig.4.a Sole and WL probe A with pin depth sett at 4mm

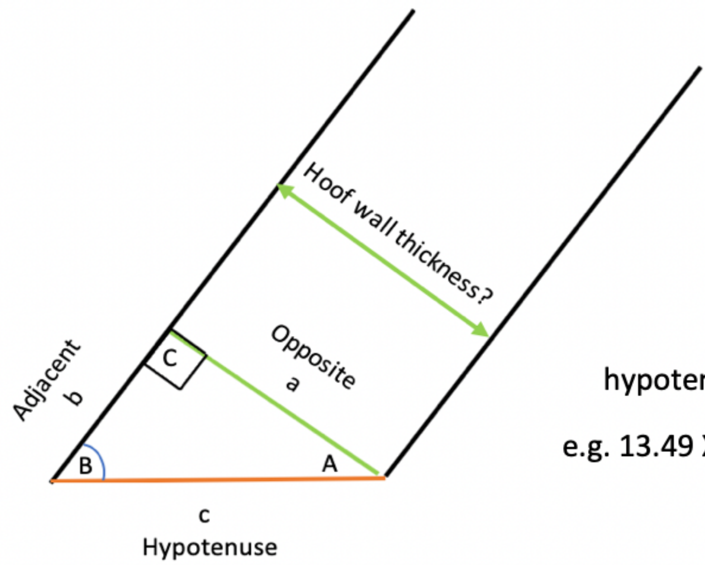
4.b HW probe B with integral digital depth gauge

The modified probe B was used to measure MC in the HW and was fitted with an integral [6]digital depth gauge, so the depth that the pins penetrate the HW can be pre-set prior to taking a reading (Figure 4.b).

How to measure hoof wall width using mathematics

Hoof wall width was measured prior to testing using the formula (hypotenuse x sin (B) = opposite). The HW thickness on the solear surface at the toe is misleading to the true HW thickness due to the angulation of the dorsal wall which is between 50-55 degrees in the ideally conformed foot Baxter., (2011).

A modified hoof gauge was used to measure hoof wall angle (B) and [7]Vernier callipers to measure the HW thickness on the solar surface hypotenuse between the stratum internum and the hoof gauge representing the hoof wall angle (Figure.5). This process was used to accurately calculate a 33% depth of the hoof wall across all feet used in the study and give a measurement to set the depth gauge. This method was tested and proven to be very accurate in the pilot study.



hypotenuse x sin (B) = opposite

e.g. 13.49 X sin (50°) = 10.33/3=3.44mm

Fig.5 How to measure the hoof wall width using mathematics

Probe application to the foot

MC readings were taken in the HW at 33% depth of the HW accurately using the integral depth gauge. Probe application to the HW can be seen in (Figure.6).

Fig.6 Hoof wall probe application

Probe application to the sole can be seen in (Figure 7.a). Probe application to the WL can be seen in (Figure 7.b) The pins are marked at a 4mm in black which indicated the depth to insert the pins, at which MC values were recorded.

Fig.7.a Probe application to the sole 7.b Probe application to the WL

Data collection

The lab protocol is explained in a flow diagram. The same process was used for both the left and right forelimbs (Figure 8).

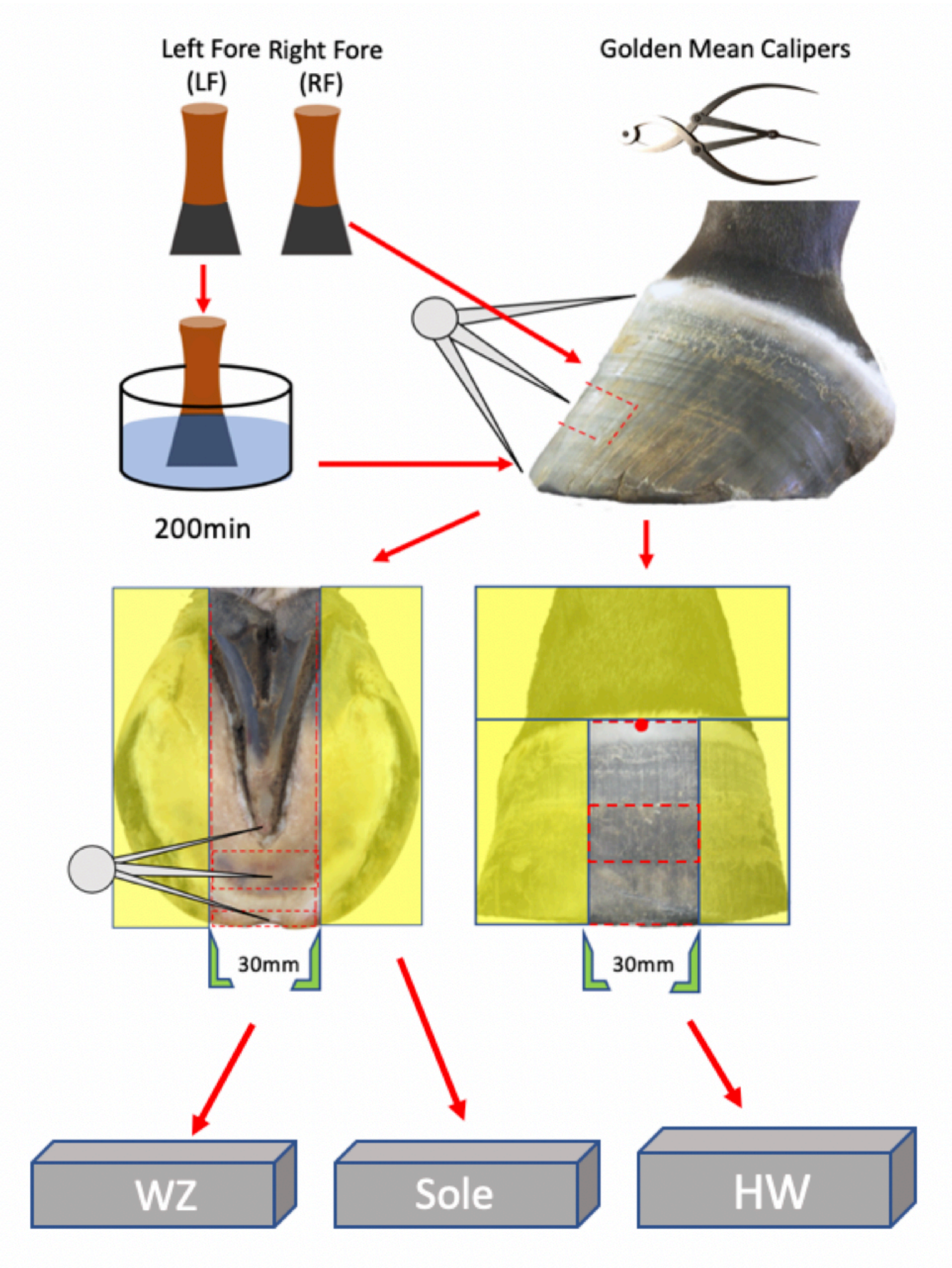


Fig.8 Flow diagram showing lab protocol

[8]Golden mean Phi callipers were used to standardise a point across all feet to take MC readings with the moisture meters in the HW, sole and WL. Using a marker pen, a 30mm x 15mm section was marked in the dorsal wall and sole and a 30mm complete section of the WL in the same place across the representative set.

On each foot, MC readings in these specific areas were obtained with device A and with device B using 8 settings. The pins were positioned three times in each marked area and three readings were taken in each section and the average of these three readings was used for data analysis. There were no outliers in the data sets for the HW, sole and WL.

Directly after MC readings had been obtained, the marked samples were extracted from the hoof capsule to obtain the AMC value with an oven drying experiment. It was crucial to the study that the samples were extracted at the same depth as the device readings to allow for an accurate comparison.

Sample extraction to obtain actual moisture content values

Using a band saw, the yellow shaded areas were removed (figure 8). A transverse cut removed all cadaver material proximal to the coronary band and two sagittal cuts were made removing all material either side of the 30mm central section. The toe was then removed using the band saw and the full width of the WL was carefully extracted at the 4mm depth using hoof cutters and a scalpel. The 30mm x 15mm samples from the HW and the sole were extracted using a mitre gauge on the bandsaw at a 4mm depth in the sole and 33% depth of the HW. Samples were then tested using an oven drying experiment to determine the AMC which can then be used for comparisons to the device readings during data analysis.

The samples were weighed using [9]laboratory scales, pre-drying and data recorded before being placed on a drying tray and placed in the [10]lab oven. The samples remained in the oven which attained and held a temperature of 217 ˚F (103˚C) for 24 hours. Post drying, samples were again weighed and the following formula was used to determine the AMC: percentage of moisture content = ([original mass – dried mass] X 100/original mass.

Data Analysis

Statistical analyses were performed with the aid of data analysis [11]SPSS. Paired sample T tests were used to cross examine the variables and box plots were created to compare the accuracy of the device readings and the AMC values.

The results proved there to be no accurate comparisons, correction equations were used to calculate a regression method Bland and Altman., (1999) dealing with systematic increases or decreases in differences between device readings and AMC. This method of testing is well established in bio sciences. The correction equations need to be applied to the measured MC value taken with the device to correct for systematic differences between measurements and AMC values. The Bland and Altman values bias, SD, WLoA will be used to identify the most accurate device and setting to use with the correction equation. The smaller the WLoA value, the less variation there is between the device and AMC results. This is the criterion chosen for selecting the most appropriate device and setting for each anatomical location.

Box plots and a Pearson correlation test were used to express the influence of moisture content on shore hardness.

Results

Results are AMC value post extraction from the hoof capsule from the oven drying experiment at a 33% depth of the HW, 4mm depth in the sole and WL and moisture meter values (figure 9,10 and 11).

Actual moisture content results:

Hoof wall: Saturated n=20.21 SD=2.4 Non-Saturated n=18.54 SD=2.3 with a mean diff n=1.67% p=0.039

Sole: Saturated n=36.02, SD=2.79 Non-Saturated n=32.76 SD=3.5

with a mean diff n=3.26% p=0.044

White line: Saturated n=41.03 SD=4.11 Non-Saturated n=35.44 SD 3.5 with a mean diff n=5.59% p=0.15

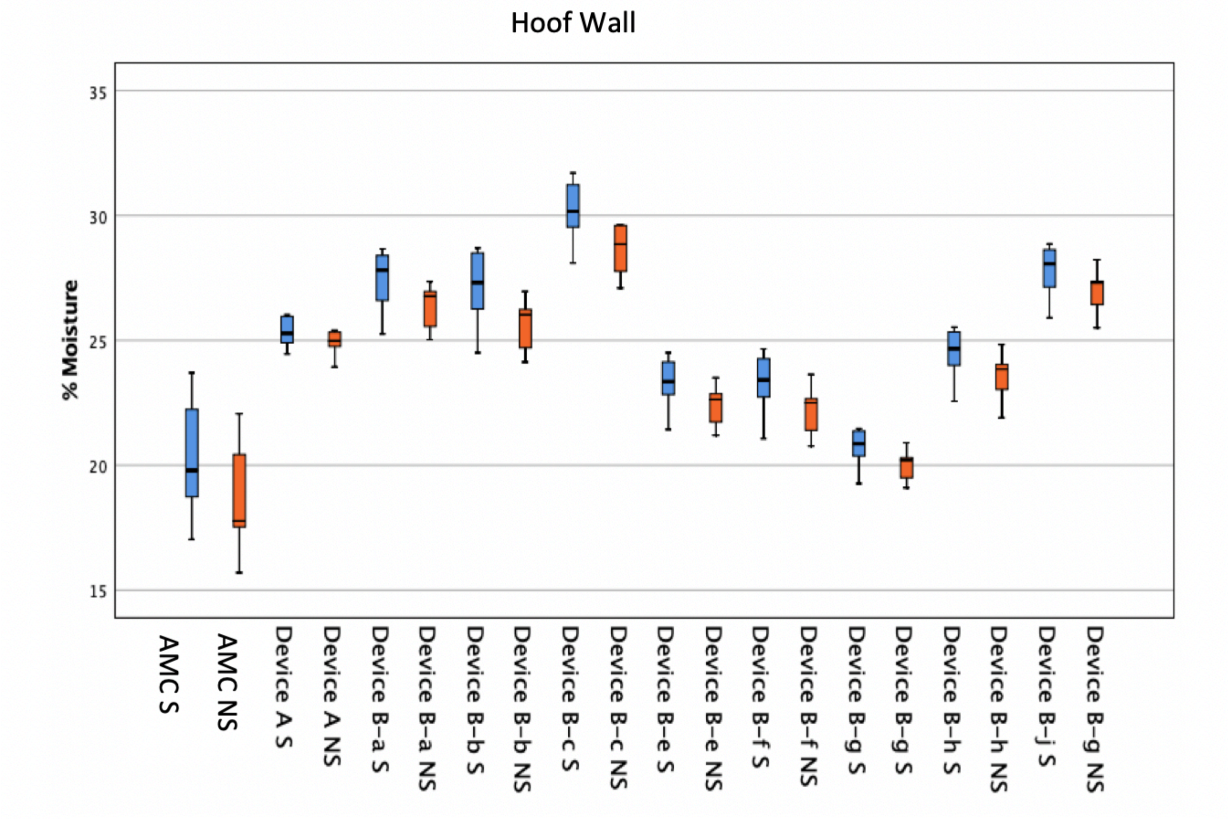


Fig.9 Box plot. HW, MC data from 12 limbs. AMC saturated (S) AMC non-saturated (NS) plotted against Device A and B. showing the minimum, first quartile, median, third quartile and maximum.

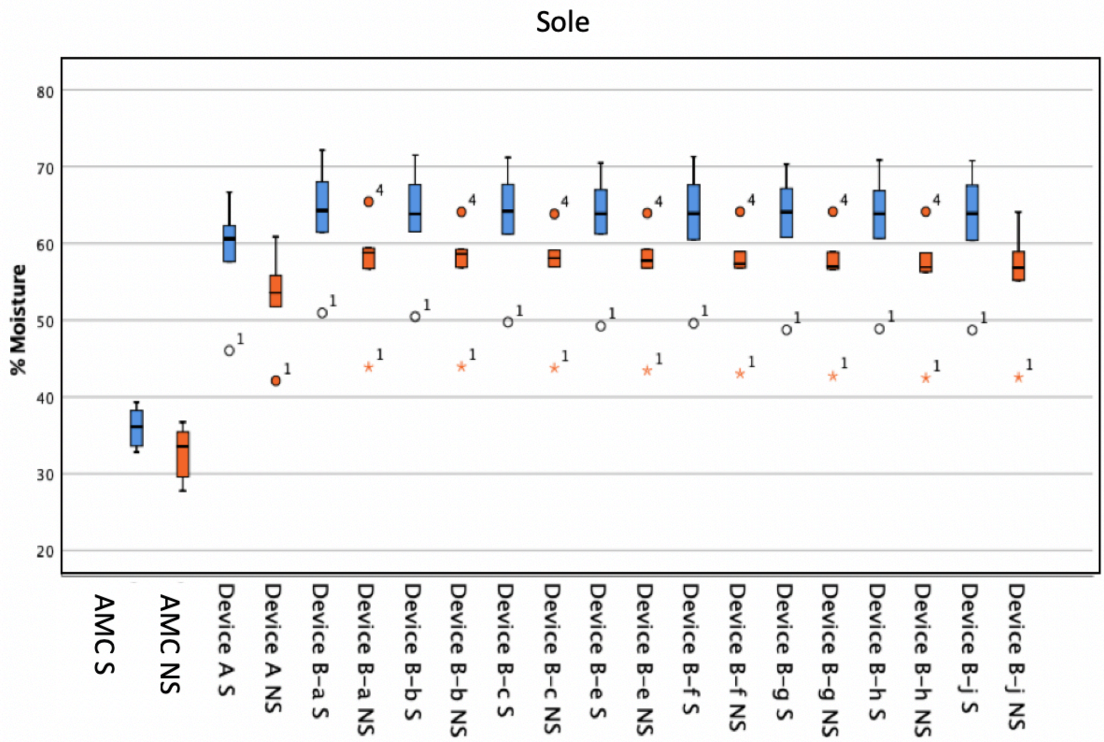


Fig.10 Box plot. Sole, MC data from 12 limbs. AMC saturated (S) AMC non-saturated (NS) plotted against Device A and B. showing the minimum, first quartile, median, third quartile and maximum.

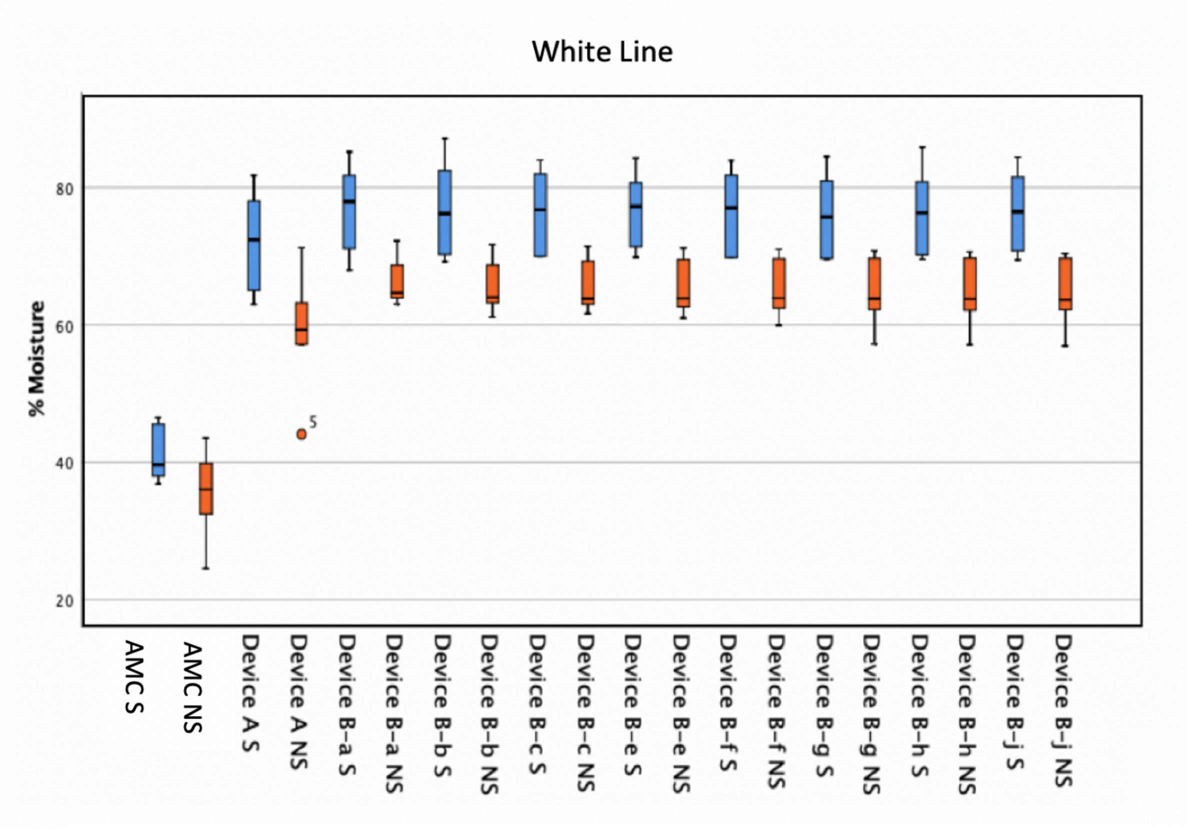


Fig.11 Box plot. WL, MC data from 12 limbs. AMC saturated (S) and AMC non-saturated (NS) plotted against Device A and B. showing the minimum, first quartile, median, third quartile and maximum. WL MC results from AMC saturated and non-saturated plotted against Device A and B.

Shore hardness results

Shore hardness: HW, (Figure 12): saturated n=128.22 SD=7.06 Non-Saturated n=139.11 SD=6.35 with a mean diff n=10.88 p=0.029 Sole: Saturated n=95.22, SD=10.23 Non-Saturated n=109.72 SD=5.52 with a mean diff n=14.50 p=0.030. WL Saturated n=79.96 SD=10.76 Non-Saturated n=93.97 SD=12.54 with a mean diff n=14.27 p=0.04

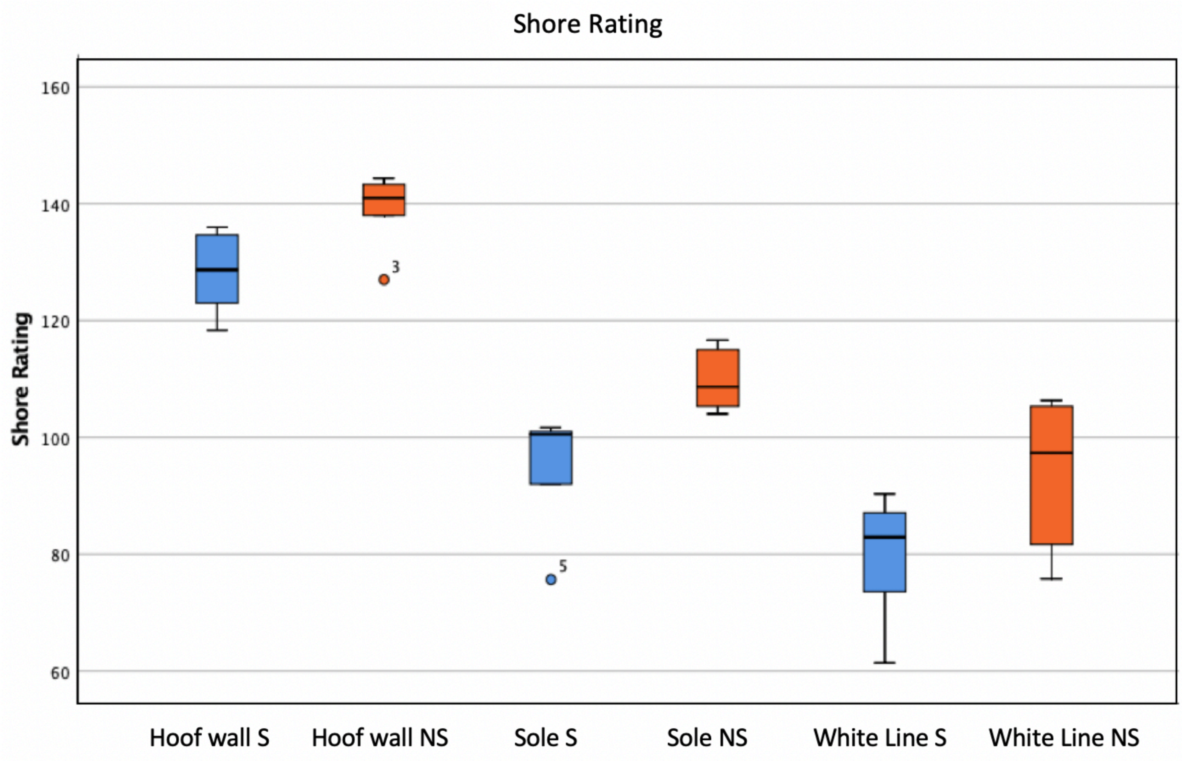


Fig.12 Box Plot. Shore hardness data from 12 limbs, in the HW, sole and WL in the saturated (S) and non-saturated (NS) feet, showing the minimum, first quartile, median, third quartile and maximum.

A pearson correlation results for the HW saturated: Pearson Correlation -239, p=0.648 non-saturated: Pearson Correlation -466, p=0.351. Sole saturated: Pearson Correlation -528, p=0.282 non-saturated: Pearson Correlation -417, p=0.411. WL saturated*:* Pearson Correlation -566 p=0.241, non-saturated: Pearson Correlation -253 p=629

Moisture meter performance

All device readings were significantly higher than the results from the oven drying experiment. Although the device readings are much higher than AMC results, the individual tolerances between saturated and non-saturated, when plotted against AMC results and device readings are very consistent as seen in the box plots.

As a result of the devices performing higher in horn, correction equations were calculated based on the regression method proposed previously, Altman and Bland., (1999). (Table 1) shows three correction equations which can be applied with the optimal device settings for each anatomical location in the hoof wall, sole and white line.

Table 1. Correction equations from regression method Bland and Altman., (1999) dealing with systematic increases or decreases in differences between device readings and AMC.

Correction Equations	A	B	AMC=a*meas+b
Hoof Wall	2.04021634	-29.54289	
Sole	0.265114	18.394541	
White Line	0.4365707	7.5463047	

(Table 2) shows the Bland and Altman values bias, SD, WLoA for the regression based corrected values and the % improvement between the WLoA value before and after application of the correction equation. The bias is the mean difference between the AMC and device values. The SD and WLoA are values representing the variation of the differences between the AMC and measured values from the representative set of saturated and unsaturated samples used in the study.

The most accurate settings are highlighted in yellow. The HW with (Device b, Setting F, WLoA 5.7) and sole (Device A, WLoA 8.3) (Device B, setting g, WLoA 19). The % improvement reveals how much the correction equations improve the WLoA values compared to the uncorrected measurement values.

Table 2. Showing the Bland Altman values bias, SD, WLoA and % improve. This is the criterion to choose a device/setting for each location as highlighted in yellow.

WLoA settin		Device A	Device B								avg
		WME	a	b	c	e	F	g	h	j	
HW	Bias	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	SD	2.1	1.8	1.6	2.1	1.5	1.4	1.5	1.6	1.5	
	WLoA	8.3	6.9	6.4	8.4	5.7	**5.7**	6.0	6.1	6.0	
	% Improve	3.6	4.1	2.1	0.5	15.1	10.1	19.0	10.0	11.9	8.5
Sole	Bias	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	SD	2.1	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	
	WLoA	**8.3**	11.0	11.1	11.1	11.1	11.1	11.1	10.9	10.9	
	% Improve	3.5	55.5	54.1	55.1	54.5	56.0	56.3	57.1	57.4	49.9
WL	Bias	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	SD	5.7	5.4	5.1	5.2	5.1	5.1	4.8	4.8	4.9	
	WLoA	22.4	21.1	19.9	20.5	20.0	19.9	19.0	**19.0**	19.1	
	% Improve	44.8	26.5	27.9	25.3	25.1	26.3	26.9	29.3	29.0	29.9

Discussion

The results showed that the moisture meters and methodology designed in this study can be accurately used to take MC readings in the three anatomical structures tested, at a specific depth in conjunction with correction equations for each structure. From these preliminary results it would suggest great value for the study to be taken forward and used in live horses, to investigate the effectiveness of topical hoof dressings with benefits for farriers and horse owners to understand how to best manage feet through changing seasons and environments.

The HW is most accurately measured using device B on setting f, the sole using device A and the WL using device B on setting h. The HW WLoA 5.7 and the sole WLoA 8.3 can be measured more reliably than the WL WLoA 19. This variation is possibly due to manufactures designing the instrument to take values in a wood which is a dense structural material whereas the WL is a very elastic and pliable structure. The WL is also an intricate structure to take a value with the heavy-duty probe that is possibly over engineered to be used in this structure. More research with a smaller hand-held probe where the pins are of less distance apart may result in the WL being measured more consistently.

As described in the methods the moisture meters are calibrated to take values in wood, if the manufactures were to calibrate the settings on the program circuit board to our AMC results from the oven based experiment, there would be no need to use the correction equations. The manufacturers methods for calibrating the device is to carry out oven drying experiments across the wide variety wood species from around world then calibrating the device settings to the results. This is because species of wood have many different densities, strengths and sap contents.

The results confirm that MC varies in the three architectural horny structures in the foot and is higher in the sole than the hoof wall as expected and confirmed in previous research by Hampson et al., (2012), Douglas et al., (1996) Reilly J.D., (2006). This is also reflected in the shore rating results showing the HW to be the hardest structure then the sole and WL being the most elastic in both saturated and non-saturated feet. Submersion of the foot for three hours influenced the hardness or elasticity of horn, which was expected in the WL and sole, however the HW was also affected with a mean difference of 10.88, p=0.029 confirming that MC does have an effect on the elasticity of the dorsal wall.

To the authors knowledge the study has obtained the first MC values in the WL from the oven drying experiment, which obtain the highest values at a 4mm depth. 35.44% pre saturation of the foot and 41.03% post saturation. This is most likely to be due to the structures composition, which is highly elastic and rich in sulfhydryl groups Pollitt,. (1996). The hardness of the white line was also affected pre and post saturation of the foot with a mean diff n=14.27 p=0.04. The WL is rarely discussed in research with the emphasis being on the hoof wall and the sole. This rapid increase in MC and stiffness raises awareness that the WL is a major architectural structure in the hoof and not just a flexible junction between the HW and the sole which it is often referred to. The WL appears to form more of an architectural rim between the HW and the sole which can be either very stiff and assist in bracing the hoof wall or a soft malleable structure which would facilitate in deformation of the distal aspect of the hoof wall.

The sole was also proven to rapidly hydrate with a MC value of 32.76% pre saturation and 36.02% post saturation at a 4mm depth. The hardness of the sole was also affected pre and post saturation with a mean diff n=14.50 p=0.030 which was higher than the WL but interestingly, the values are comparatively close. It is evident that the sole and the WL requires more investigative research to unveil more of its functional properties when hydrated and dehydrated in the hoof capsule, however this could answer some of the questions as to why some feet break down during the summer months causing deformation of the HW and depression of the solar arch in some feet.

Our results from the HW 18.54% pre saturation and 20.21% post saturation are lower than in previous research but could sit in the parameters of Hampson et al., (2012) which show results 25% to 29% as we took MC readings at a very specific depth that would not reflect the MC of the entire HW depth. Reilly J.D., (2006) also confirms the HW derives its MC axially from internal vascular structures, so MC would be significantly higher axially from our measured area. This could also be investigated with using the moisture meter taking MC readings at varying depths in the hoof wall in cadaver feet. The study's results do however contest Douglas et al., (1996), claiming the outer part of the stratum medium containing 27.9% moisture, which would be a very similar depth into zone two measured in the study.

This could increase through zone two and three but conceives to be very high compared to both our saturated and non-saturated samples.

The study shows that the HW in feet of domesticated horses react differently from feral horses in that MC does vary between saturated and non-saturated feet in zone two with a mean difference of 1.67%, p=0.039. This also influenced the hardness of the hoof wall. MC post saturation could also increase if a complete abaxial/axial section of the HW was tested, or feet saturated for longer. Hampson et al., (2012) contested the opinion that MC changes in the hoof wall, as it remains constant in feral horses and that the stratum tectoruim is an impermeable structure. This poses the question: Do domesticated horses, which have a farriery influence, change how feet react to moisture? Trimming and manipulating the dorsal wall with a rasp and removing the abaxial layer of horn does have a small influence on the absorption rate at a 33% depth of the HW, as proven in this study.

This study has shown that MC can be evaluated using the devices and methodology described in this paper. There are further research opportunities for this study to be shared and taken forward to investigate the effects of MC of feet in domesticated environments. This is a major advancement in our understanding to assist in palliative and routine foot care and gain knowledge on the effects of applying topical hoof dressings. This is believed to be the first study to be done in this field using moisture meters and would benefit from further research in different climates to help us understand some of the issue's practitioners have managing feet, particularly when influenced by extreme climatic conditions or affected by the effects of different types of bedding.

Conclusion

The most significant finding is that the moisture meters and methodology from this study, can be used to take accurate MC readings in the three anatomical structures tested in the foot. This is a breakthrough for future research and an opportunity to find out more about how MC effects feet in domestic environments and can be used in further research investigating the effectiveness of topical hoof dressing. The instrumentation can be taken forward from this study and used in live horses.

An impactful finding was that MC within the HW of domesticated horses which have had a farriery influence, has a small increase at a 33% depth of the hoof wall. This also decreased the hardness of the structure, when the foot is exposed to saturation proximal to the coronary band. This was proven not to change in feral horses. Trimming and manipulating the dorsal wall with a rasp and removing the abaxial layer of horn can affect the absorption rate, as proven in this study.

The first recorded MC values were obtained in the WL 35.44% pre-saturation of the hoof and 41.03% post-saturation at a 4mm depth. The WL is rarely discussed in research with the emphasis being on the hoof wall and the sole. This rapid increase in MC and stiffness raises awareness that the WL is a major architectural structure that functions in unison with the hoof wall and sole and requires more investigative research.

This is believed to be the first study to be undertaken in this field using a moisture meter.

Equipment Addresses

1, Parafilm™, Cam Lab UK)

2, Shore Digital Hardness Tester (Scale A)., Engineering and Gauge LTD, 11 Station rd, St. Albans, Herts, AL4 0HA, UK

3, Protometer Digital Mini (BLD5702)., Survey Express Services, 218-220, Brownhill rd, London, SE6 1AT, UK

4,Protometer Timbermaster (BLD5605)., Survey Express Services, 218-220, Brownhill rd, London SE6 1AT. UK

5,Protometer Heavy Duty (BLD5060)., Survey Express Services, 218-220, Brownhill rd, London SE6 1AT. UK

6, Insize Digital Depth Gauge (1145)., Unit A Riverside Drive, Cleckheaton, West Yorkshire, BD19 4DH. UK

7, Insize Digital Vernier Callipers (1108)., Unit A Riverside Drive, Cleckheaton, West Yorkshire, BD19 4DH. UK

8, Golden Mean Callipers (Phi ratio 1:1618)., The shoeing lab, Grimley, Worcester, WR2 6LR. UK

9, laboratory scales. (Fisher Brand™ MH-214 0.1mg)., Fisher Scientific LTD, Bishop Meadow rd, Loughborough. LE11 5RG. UK

10, Vulcan Incubator., LTE Scientific LTD, Greenfield, Oldham, OL3 7EN. UK

11, IBM SPSS, Version 25, UK

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Appendices

Appendix i

This project was granted approval by the Royal Veterinary Colleges Ethics and Welfare Committee.

Appendix ii

As part of the preliminary phase of the research project a pilot study was undertaken with the following goals.

1: To ensure measuring hoof wall width using mathematics was accurate and the methodology and equipment worked well and was practical to use. This was carried out on 6 cadaver front feet of different sizes and shape. All results were very accurate.

2: The lab protocol was trialled and tested 6 times to ensure the design was practical and the equipment was suitable and easy to use. The sample extraction was also repeated several times on cadaver feet to ensure that the process could be repeated easily and accurately.

3: The accuracy and usability of the moisture probes were trialled and tested in the structures used in the study. The probes were also tested post being modified, using the calibration tool that accompanies the moisture meters to ensure that modifying casing using stainless steel, thermoplastic and chemical anchor did not interfere with the manufacture's device settings.

4: The oven drying experiment was tested ensuring the drying trays for left and right feet were easy to use and samples were kept completely separate for saturated and non-saturated feet. The scales and calculations to obtain the AMC trialled to ensure it could be repeated consistently.

5: The testing protocol for using the durometer to measure hardness of the horn was trialled to ensure accurate results could be repeated in left and right feet.

6: Data spreadsheets were trailed and altered to ensure recording data in the lab was as easy as possible due to large amount of data that had to be manually recorded.

Appendix iii

Email communication from Simon Curtis FWCF, BSc (Hons), PHD, HonAssocRCVS, granting permission to use diagram From Corrective Farriery volume II, page 359, (figure 1)

Hi Andrew

Use with pleasure.

Please just end your legend with *courtesy of S Curtis*.

Kind Regards Simon Curtis

Appendix iv

Email communication from Christopher Pollitt BVSc, PHD granting permission to use a photo from Colour Atlas of the Horses Foot (1995) illustrating a transverse section of the hoof wall, showing four distinct zones of tubular density (figure 2)

Dear Andrew

You are welcome to use the photo.

Do you have the publication by Hampson et al, on moisture content of the hoof?

Cheers Chris Pollitt

Appendix v

Table of data gathered from the lab experiment. device readings are from the Hoof wall

Moisture Content data Hoof wall. Device A (WME meter) Device B (Timbermaster 8 settings) proximal/middle/distal																	
						Device A %	Device B MC %										
HorseID	Limb	Sutuation	Time	Hoof wall width	Depth	WME	Setting A	Setting B	Setting C	Setting E	Setting F	Setting G	Settting H	Setting J	Shore rating	Foot width and length	Surface temp
1	LF	Exposed	200	w 25/angle 41=16	4.5	25.4/23.8/25.5	26.4/26.1/27.3	26.1/25.2/27.6	29.6/28.8/30.5	22.8/22.2/23.6	22.6/21.9/23.7	20.3/19.8/21	24/23.4/25	27.4/26.8/28.4	132/136/140	6x6	12.6
1	RF	Not Exposed	0	w 25/angle 39=16	4.5	25.1/25.1/24.6	26.3/27.8/25.8	25.4/27.2/25	28.8/30.5/28.6	22.2/23.5/21.9	22.0/23.5/21.6	19.9/20.9/19.6	23.4/24.8/22.9	26.9/28.3/26.5	139/140/141	6x6	12.6
2	LF	Exposed	200	w 22/angle 48=16.34	4	25.6/22.8/25	26.4/25.2/24.2	25.7/24.5/23.3	29.3/28/27	22.5/21.3/20.5	22.3/20.9/20	20./19.2/18.6	24.1/22.2/21.4	26.9/25.8/25	135/131/138	5 3/4 x 6	14.4
2	RF	Not Exposed	0	w 22/angle 50=17	4	25.4/23.2/23.7	25.9/25/24.2	25.1/24.2/23.1	28.7/27.9/26.7	22/21.3/20.3	21.8/20.8/19.7	19.7/19.2/18.4	23.2/22.3/20.2	26.6/26/23.9	141/145/144	5 3/4 x 6	15
3	LF	Exposed	200	w 22/angle 50=17	3.8	26.2/25/25.7	26.9/26.8/29.9	26.5/26.5/25.9	29.9/29.1/29.6	23.6/22.6/22.3	23/22.2/23	20.7/20.4/20.4	24.6/23.3/24.1	27.8/26.8/26.8	126/122/128	5/14 x 5 1/2	15.6
3	RF	Not Exposed	0	w 20/angle 50=17	3.8	26.3/23.5/25.6	26.1/24.9/25.7	25.2/24/24.9	28.8/27.8/28.6	22.2/21.1/21.9	21.9/20.7/21.6	19.8/19.1/19.6	23.9/22.2/23	26.9/25.9/26.5	126/131/124	5/14 x 5 1/2	15
4	LF	Exposed	200	w 22/angle 48=16.34	4	26.2/25.1/26.8	29.2/27.8/28.2	29.7/27.9/27.9	31.9/31/30.8	24.8/24.1/23.5	25/24.3/23.5	21.8/21.3/21	25.9/25.4/24.7	29/28.7/28.1	120/116/119	5 3/4 x 6	12
4	RF	Not Exposed	0	w 25/angle 45=17.6	4.4	25.5/24.7/25.8	26.6/26.9/27.2	25.5/26.5/26.7	29.1/29.9/29.9	22.5/23.1/23	22.3/23/22.7	20.1/20.5/20.2	23.8/24.3/23.9	27.2/27.7/27.2	144/146/143	5 3/4 x 6	12
5	LF	Exposed	200	w 20/angle 46=14.38	3.5	26.3/24.1/24.4	27.8/27.1/28.4	27.2/26.4/28.4	30.7/29.8/31.7	23.9/23/24.6	24.3/23/25	21.4/20.5/21.8	25.4/24.3/25.9	28.9/27.6/29.4	126/123/120	5 1/4 X 3/4	14
5	RF	Not Exposed	0	w20/angle 46=14.38	3.5	25.5/23.6/25.2	26.5/27.2/27.2	25.5/26.5/26.6	29.1/29.8/29.9	22.3/22.9/23	22.1/22.8/23	20.2/20.2/20.5	23.8/24/24.3	27.2/27.3/27.6	136/138/142	5 1/4 X 3/4	14
6	LF	Exposed	200	w16/angle 49=12	3	26.9/25/26	28.2/29.4/28.4	28.8/29.2/28.3	31.8/32.1/31.4	24.5/24.7/24.3	24.7/24.9/24.4	21.5/21.6/21.3	25.6/25.7/25.3	28.9/29/28.7	131/133/134	5 1/4 x 51/2	13.5
6	RF	Not Exposed	0	w16/angle 49=12	3	26.6/24.8/24.8	27.6/28.0/26.5	27.5/27.5/25.9	31/20.8/29.5	24/23.7/22.8	24.3/23.9/22.7	21.3/21.1/20.3	25.4/25/24.1	28.8/28.4/27.5	143/140/144	5 1/4x 5 1/2	13.6

Appendix vi

Table of data gathered from the lab experiment. device readings are from the sole

Moisture Content data Sole. Device A (WME meter) Device B (Timbermaster 8 settings) palmer/middle/dorsal 4mm														
				Device A MC %	Device B MC READING									
HorseID	Limb	Sutuation	Time	WME	Setting A	Setting B	Setting C	Setting E	Setting F	Setting G	Settting H	Setting J	Shore rating	Surface temp
1	LF	Exposed	200	46.6/44.5/47	50/51.2/51.6	49/50.6/51.8	48.5/50.1/50.6	48/49.8/49.9	50.2/49/49.5	48.5/48.2/49.5	49.2/47.8/49.6	48.9/47.8/49.4	95/102/105	12
1	RF	Not Exposed	0	41.4/42.1/42.8	42.4/44/45.2	41.8/44.9/45.1	41.4/44.6/45.3	40.9/44.3/45.1	40/44/45.1	39.4/43.8/44.9	39.1/43.5/44.8	40/43.1/44.5	110/115/120	12.6
2	LF	Exposed	200	65/60.3/61.6	66.8/65/68.1	66.5/64.6/67	66.1/65.4/69.8	67.7/63.7/67.9	67.6/67.6/67.6	65.2/66.1/70.2	65.6/66.8/68.2	64.8/68.2/69.7	102/98/103	14
2	RF	Not Exposed	0	58.5/54.8/54.2	59.4/61.3/57.5	58.7/61.5/57.4	58.2/59.4/57.3	57.4/58.8/57.3	56.6/58.2/57.1	55.8/57.7/56.8	54.9/57.4/56.6	52.2/57/56.4	105/108/103	15
3	LF	Exposed	200	55/60.1/57.8	60.5/62.7/61.2	59/64.2/61.8	60/64/59.6	60.8/62.5/60.4	60.5/61.7/59.3	61.6/62.2/60.1	60.1/61.8/60.7	60.1/61.6/61.6	102/98/101	12.8
3	RF	Not Exposed	0	52/50/53.3	58.9/52.4/58.8	59.5/52/59.1	59.8/51.9/59.1	59.7/51.6/59	59.8/51.6/59	59.7/51.4/58.8	59.8/51.3/58.7	60.1/51.3/58.8	103/103/106	7.9
4	LF	Exposed	200	70.6/63.8/65.6	75.3/72/69.1	75.4/69.9/69.2	76.2/68.4/69	75.7/68.4/67.3	75.6/68.5/69.8	74.6/68.3/68.1	75.3/68.4/68.9	74.5/68.6/69.2	89/93/94	10.4
4	RF	Not Exposed	0	64.3/59.2/59.1	64/63.9/68.4	64.8/60.8/66.7	64.9/59.8/66.8	65/59.8/67	64.8/60.4/67.2	64.5/60.2/67.7	64.7/60.1/67.6	64.7/60/67.5	106/106/104	12.8
5	LF	Exposed	200	59.9/58.9/58.2	62.2/62.4/61.2	62.7/61.1/60.8	62.8/60.7/61.4	62.8/60.3/60.8	62.8/60/60.4	62.6/59.6/60.2	62.5/59.4/60.1	62.3/59.1/59.8	76/79/72	10.8
5	RF	Not Exposed	0	53.6/50.7/54.9	58.5/57.6/58.9	58.7/56.8/58.6	58.8/56.5/58.3	58.8/56.2/58	58.7/55.6/57.9	58.6/55.4/57.8	58.6/55.3/57.7	58.5/54.6/57.6	107/113/116	10.8
6	LF	Exposed	200	61/63.3/62.5	66/69/69.1	65/69.1/68.8	65/69.1/68.9	63.7/69/68.3	63.1/69/68	64.2/68.4/67.9	64.2/68.8/67.6	64.1/68.4/67.5	102/98/105	9.9
6	RF	Not Exposed	0	53.2/55.8/53.4	58.3/61/58.4	58.4/61.1/58.2	58.3/61/58	58.9/61/57.8	58.2/60.9/57.7	58.2/60.8/57.6	58.1/60.7/57.5	58.8/60.6/57.3	118/120/112	9.9

Appendix vii

Table of data gathered from the lab experiment. device readings are from the WL

Moisture Content data White Line. Device A (WME meter) Device B (Timbermaster 8 settings palmer/middle/dorsal														
				Device A MC %	Device B MC %									
HorseID	**Limb**	**Sutuation**	**Time**	**WME**	**Setting A**	**Setting B**	**Setting C**	**Setting E**	**Setting F**	**Setting G**	**Settting H**	**Setting J**	**Shore rating**	**Temp C**
1	LF	Exposed	200	81.4//81.6/82.2	88/85.3/82.2	88.2/89.1/84	86.3/82.6/83	87/83.1/82.6	87.5/82.1/82.2	85.2/81.2/87.1	85.6/85.9/86.1	84.8/86.1/82.3	65/58.2/61	12
1	RF	Not Exposed	0	55.1/61.1/68	62.1/63.5/69.5	60.9/63.4/69.8	60.4/63.1/70	59.9/62.7/71.3	59.3/62.6/72.2	58.9/62.4/72.6	58.8/62.2/72.5	58.4/62.1/72.5	83/78/84	13
2	LF	Exposed	200	77/72.6/75.3	83/78.4/83.8	82.4/78.5/86.4	82.2/78.3/85.4	82.4/78.1/81.6	82.1/79.4/83.8	80.7/77.2/85	81.7/78.6/82.2	82/79.8/82.8	70.8/72/78	13.6
2	RF	Not Exposed	0	73.4/66.7/73.7	73.5/73.2/70	72.9/71.3/70.9	72.6/70.5/71.2	72.3/70/71.3	72.1/69.7/71.3	71.8/69.3/71.3	71.6/68.9/71.4	71.3/68.5/71.3	76.5/71.9/79	13.7
3	LF	Exposed	200	62/61.2/65.8	62.9/68.7/72.3	67.6/71.6/68.4	68.1/71.7/70	68.3/71.5/74.4	67.5/68.7/73.2	67.5/70.2/70.8	69.1/70.8/70.7	68.4/70.3/73.6	83.8/89.9/87.6	11.1
3	RF	Not Exposed	0	54.4/58/59.2	63/62.6/63.5	63.6/62.4/63.6	63.5/62.4/63.6	63.6/62.3/63.5	63.5/62.2/63.6	63.5/62.1/63.4	63.5/62.2/63.4	63.4/62.2/63.4	101/111/104	12.7
4	LF	Exposed	200	79.9/75.4/78.8	81.3/78.3/81.8	78.2/76.7/76.8	77.4/82.8/78.2	82.1/80.7/78.2	80.2/79.9/79.3	78.7/76.8/78.5	78/79.1/80.3	77.6/82.3/78.9	82.9/85/90	9.2
4	RF	Not Exposed	0	62/61.2/66.4	62.2/67.4/63.3	59.2/64.3/59.9	60.4/63.4/61.1	57.3/63.5/62.2	56.5/61.1/62.2	54.3/59.2/58.2	56.7/57.6/57	58.2/56.5/56.1	93/96/101	10
5	LF	Exposed	200	68.9/69.7/70.8	76.3/73.4/76.6	75.3/74.3/75.8	75/71.7/75.4	74.6/72.8/75.1	74.1/73.8/74.8	73.8/71.7/74.8	73.6/72.2/74.6	73.4/72.1/74.5	75.9/80.9/82.6	10.8
5	RF	Not Exposed	0	63.6/62.7/65.2	68.2/67.9/70	68.7/66.6/70.9	69/67.6/71.2	69.2/68.1/71.2	69.1/68.6/71.2	69.3/68.7/71.1	69.3/68.9/71	69.3/69/70.8	95.2/101/98	11
6	LF	Exposed	200	65.2/63/66.9	70.5/69.5/73.4	69.5/68.2/73.1	69.3/67.9/72.8	69.2/67.7/72.7	69.1/67.6/72.6	69.1/67.4/72.5	69/67.3/72.4	68.8/67.2/72.4	88.8/90.2/92	9.3
6	RF	Not Exposed	0	57.2/57.4/56.9	65.1/64.9/61.8	63.8/64.5/61.5	63.5/64.2/61.3	62.7/64/61.2	62.5/63.8/61.1	62.3/63.6/60.8	62.2/63.5/60.7	62.1/63.9/60.6	102/109/108	9.5

Appendix viii

Table of data. AMC data. Averages from the device settings. Shore rating Averages

horseID	hwamcsat	hwasatwme	hwbsettasat	hwbsettbsat	hwbsettcsat	hwbsettesat	hwbsettfsat	hwbsettgsat	hwbsetthsat	hwbsettjsat	hwshoresat
1	18.74	24.9	26.6	26.26	29.63	22.87	22.73	20.37	24.13	27.53	136.00
2	18.82	24.46	25.26	24.5	28.10	21.43	21.07	19.27	22.57	25.90	134.67
3	17.03	25.63	27.86	27.3	29.53	22.83	22.73	20.50	24.00	27.13	125.33
4	22.24	26.03	28.4	28.5	31.23	24.13	24.27	21.37	25.33	28.60	118.33
5	20.76	24.93	27.76	27.33	30.7	23.83	24.1	21.23	25.2	28.63	123
6	23.7	25.96	28.66	28.7	31.7	24.5	24.66	21.46	25.53	28.86	132
horseID	**hwamcnonsat**	**hwanonsatwme**	**hwbsettanonsat**	**hwbsettbnonsat**	**hwbsettcnonsat**	**hwbsettenonsat**	**hwbsettfnonsat**	**hwbsettgnonsat**	**hwbsetthnonsat**	**hwbsettjnonsat**	**hwshorenonsat**
1	17.66	24.83	26.63	25.86	29.30	22.53	22.37	20.13	23.70	27.23	140.00
2	17.53	23.93	25.03	24.13	27.77	21.20	20.77	19.10	21.90	25.50	143.33
3	15.7	25.13	25.56	24.7	28.40	21.73	21.40	19.50	23.03	26.43	127.00
4	17.88	25.33	26.9	26.23	29.63	22.87	22.67	20.27	24.00	27.37	144.33
5	20.43	24.76	26.96	26.2	29.6	22.73	22.63	20.3	24.03	27.36	138
6	22.06	25.4	27.36	26.96	27.1	23.5	23.63	20.9	24.83	28.23	142
horseID	**solamcsat**	**solasatwme**	**solbsettasat**	**solbsettbsat**	**solbsettcsat**	**solbsettesat**	**solbsettfsat**	**solbsettgsat**	**solbsetthsat**	**solbsettjsat**	**solshoresat**
1	32.8	46.03	50.93	50.47	49.73	49.23	49.57	48.73	48.87	48.70	100.67
2	34.2	62.30	66.63	66.03	67.10	66.43	67.60	67.17	66.87	67.57	101.00
3	33.6	57.63	61.47	61.67	61.20	61.23	60.50	61.30	60.87	61.10	100.33
4	39.29	66.67	72.13	71.50	71.20	70.47	71.30	70.33	70.87	70.77	92.00
5	38	59	61.93	61.53	61.3	61.3	61.06	60.8	60.66	60.4	75.66
6	38.23	62.2	68.03	67.63	67.66	67	66.7	66.83	66.86	66.66	101.66
horseID	**solamcnonsat**	**solanonsatwme**	**solbsettanonsat**	**solbsettbnonsat**	**solbsettcnonsat**	**solbsettenonsat**	**solbsettfnonsat**	**solbsettgnonsat**	**solbsetthnonsat**	**solbsettjnonsat**	**solshorenonsat**
1	32.42	42.10	43.87	43.93	43.77	43.43	43.03	42.70	42.47	42.53	115.00
2	27.78	55.83	59.40	59.20	58.30	57.83	57.30	56.77	56.30	55.20	105.33
3	29.57	51.77	56.70	56.87	56.93	56.77	56.80	56.63	56.60	56.73	104.00
4	36.7	60.87	65.43	64.10	63.83	63.93	64.13	64.13	64.13	64.07	105.33
5	35.44	53	58.33	58.03	57.86	57.66	57.4	57.26	57.2	56.9	112
6	34.67	54.13	59.23	59.23	59.1	59.23	58.93	58.86	58.76	58.9	116.66
horseID	**wzamcsat**	**wzasatwme**	**wzbsettasat**	**wzbsettbsat**	**wzbsettcsat**	**wzbsettesat**	**wzbsettfsat**	**wzbsettgsat**	**wzbsetthsat**	**wzbsettjsat**	**wzshoresat**
1	45.56	81.73	85.17	87.10	83.97	84.23	83.93	84.50	85.87	84.40	61.40
2	38	74.97	81.73	82.43	81.97	80.70	81.77	80.97	80.83	81.53	73.60
3	41.04	63.00	67.97	69.20	69.93	71.40	69.80	69.50	70.20	70.77	87.10
4	38.28	78.03	80.47	77.23	79.47	80.33	79.80	78.00	79.13	79.60	85.97
5	46.51	69.8	75.43	75.13	74.03	74.16	74.23	73.43	73.46	73.33	79.8
6	36.84	65.03	71.13	70.26	70	69.86	69.76	69.66	69.56	69.46	90.33
horseID	**wzamcnonsat**	**wzanonsatwme**	**wzbsettanonsat**	**wzbsettbnonsat**	**wzbsettcnonsat**	**wzbsettenonsat**	**bsettfwznonsat**	**wzbsettgnonsat**	**wzbsetthnonsat**	**wzbsettjnonsat**	**wzshorenonsat**
1	43.54	61.40	65.03	64.70	64.50	64.63	64.70	64.63	64.50	64.33	81.67
2	35.17	71.27	72.23	71.70	71.43	71.20	71.03	70.80	70.63	70.37	75.80
3	39.85	57.20	63.03	63.20	63.17	63.13	63.10	63.00	63.03	63.00	105.33
4	24.55	63.20	64.30	61.13	61.63	61.00	59.93	57.23	57.10	56.93	96.67
5	37.03	44.1	68.7	68.73	69.26	69.5	69.63	69.7	69.73	69.7	98.06
6	32.5	57.16	63.93	63.26	63	62.63	62.46	62.23	62.13	62.2	106.33

Appendix vii

Table of data gathered from the oven drying experiment

Oven Drying Data						
HorseID	Limb	Exposued/Not Exposed to sutuation	Time	Wall_ pre drying weight gm	wall_post drying weight gm 24hr	actual mc % value
1	LF	Exposed	200	21	17.07	18.74
1	RF	Not Exposed	0	19.98	16.45	17.66
2	LF	Exposed	200	20.4	16.56	18.82
2	RF	Not Exposed	0	20.53	16.93	17.53
3	LF	Exposed	200	20.89	17.85	17.03
3	RF	Not Exposed	0	20	16.86	15.7
4	LF	Exposed	200	20.63	16.04	22.24
4	RF	Not Exposed	0	20.46	16.8	17.88
5	LF	Exposed	200	13	10.3	20.76
5	RF	Not Exposed	0	13.7	10.9	20.43
6	LF	Exposed	200	13.5	10.3	23.7
6	RF	Not Exposed	0	14.5	11.3	22.06
HorseID	Limb	Exposued/Not Exposed to sutuation	Time	Sole_pre drying weight gm	Sole_post drying weight gm 24hrs	actual mc % value
1	LF	Exposed	200	20	13.44	32.8
1	RF	Not Exposed	0	19.4	13.11	32.42
2	LF	Exposed	200	12.6	8.28	34.2
2	RF	Not Exposed	0	17.6	12.71	27.78
3	LF	Exposed	200	13.39	8.89	33.6
3	RF	Not Exposed	0	14	9.86	29.57
4	LF	Exposed	200	9.62	5.84	39.29
4	RF	Not Exposed	0	6.81	4.31	36.7
5	LF	Exposed	200	7.6	4.7	38
5	RF	Not Exposed	0	7.9	5.1	35.44
6	LF	Exposed	200	6.8	4.2	38.23
6	RF	Not Exposed	0	7.96	5.2	34.67
HorseID	Limb	Exposued/Not Exposed to sutuation	Time	WZ_pre drying weight gm	WZ_post drying weight gm 24 hrs	actual % value
1	LF	Exposed	200	7.9	4.3	45.56
1	RF	Not Exposed	0	6.2	3.5	43.54
2	LF	Exposed	200	5.5	3.41	38
2	RF	Not Exposed	0	2.9	1.88	35.17
3	LF	Exposed	200	7.82	4.61	41.04
3	RF	Not Exposed	0	7	4.21	39.85
4	LF	Exposed	200	5.12	3.16	38.28
4	RF	Not Exposed	0	3.34	2.52	24.55
5	LF	Exposed	200	4.3	2.3	46.51
5	RF	Not Exposed	0	2.7	1.7	37.03
6	LF	Exposed	200	3.8	2.4	36.84
6	RF	Not Exposed	0	4.2	2.7	32.5