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**Lameness of dairy cattle: Factors affecting the  
mechanical properties, haemorrhage levels, growth and  
wear rates of bovine claw horn**

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**Lameness of dairy cattle: Factors affecting the  
mechanical properties, haemorrhage levels, growth and  
wear rates of bovine claw horn**

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The present study aimed to determine with the use of mechanical testing parameters the effects of diet supplements, breed and time (prepartum /post partum) on lesion development, severity and the integrity of bovine claw horn.

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### **Declaration**

Each chapter is set out in the style of; the Journal of Dairy Science to which the papers have been submitted. Consequently there is some repetition, particularly in the methods and references sections. The submitted papers include other authors, but for each of the chapters my input was the greatest. I, with the appropriate assistance of my co-authors / supervisors, designed and carried out the research, analysed the data and wrote the papers.

## Abstract

Lameness is one of the main economic and welfare issues faced by the global dairy industry. It mainly affects the hind claws and the main causes / types are; claw horn lesions of the sole and white line (WL), along with foot rot (NZ) and digital dermatitis (UK). This thesis aims to apply and develop mechanical tests to determine the effect of dietary supplements, animal breed and number of days postpartum (dpp) on claw horn (CH) mechanical properties. Supplementation with live yeast (UK) significantly increased the puncture resistance (PR) of sole horn ( $P < 0.05$ ), level of mean sole haemorrhage percentage, total combined lesion score (TLS) and wear rates ( $P < 0.10$ ), while increasing daily mean milk yield, total milk fat and protein without significant increases in feed intake, providing an increase in feed conversion efficiency. In growing (NZ) dairy cattle PR was lower in 1, 2 (WL) compared with sole (4 and 5) while zones 4 and 5 did not differ significantly. Dairy breed (NZ) affected the PR of the CH, significantly ( $P < 0.001$ ) lower PR in CH of Friesian (all 5 IFM regions) compared with Friesian X Jersey (FxJ). Lactating dairy heifers (partition 22 to 24 months) from 0 to 160 d pp showed that the breed did not significantly affect the; number, percentage or TLS of sole or WL lesions, with the exception of 160 dpp where Friesian heifers had significantly ( $P < 0.05$ ) higher WL and sole lesions compared with FxJ. Mechanical properties (PR) of CH, declined significantly with increasing number of days post partum (dpp), while EM was significantly stiffer at 30 d pp compared with 120 dpp. PR was reduced significantly by increasing lesion score (LS), but was not confirmed by Vickers hardness and EM results. Hydration of CH significantly lowered EM compared to dried horn or horn at physiological moisture content. Short term (200 d), neither the form (zinc as salt or complexes with yeast) nor level of zinc (At 1.0 or at 0.3 of NRC recommended levels (RL)) did not significantly affect; locomotion score; growth and wear rates; claw measurements and sole and WL lesions were not significantly effected by form or level of supplemental zinc up to 150 d pp. Overall, the number of days pp (dpp) significantly increased the level of sole and WL lesions, and reduced CH PR and elastic modulus (EM).

## General summary

Lameness of dairy cattle is one of the main economic and welfare issues faced by the global dairy industry. The incidence of lameness has increased in recent years, affecting approximately 35%, in the UK, and 22%, in New Zealand, of dairy cattle. In the majority of cases the hind claws are affected and the main causes / types of lameness are; claw horn lesions (CHL) of the sole and white line, along with foot rot in New Zealand and digital dermatitis in the UK. This thesis aimed to apply and develop mechanical tests to determine the effect of; dietary supplements (zinc and live yeast), animal breed and number of days postpartum (dpp) on claw horn mechanical properties, along with the assessment lesion development and severity for both sole and the white line, horn growth and wear rates, and locomotion score of dairy cattle in UK and New Zealand based systems.

The rapid inclusion of the Holstein into the UK has led to substantial increases in the milk yield potential of UK dairy cattle and the need to adopt higher energy dense feeds and diets, with lower effective fibre levels. This has resulted in an increased occurrence of rumen acidosis, in particular sub-acute rumen acidosis (SARA). As a consequence, there has been a renewed interest in dietary supplements that modify rumen pH, especially naturally occurring microbial products, such as yeast. However despite the relationship between rumen acidosis and laminitis no research had been completed to assess the effect of yeast supplementation on claw horn structural integrity, CHL and lameness. In Chapter two a mixed forage diet (UK) was supplemented with live yeast and the affect on claw horn was assessed using mechanical and lesion scoring methodologies. Supplementation with live yeast significantly increased the puncture resistance (PR) of sole horn ( $P < 0.05$ ), level of mean sole hemorrhage percentage, total combined lesion score (TLS) and wear rates ( $P < 0.10$ ), while increasing daily mean milk yield, total milk fat and protein without significant increases in feed intake, providing an increase in feed conversion efficiency.



Overall, the number of days pp (dpp) significantly affected the level of sole and WL lesions, claw horn PR, growth and wear rates. Live yeast clearly offers, in some diet situations, the potential to reduce the severity of sole hemorrhaging and in improving claw horn quality and warrants further research into both the mechanism and effect of live yeast in a range of dairy cattle diets, were potential improvements in; animal productivity, feed use efficiency and animal health may be gained. The aim of this thesis was to apply and develop mechanical testing of bovine claw horn and this work showed that the use of PR was a valid indicator of dietary factors that can affect the structural integrity and strength of bovine claw horn, as was claw horn lesion scoring (CHL) and as a consequence these method were applied in New Zealand in Chapter three.

In New Zealand to facilitate 'all year round' grazing systems dairy cattle are commonly selected for lower body weight and small breeds such as Jersey and in particular the use of cross bred (Friesian x Jersey) dairy animals, including the provision of cross bred sires in the artificial insemination catalogue, has led to a high proportion of cross bred dairy cattle in the New Zealand dairy herd. There have been some reports of lower levels of lameness in Jersey and cross bred compared to Frisian dairy cattle, which has been, in part, potentially attributed to differences on claw horn colour and strength. However, there is a limited amount of detailed information that characterising the dynamics of claw horn lesion development or levels and CHL scoring, which was developed in Holstein Frisian cattle with light claw horn has never been applied to cross bred dairy cattle, which tend to commonly have dark almost black claw horn. In Chapter three both mechanical testing and lesion scoring was applied to Frisian and cross bred (Friesians x Jersey) dairy cattle during growing and first lactation phases and the international foot map (IFM) regions were used to compare claw horn strength. The growing dairy cattle (0 to 4 m of age) showed no signs of claw horn lesions, while PR differed significantly between differing regions of the IFM, with lower PR in 1, 2 (WL) compared with sole (4 and 5) while zones 4 and 5 did not differ significantly. The breed affected the PR of the claw horn, with significantly

( $P < 0.001$ ) lower PR in claw horn of Friesian (at all 5 IFM regions) compared with Friesian X Jersey (FxJ). Lactating dairy heifers (partition at 22 to 24 months age) from 0 to 160 d pp showed that the breed did not significantly affect the; number, percentage or TLS of sole or WL lesions, with the exception of 160 dpp where Friesian heifers had significantly ( $P < 0.05$ ) higher WL and sole lesions compared with FxJ. Overall, PR significantly decreased with increasing number of dpp and with increased lesion score (LS) demonstrating that the resistance to damage and thus claw horn integrity was reduced as lactation continued. The assessment of lesion score, using the existing techniques, were found to be more difficult to apply accurately in cross bred dairy cattle, potentially these methods are less suitable for application to cross bred dairy cattle (dark claw horn being most common) than to Friesian cattle (selected for white socks and thus light claw horn predominating) for which they were developed. This warrants further research, using morbid claw tissue, as would the effect of cattle breed and within breed variation, for which PR shows great potential in determining the differences and dynamics in claw horn integrity and function of differing breeds of cattle. The identification of specific genes that increase claw horn integrity and resilience, which may lead to reduced claw horn penetration and claw infection would be ideal. In this Chapter PR produced useable and repeatable data, however, material scientists favour elastic modulus (EM) as a method and while Winkler (2005) tried one method of EM, which used self tightening grips and required larger 'dog bone' shaped claw horn samples. This was the limiting factor, resulting in fewer suitable claw horn samples and insufficient sample size to produce sufficient data to make comparisons. As a consequence, Chapter four aims to adopt and develop a new method for EM.

In Chapter four the EM, Vickers hardness and PR tests were used, the EM test, which was recently developed, and has never been applied to bovine claw horn? The main advantages of this test were that it required only relatively small horn samples and allowed the measurement of 'creep' in the claw sample to be measured. The EM, Vickers hardness and PR of claw horn from two differing

periods postpartum were compared. The mechanical properties (PR) of claw horn, declined significantly with increasing number of days post partum (dpp), while EM was significantly stiffer at 30 d pp compared with 120 dpp. PR was reduced significantly by increasing lesion score (LS), but was not confirmed by the Vickers hardness and EM results. Hydration of claw horn significantly lowered EM compared to dried horn and horn at physiological moisture content. Mechanical properties tests (PR and EM) offered the potential to assess in the determination of the effect of factors such as; breed nutrition, parturition and environment that affect claw horn composition, integrity and physical function. The mechanical integrity of claw horn is particularly pertinent in grazing based dairy production systems and these mechanical tests for claw horn, and the development of others, warrant further application, research and development.

The supplementation of dairy cow diets with micronutrients has been found to be affective in reducing lameness in some situations and the use of technologies that combine micronutrients with microbial products has gained support in increasing micro-nutrient absorption by the animal. This has positive implications for reduced environmental pollution and efficacy of micronutrient use. The detailed measurement of the effect of micronutrient supplementation on claw horn integrity has not been assessed in detail using mechanical techniques. In Chapter five the short term (200 d) effect of differing levels and forms of dietary zinc are assessed, in the UK, using CHL scoring, EM and PR. The form (zinc as salt or complexes with yeast) and level of zinc (At 1.0 or at 0.3 of NRC recommended levels (RL)) supplementation did not significantly affect; locomotion score; growth and wear rates; claw measurements and sole and white line (WL) lesions were not significantly effected by form or level of supplemental zinc up to 150 d pp. Milk yield, corrected milk yield and total fat and protein yield were not significantly affected by the form of zinc offered at 1.0 RL, but the reduction in zinc levels to 0.3 RL resulting in a significant ( $P < 0.05$ ) reduction in milk yield. Overall, the number of days pp (dpp) significantly affected the level of sole and WL lesions, claw horn PR and elastic modulus (EM), growth

and wear rates. PR and EM proved to be successful in detecting changes in claw horn integrity due to increased CHL score typical to increasing number of dpp. The effect of differing forms and levels of zinc on animal health and productivity warrants further research over longer feeding periods to assess more fully the longer term effects of zinc and zinc combined with other micronutrients in the development of high quality claw horn and its effect on sole and WL lesions score and horn function. This was unfortunately beyond the level of funding and resources available in this particular case.

**Key words:** Claw horn, mechanical properties, lameness, dairy cattle, Zinc, Yeast.

**Glossary of frequently used abbreviations**

BCH	Bovine claw horn
BCS:	Body condition score
CE:	Cell envelope
CH:	Claw horn
CHD:	Claw horn disease
CHL:	Claw horn lesion
CP:	Crude protein
DD:	Digital dermatitis
d:	day(s)
DM:	Dry matter
DMI:	Dry matter intake
D pp:	Days <i>postpartum</i>
EM:	Elastic modulus
ICS:	Intracellular cementing substance
IDD:	Inter-digital dermatitis
IFAP:	Intermediate filament associated proteins
IFM:	International foot map
FCE:	Feed conversion efficiency
Fr:	Friesian
FxJ:	Friesian x Jersey
GPa:	Giga Pascal's
LS:	Lesion score
LY:	Live yeast
MC:	Moisture content
MMP's:	Matrixmettallonoprotinases
MPa:	Mega Pascal
MR:	Mixed ration
NC:	Net change
NEB:	Negative energy balance

N/mm <sup>2</sup> :	Newton/mm <sup>2</sup>
NP:	Non pigmented
NLY:	No live yeast
NRL:	National recommended levels
NS:	Not significant
NZ:	New Zealand
NZF:	New Zealand Friesian
OrZn:	Organic Zinc
P:	Pigmented
pp:	<i>Postpartum</i>
PR:	Puncture resistance
RL:	Recommended levels
RH:	Relative humidity
S:	Sole
SARA:	Sub clinical acidosis
SCC:	Somatic cell count
TLS:	Total lesion score
UK:	United Kingdom
WL:	White line
VH:	Vickers hardness
WR:	Wear rate
Zn:	Zinc
ZnOX:	Zinc Oxide

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