Prevalence of white line disease and the association with other claw defects in slaughter sows

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Abstract

Claw defects are very common in the Netherlands, but are still an under investigated problem in sows. The aim of this study was to investigate the prevalence of white line disease (WLD) and other claw defects (sole cracks, hemorrhages, wall cracks and heel overgrowth) in slaughter sows and the association between WLD and the other claw defects. Three hundred claws of slaughter sows were randomly collected in a slaughterhouse in Groenlo, the Netherlands. After visual scoring of the claw lesions, using a designed protocol, the claws were dissected and scored again on defects. The most common claw defects were heel overgrowth in both front and hind claws with a prevalence of 95,7 and 100% and hemorrhages with 100%, followed by sole cracks (97.1 and 96.6%), wall cracks (39.6 and 78.5%) and WLD (10.8 and 14.4%). Within WLD, the WLD which extended through the sole had a prevalence of 26.6% in the front claws and 45.6% in the hind claws. There was an association between WLD and whether the claws were front or hind claws (OR = 2.44, with a 95% CI of 1.49-3.92). The second one is the association between WLD and the presence of and in case of presence, the severity of a sole crack. (severe sole crack, OR = 8.28, with a 95% CI of 1.02-67.02). Furthermore, a notable result is the high prevalence of hemorrhages in the claws of slaughter sows. Recommendations for further research could include extra research about the prevalence and associations of claw defects. Other factors should be included, such as; type of floor, whether a claw is a left or a right claw, the clinical state of the animals and perchance the association between claw defects and lameness.

Contents

Preface

All students of Veterinary Medicine at the University of Utrecht have to do a research project. This paper is the final report of this project, which was led by dr. A. van Nes from the department of Population Health Sciences and drs. M.A.M. Houben from the Royal GD.

The research was performed to gain insight in the prevalence of claw defects in slaughter sows, with special attention to white line disease. The practical work was executed on claws of slaughtered sows.

In chapter 1, there is an introduction. Chapter 2 describes the background of this study, by explaining the anatomy of the claw, the occurrence of white line disease and other claw disorders nutritional factors. In chapter 3, the materials and methods are discussed and, subsequently, the results are presented in chapter 4. Finally, in chapter 5, the methods and results are evaluated in the discussion and conclusion.

1. Introduction

The last years, animal health became more and more important. The societal impact on farmers became higher, with special attention to animal welfare (Kanis et al., 2003). The Netherlands is seen as one of the leading countries in this topic, however there are still some issues which play a role in animal health and welfare (Varkenshouderij Archieven (2020) LTO; Nalon et al., 2019). One of these issues is the prevalence of claw disorders in pigs (Anil et al., 2009; Nalon et al., 2013) In sows, claw disorders are common (Dewey et al., 1993). However, in every day farm-life, claw disorders are often not reported (probably due to the difficulty of in-depth clinical inspection of claws on farms) (Nalon et al.,2019; Ison et al., 2014).
The pathogenesis of white line disease (WLD) in sows and ways to prevent these are greatly unknown. Therefore, it is crucial to do research on the prevalence on white line lesions and other claw defects, so reliable data will be generated to do research about the association between WLD and other claw defects. Observations of claws of slaughter sows after the scalding and dehairing process may facilitate extensive investigation of claw disorders (Anil et al., 2007; Nalon et al., 2013; Zimmerman et al., 2012).
The goal of this study is to gain more insight into claw defects, with special attention for WLD in sows, to eventually improve their general wellbeing. To achieve that goal the objectives of this study were to investigate the prevalence of WLD and other claw defects (sole cracks, haemorrhages, wall cracks and heel overgrowth) in slaughter sows and the association between WLD and the other claw defects.

2. Background

2.1 Anatomy of the claw

The pig has sixteen digits, four on each leg. Two of them are weight bearing digits (the third and fourth digit) and two of them are non-weightbearing accessory digits (the second and fifth digit), also called dewclaws. The first digit is lacking in the pig. The third digit is medial and the fourth digit is lateral. The lateral digit is larger than the medial digit in all feet. However, the dissimilarity in size in the hind feet is more prominent than in the front feet (Zimmerman et al., 2012). The dewclaws are located caudal to the larger digits. A digit consists of the claw, which includes the hard wall, hard sole and soft heel. The distal phalanx (P3) and the distal part of the middle phalanx (P2) are covered by each claw. The volar surface of the claw consists of the wall, the sole, and the large heel, which includes the digital cushion. The heel is a prominent part of the claw, while the sole is relatively small. The junction between the wall and the sole of the claw is a nonpigmented soft wall of horn, named the white line (Zimmerman et al., 2012).

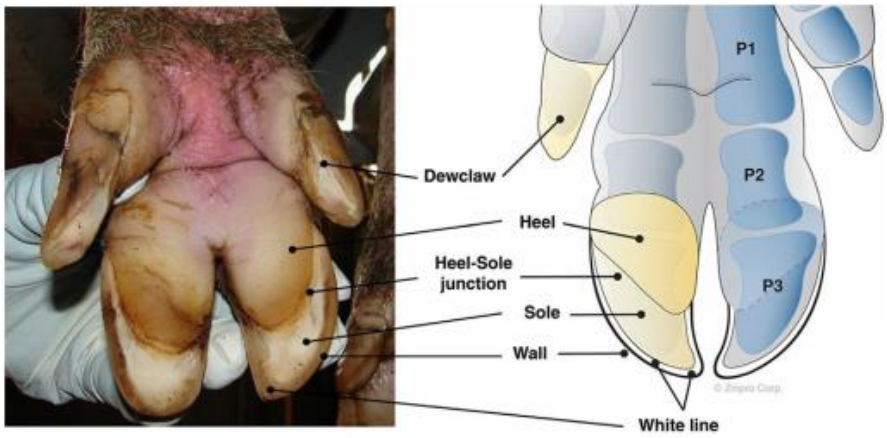

Figure 1. The anatomy of the sow claw. (Nalon et al., 2013)

The inside of the claw consists of the phalanx, the subcutis, the dermis (also called the corium), the vascular basement membrane and the epidermis. The dermis contains blood vessels and nerves and is a supportive connective tissue layer for the epidermis. This layer provides the stratum basale (germinal layer) with hormones and nutrients, which includes vitamins, minerals and trace elements. With the nutrients and hormones, the stratum basale produces epidermal cells. The epidermal cells proliferate and differentiate, forming the distal layers of the epidermis (Zimmerman et al., 2012). Furthermore, the epidermal cells differentiate and produce keratins. The process of keratinization depends on the supply of nutrients, because the nutrients are important for the integrity of the horn. If the keratinizing epidermal cells don't receive sufficient nutrients, like biotin, zinc and calcium, the quality of the horn will decrease. The inferior horn quality leads to an increase of its susceptibility to damage. This increase in susceptibility may result in lameness and claw defects (Zimmerman et al., 2012).

2.2 White line disease

As mentioned before in chapter 2.1, the white line is a nonpigmented soft wall of horn, between the wall and the sole of the claw (Zimmerman et al., 2012). White line disease is characterized by the haemorrhage into or an avulsion of the abaxial wall, which is most commonly at the heel-sole junction (MSD Veterinary Manual, 2015).
The white line in animals consists of 3 parts; the outer, intermediate and inner parts. These parts all contain different kinds of horn (nontubular horn, cap horn and tubular horn). Because of this difference in horn, weakness in the white line may arise. When there is a normal keratinization and cornification of horn cells, the strength and resistance of the white line is improved.
There are several reasons for causing weakness in the white line, which increases the risk of lesions. First, with a disease as e.g. laminitis, the quality of the horn is decreased because of a decrease in blood flow to the corium. If this happens, the keratinization and cornification will also decrease and the white line is weakened, therefore increasing the chance on separation of the white line. Second, foreign material (stones, bacteria, fungi) can get trapped in the white line, causing a white line lesion (Mülling et al., 2002; Shearer et al., 2017). Third, as discussed in chapter 2.1, the integrity of the horn is affected if there is an insufficient supply of nutrients for the keratinization. Affected horn is more susceptible to damage caused by, for example, trauma

(Zimmerman et al., 2012). Finally, other factors associated with WLD and claw lesions are the surface on which the animals live and a lack in specific nutrients, like biotin and zinc (Simmins et al., 1988).
WLD is a common affliction in farm animals, such as cows and horses. In cows, a factor causing the white line defect/lesion may be a physical one, like standing or being pushed on a rough hard floor (Cook et al., 2017). In horses, WLD is also a common hoof defect. It often occurs from a primary disease, like chronic laminitis or hoof imbalance. When a keratolytic process starts on the solar surface of the hoof, separation may occur. This separation is in the nonpigmented horn between the stratum lamellatum and the stratum medium. As with cows and sows, bacteria and other foreign material can invade the separation leading to infection (O'Grady et al., 2010).

2.3 Other claw defects

Apart from WLD, there are four other common claw defects, such as: wall crack, sole crack, heel overgrowth and haemorrhages. The first claw defect is a crack in the wall, of which there are two types: false sand cracks or true sand cracks. The false sand crack is a vertical crack starting at the white line. A true sand crack is a crack starting at the coronary band. Not only vertical cracks can occur, horizontal cracks can also arise in the wall (Zimmerman et al., 2012). Cracks in the sole are mostly seen at the junction of the heel and sole (Zimmerman et al., 2012). Another claw defect is a hyperkeratinisation, caused by continuous trauma, which is also called heel overgrowth (Zimmerman et al., 2012). The last one that will be discussed is the haemorrhage, which is a dark discoloured area and mostly caused by trauma from the outside of the claw (Zimmerman et al., 2012).

2.4 Nutritional effects

Nutrition, and mainly the presence of biotin, zinc and calcium, is an important factor in the integrity of the claw horn, as was concluded in chapter 2.1. First, biotin is a form of vitamin B8 and it increases the compressive strength of the mid-abaxial sidewall region. The hardness of this region and of the heel bulb is increased when biotin is supplemented. (Webb et al., 1984) However, there are also studies where no improvements in claw integrity, after supplementation with biotin, were found (Kempson et al., 1989; Webb et al., 1984; Lewis et al., 1991; Penny et al., 1980). Misir et al. (1986) found that, in order to decrease the prevalence of claw disorders, a concentration of at least 200 ng biotin/kg dry matter should be in the forage. Timmer (2004) found that a supplementation of 2000 µg biotin/ kg feed for a longer period of time, improves the claw integrity, therefore decreasing the likelihood of developing claw defects. Second, zinc is an element which has influence on regulatory and catalytic functions in the claw and it maintains structure, which is important for the production of horn (Van Riet et al., 2013). Finally, calcium regulates and initiates the processes of keratinization and cornification, which are important processes in the production of horn. A lack of calcium in the feed over time can lead to a lower plasma concentration. Keratinocytes use calcium, but when there is a shortage in the plasma, inferior horn will be produced (Mülling et al., 1999; Tomlinson et al., 2004).

3. Materials and methods

3.1 Experimental design

To analyse prevalence and determine an association between WLD and other claw defects we designed a cross sectional study. This study was conducted on three hundred randomly selected claws from sows that were selected after the scalding and dehairing process in a Dutch slaughterhouse in Groenlo. It was not known whether there was one claw selected per claw, or of there were more claws originating from one sow. We calculated the sample size needed for this study with an expected prevalence of 0.7 (Anil et al., 2007), a total width of confidence interval of 0.1 and a confidence level of 0.8. (Sampsize, 2003, assessed on November 25th) Between the transport and lesion scoring in this study, the claws were stored in a freezer, with a temperature of -20°C. The claws were taken to the necropsy department of the Royal GD. It is important to note that the claws were separated into 150 front and 150 hind claws. This has been done to analyze whether the defects are more or less severe in the front/ hind claws, which might be explained by the animal's weight distribution. After visual evaluation of the claw lesions, using a protocol adapted from Zinpro (2018) and Diaz et al. (2013), the claws were dissected into 3 slices, as is shown in Figure 1 and Figure 2. Pictures were taken of all the slices (both sides) and have been scored with the scorings protocol based on the protocol of Zinpro (2018) and Diaz et al. (2013). The prevalence of the different claw defects was calculated, based on the collected data. The association between WLD and the claw defects was also calculated. Further explaining will be done in chapter 3.3.

3.2 Claw lesion scoring

To score the claws that were sliced as described above, a combination of a strategy by Zinpro (2018) and Diaz et al. (2013) was used. This provides a visual protocol for a number of defects (heel overgrowth, sole crack, wall crack, white line), which is accompanied by a description of the most important features. However, in this study we intend to evaluate the claws also for hemorrhages and white lines through the soles, which are not included in the protocol by Zinpro (2018) and Diaz et al. (2013). The scoring was based on the type of the lesion and the level of severity (1= mild, 2= moderate and 3= severe) Zinpro (2018).
The scoring strategy for white line through the sole and the hemorrhages was designed in this study. The white line defect score consists out of two parts; the white line and the white line through the sole. The scoring for white line through the sole was based on the scoring description by Zinpro (2018) for white line. However, for white line in the sole, not just the horizontal, but also the vertical penetration of white line is included. The hemorrhages were scored when there was a penetration of blood in the slice. The full protocol can be perused in Table 1.
The protocol is applied by evaluating all three slices (also both sides of the slices) of one claw, and first deciding for each defect what slice shows the most severe symptoms of that defects. Next, for that selected slice, the scoring protocol, as described in Table 1, is used to decide upon a score. For example, if scoring hemorrhages in Figure 2, the most severe symptoms can be seen in slice 1, and shows a penetration of 1/3 to 2/3 of the slice. Therefore, the claw shown in Figure 2 and 3 receives a score of 2 on the defect hemorrhages. As explained in the experimental design, a scoring protocol (Table 1) was made to classify the lesions. Three slices from each claw were cut horizontally, which can be seen in Figure 2 and 3. If the white line defect went through the upper side of the first slide (sole), it was scored as a white line defect through the sole. If not, the defect was scored

as a white line defect that did not go through the sole. By looking at the sole, a 1, 2 or 3 was scored. The scoring of the other claw defects is described in Table 1.

Figure 2. Picture of the underside of each slice taken from a sow claw, where 1 is the bottom slice, 2 is the middle slice and 3 is the slice that was taken highest up in the claw.

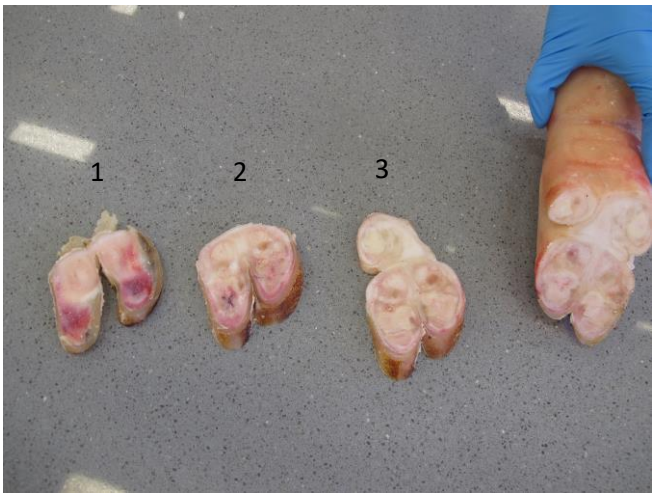

Figure 3. Picture of the inside view of each slice taken from a sow claw, where 1 is the bottom slice, 2 is the middle slice and 3 is the slice that was taken highest up in the claw.

Table 1. Scoring protocol of claws to identify the severity of the individual claw defects, of which parts were taken from Zinpro (2018) and Diaz (2013).

	Scores			
Claw lesion category	*0*	*1*	*2*	*3*
White line	Normal	Shallow and/or short separation along white line.	Long separation along white line.	Long and deep separation along white line.
White line through the sole	Normal	Shallow and/ or short separation along white line, scored on length and depth.	Long separation along white line, scored on length and depth.	Long and deep separation along white line.
Cracks in the wall (horizontal and vertical)	Normal	Horizontal: haemorrhage evident, short/shallow horizontal crack in toe wall. Vertical: short/shallow crack in vertical wall.	Horizontal: long but shallow horizontal crack in toe wall. Vertical: long but shallow vertical crack in the wall.	Horizontal: multiple or deep horizontal crack(s) in toe wall. Vertical: multiple or deep vertical crack(s) in the wall.
Sole crack	Normal	Slight separation.	Long separation.	Long and deep separation.
Heel overgrowth	Normal	Slight overgrowth and/ or erosion in soft heel tissue.	Numerous cracks with obvious overgrowth and erosion.	Large amount of erosion and overgrowth and cracks.
Hemorrhage	Normal	1/3 of the inside of the claw covered.	1/3 – 2/3 of the inside of the claw covered.	More than 2/3 of the inside of the claw covered.

With this scoring protocol, the prevalence of the white line defects and other claw defects in claws from slaughter sows was determined.

3.3 Statistics

After scoring the claws, the goal was to evaluate the defects in two ways, using statistics: the prevalence of the defects in the claws and the association between the individual defects in the claws and WLD. The first analysis conducted is to evaluate the prevalence of the individual defects in the front and hind claws. First, to allow analysis of presence, without evaluating the severity, the scoring as described in 2.2 is made binary (1 means present, 0 means not present). Second, the prevalence is calculated using equations 1 and 2:

1. $\frac{\text{affected front claws}}{\text{total front claws}}$ x 100%= prevalence front claws

2. $\frac{\text{affected hind claws}}{\text{total hind claws}}$ x 100% = prevalence hind claws

The second analysis was the calculation of the association between WLD and other defects present in the claws, using both front and hind claws. Therefore, the program SPSS was used. A generalized linear model (GLM) was performed, with the presence of WLD used as dependent variable. A backward selection procedure was performed. The first model contained all possible explanatory variables of WLD, namely, the severity of wall cracks, sole cracks, heel erosions, hemorrhages and whether it was a front or a hind claw. At each step, the variable that was the least significant according to the likelihood ratio Chi square was removed. This process continued until no nonsignificant variables remained (see Table 2, the independent variables with a p-value <0.05 were selected for the final model). In addition, interaction between independent variables was explored for the final model.

Table 2. Procedure of backward selection used in this study.

Model	Variables				
1	Sole crack	Claw front/hind	Wall crack	Heel erosion	Haemorrhages
2	Sole crack	Claw front/ hind	Wall crack	Heel erosion	-
3	Sole crack	Claw front/hind	Wall crack	-	-
4 (final model)	Sole crack	Claw front/hind	-	-	-
5 (model with interaction – lower Likelihood ratio)	Sole crack	Claw front/hind	Sole crack*claw front/hind	-	-

4. Results

4.1 Prevalence

As explained in the experimental design, 150 front claws and 150 hind claws were considered. A miscalculation in collecting the claws resulted in 151 front claws and 149 hind claws. However, during the scoring of the claws, 12 front claws were excluded, because of the absence of the sole and wall. This resulted in a total of 139 front claws and 149 hind claws.
Below the prevalence of the different claw defects are enumerated. The results from the front claws are presented in Table 3, whereas the hind claws are presented in Table 4. First, the prevalence of WLD was 10.8 % in the front claws and 14.4 % in the hind claws. Second, WLD through the sole had a prevalence of 26.6 % in the front claws and 45.6 % in the hind claws. The WLD through the sole is calculated as a part of WLD. Third, the lesions with the highest prevalence in the front claws were the haemorrhages, sole cracks and heel overgrowth with 100%, 97.1 % and 95.7 %. Finally, in the hind claws, the highest prevalence was represented by the same claw defects.

Table 3. Prevalence of claw defects in front claws, where score 1, 2 and 3 are the prevalence's in percentages of the prevalence and count up to 100%.

Score	*WLD*	*WL through the sole*	*Crack(s) in the wall*	*Sole crack*	*Heel overgrowth*	*Hemorrhage*
Total	10.8	26.6	39.6	97.1	95.7	100
Score 1	46.7	62.2	54.6	59.3	60.9	0.7
Score 2	53.3	35.1	38.2	34.1	31.6	11.5
Score 3	0.00	2.7	7.3	6.7	7.5	87.8

Table 4. Prevalence of claw defects in hind claws, where score 1, 2 and 3 are the prevalence's in percentages of the prevalence and count up to 100%.

Score	*WLD*	*WL through the sole*	*Cracks(s) in the wall*	*Sole crack*	*Heel overgrowth*	*Hemorrhage*
Total	14.4	45.5	78.5	96.6	100	100
Score 1	85.0	61.7	67.5	63.9	28.9	0.7
Score 2	15.0	36.8	29.1	34.0	59.7	8.7
Score 3	0.0	1.5	3.4	2.1	11.4	90.6

In chapter 4.1.1 - 4.1.5 more detailed explanations of the individual defects are provided.

4.1.1 White line defect

The prevalence of the white line in total is 10.8 % in the front claws (Table 3) and a little higher in the hind claws with 14.4% (Table 4). The total prevalence of WL through the sole is a part of the total prevalence of the WL, with a score of 26.6% in the front claws (Table 3) and 45.6% in the hind claws (Table 4).

4.1.2 Wall crack

It is notable that the percentage of wall cracks in the hind claws (78.5%) (Table 4) is much higher than in the front claws (39.6%) (Table 3). Score 1 is higher in the hind claws, whereas score 2 was slightly higher in the front claws. In both front and hind claws, the score 3 has the lowest prevalence (Table 3 and 4).

4.1.3 Sole crack

The prevalence of the sole cracks in front and hind claws is almost the same, with a prevalence of 97.1% (Table 3) in the front claws and 96.6 % (Table 4) in the hind claws.

4.1.4 Heel overgrowth

Heel overgrowth is one of the most common claw defects. However, the front claws with 95.7% (Table 3) are less affected than the hind claws with 100% (Table 4). Striking is that score 1 scores much higher in the front claws with 60.9% (Table 3). Score 2 scores higher in the hind claws with 59.7% (Table 4).

4.1.5 Hemorrhage

Alongside with the heel overgrowth, the hemorrhages are the most common defects in both front and hind claws with a prevalence of 100% (Table 3 and 4). Most of the hemorrhages were scored as 3, which means that the hemorrhage covers more than two thirds of the claw. In the front claws (Table 3), the prevalence of score 1 and 2 is higher than in the hind claws (Table 4). However, the prevalence of score 3 in the hind claws is higher than in the front claws (Table 3 and 4).

4.2 White line disease and association with other claw diseases

As explained earlier, the association between WLD and other claw diseases was calculated with the GLM. In Table 5, the outcome of the final model is shown. As can be seen in Table 5, there are two associations with WLD. The first one is the association between WLD and whether the claw is a front or a hind claw. The second one is the association between WLD and the presence of and in case of presence, the severity of a sole crack.
In Table 6 the odds ratios (OR) of the independent variables can be seen. The OR of the front versus hind claws, shows that the odds on having WLD in the hind claw is 2.44 times higher than having WLD in the front claw, in absence of a sole crack. In case of a sole crack, there is an effect of the severity of the sole crack on having WLD. If the severity of the sole crack increases, the OR increases as well. This shows that the odds of having WLD is higher when the severity of the sole crack increases, up to an OR of 8.28 (95% CI 1.02 – 67.02) in case of a severe sole crack, compared to not having a sole crack.
As explained in chapter 3.3 an interaction between between 'front/hind claw' and sole crack (severity) was included. However, this did not improve the model (Likelihood ratio p-value of 0.9) so, the final model has 'front/hind claw' and sole crack severity as independent variables.

Table 5. GLM of both front and hind claws.
Test of Model Effect
Type III

Source	*Likelihood Ratio Chi-square*	*Sig.*
(Intercept)	1.09	0.297
Front/hind claw	13.02	<0.001
Sole crack (severity)	10.08	0.018

Table 6. OR and 95% CI of independent variables

Front/ hind claw	*OR*	*95% CI of OR*
Front claw (reference)	-	-
Hind claw	2.44	1.49 - 3.92
Sole crack (severity)		
None (reference)	-	-
Mild	1.75	0.41 – 7.46
Moderate	3.19	0.73 – 13.99
Severe	8.28	1.02 – 67.02

5. Discussion

The aim of this study was to investigate the prevalence of WLD and other claw defects (sole cracks, hemorrhages, wall cracks and heel overgrowth) in slaughter sows and the association between WLD and the other claw defects. In this study, 300 claws from slaughter sows were collected and dissected. A scoring protocol was designed, using Zinpro (2018) and Diaz et al. (2013) as an example, for scoring the most common claw lesions. The rest of the protocol was designed in this study. The results show the prevalence of WLD is 10.8% in the front claws and 14.4% in the hind claws. WLD (scored as a part of WLD) which extended through the sole had a prevalence of 26.6% in the front claws and 45.6% in the hind claws. The most common claw defects were heel overgrowth, hemorrhages and sole cracks in both front and hind claws with a prevalence close or equal to 100%. Wall cracks had a prevalence of 39.6% in the front claws and 78.5% in the hind claws. There was an association between WLD and whether the affected claw was a front or a hind claw (OR: 2.44, 95% CI of 1.49 – 3.92). A second association was found between WLD and the presence of and in case of presence, the severity of a sole crack. (severe sole crack, OR = 8.28, with a 95% CI of 1.02-67.02). An unexpected outcome of this study was the high prevalence of hemorrhages and heel erosion.

The prevalence of WLD found in this study differed from the prevalence of claw disorders in other studies. Anil et al. (2007) found a prevalence of 60.9% of white line lesions in sows. Other prevalence's have been found in the studies of Mouttotou et al. (1997) with 55.4% and Varagka et al. (2016) with 71.6%. The latter study also collected claws from one abattoir, whereas in the study of Mouttoutou et al. (1997) sows from several farms were selected and culled at the abattoir. The results of this study show that the prevalence of white line defects in sows is very low in comparison with these studies. Moreover, it is also possible that the prevalence of WLD is lower because of better feeding and housing in the Netherlands and other geographical differences. The claws were scored with a designed protocol, which is not the same as the protocols the other authors used. This could contribute to the difference in prevalence. Another cause could be that the claws needed for this study were not randomly collected in the Netherlands, but originated from farms which are connected to one slaughterhouse. It is unknown from how many farms the sows came. It is also not known if there was one claw selected per sow, or if there were more claws collected from one sow.

This study showed an association between WLD and whether the claws were front or hind claws (OR of 2.44 with an 95% CI of 1.49 – 3.92). This means that the odds on having WLD in the hind claw is 2.44 times higher as having WLD in the front claw. Carvalho et al. (2009) published results which showed that the highest stress was found on the inner claws of the front legs and that there was a significant difference (p=0,002) between the forces on the inner claw and the outer claws. In the rear legs however, the pressure difference between the inner and the outer claw was greater than in the front legs. This could be an explanation for the higher occurrence of claw defects in the outer claw of the rear leg in comparison with the front leg (Carvalho et al., 2009; Smith and Robertson, 1971; Wright et al., 1972).

The second association was that between the sole crack and having WLD. There was an effect on the severity of a sole crack and having WLD. If the severity of the sole crack increased, the OR increased as well. Research about the association between WLD and other claw defects is uncommon and innovative and therefore there are not many available. The association found between the occurrence of WLD and the severity of the sole crack could be explained by a shifting of the pressure in a claw with WLD or a sole crack. However, it is hard to say which claw defect

was first and it is not known if the WLD and sole crack always occurred in the same claw. Another cause could be the weakening of the affected claw, with dirt accumulated in a crack or WLD. This can result in a claw which more susceptible for other claw defects.
Hemorrhages were found in all studied claws and thus no association could be found between WLD and hemorrhages. On forehand we did expect an association, because all claws had hemorrhages. Perchance the occurrence of the hemorrhages is due to another disease, or that due to a condition in one claw, the pressure on the other claw increases, causing WLD to develop in that claw. Leach et al. (1997) hypothesized that there are different causative mechanisms for hemorrhages in the sole and in the white line. These hemorrhages are thought to be a reflection of early defects like laminitis. Earlier alterations in the pedal bone of suspensory apparatus, which could be caused by hormonal changes can also be reflected by hemorrhages (Nilsson, 1963; Kempson and Logue, 1993; Ossent, 1999; Bergsten, 1994).
The high prevalence of heel erosion could be explained by the type of the floor were the sows were kept on. KilBride et al. (2009) found out that deep bedding and soft soil floors provided the best protection against heel/sole erosions. Mouttoutou et al. (1997) found a prevalence of 13% of heel erosion. The prevalence of heel erosion in this study was 100%, which is quite a big difference. This could be explained by the fact that Mouttoutou et al. (1997) used finishing pigs for his study, who do not live as long as the average sow. Sows are longer exposed to the same floor, which could explain the high prevalence of heel erosion found in this study. Unfortunately, it is not known on what floor types the sows, used in this study, had to live.
In conclusion, the outcome of this study shows the prevalence of WLD is low compared to other studies. There was an association between WLD and whether the claws were front or hindclaws (OR = 2.44). The second association was that between the sole crack and having WLD, which shows that there is an effect on the severity of sole crack and having WLD. Furthermore, a notable result is the high prevalence of hemorrhages and heel erosions in the claws of slaughter sows.
As mentioned before, the welfare of pigs became more important. In the Netherlands however, issues like claw disorders still play a role in animal welfare. This could affect the animal welfare. It is crucial to do research on the prevalence of WLD and other claw defects, so reliable data will be generated and animal welfare will improve. Recommendations for further research could include extra research about the prevalence and associations of claw defects. Other factors should be included, such as; type of floor, whether a claw is a left or a right claw, the clinical state of the animals and perchance the association between claw defects and lameness.

6. References

Anil, S. S., Anil, L., Deen, J., Baidoo, S. K., & Walker, R. D. (2007). Factors associated with claw lesions in gestating sows. J.Swine Health Prod., 15(2), 78–83.

Anil, S. S., Anil, L., & Deen, J. (2009). Effect of lameness on sow longevity. Journal of the American Veterinary Medical Association, 235(6), 734–738.

Bergsten, C. (1994). Haemorrhages of the sole horn of dairy cows as an epidemiological study. Acta vet. scand, 35, 55-66.

Carvalho, V. C., de Alencar Nääs, I., Mollo Neto, M., & Souza, S. R. L. (2009). Measurement of pig claw pressure distribution. Biosystems Engineering, 103(3), 357–363.

Cook, N. (2017). A life cycle-oriented approach to lameness control. Proceedings of the Western Dairy Management Conference, Reno.

Dewey C.E., Friendship R.M., Wilson M.R. (1993). Clinical and postmortem examination of sows culled for lameness. Can Vet J. 34:555–556.

Díaz, J. A. C., Fahey, A. G., KilBride, A. L., Green, L. E., & Boyle, L. A. (2013a). Longitudinal study of the effect of rubber slat mats on locomotory ability, body, limb and claw lesions, and dirtiness of group housed sows. Journal of Animal Science, 91(8), 3940–3954.

Ison, S.H.; Rutherford, K.M.D. (2014). Attitudes of farmers and veterinarians towards pain and the use of pain relief in pigs. Vet. J., 202, 622–627.

Kanis, E., Groen, A. F., & De Greef, K. H. (2003). Societal Concerns about Pork and Pork Production and Their Relationships to the Production System. Journal of Agricultural and Environmental Ethics, 16(2), 137–162.

Kempson, S., Currie, R., & Johnston, A. (1989). Influence of biotin supplementation on pig claw horn: a scanning electron microscopic study. Veterinary Record, 124(2), 37–40.

Kempson, S., & Logue, D. (1993). Ultrastructural observations of hoof horn from dairy cows: changes in the white line during the first lactation. Veterinary Record, 132(21), 524–527.

KilBride, A., Gillman, C., Ossent, P., & Green, L. (2009). Impact of flooring on the health and welfare of pigs. *In Practice*, *31*(8), 390–395.

Leach, K. A., Logue, D. N., Kempson, S. A., Offer, J. E., Ternent, H. E., & Randalls, J. M. (1997). Claw lesions in dairy cattle: Development of sole and white line haemorrhages during the first lactation. The Veterinary Journal, 154(3), 215–225.

Lewis, A. J., Cromwell, G. L., & Pettigrew, J. E. (1991). Effects of supplemental biotin during gestation and lactation on reproductive performance of sows: a cooperative study. Journal of Animal Science, 69(1), 207.

Misir, R., & Blair, R. (1986). Effect of biotin supplementation of a barley-wheat diet on restoration of healthy feet, legs and skin of biotin deficient sows. Research in Veterinary Science, 40(2), 212–218.

Mouttotou, N., Hatchell, F. M., Lundervold, M., & Green, L. E. (1997). Prevalence and distribution of foot lesions in finishing pigs in south-west England. Veterinary Record, 141(5), 115–120.

MSD Veterinary Manual. (2015). *White Line Disease in Cattle*. Veterinary Manual. https://www.msdvetmanual.com/musculoskeletal-system/lameness-in-cattle/white-line-disease-in-cattle

Mülling, C. K. W., Bragulla, H. H., Reese, S., Budras, K.-D., & Steinberg, W. (1999). How structures in bovine hoof epidermis are influenced by nutritional factors. Anatomia, Histologia, Embryologia: Journal of Veterinary Medicine Series C, 28(2), 103–108.

Mülling, C. K. W. (2002, January). Theories on the pathogenesis of white line disease–an anatomical perspective. In Proceedings of the 12th International Symposium on Lameness in Ruminants, Orlando, Florida (pp. 90-98).

Nalon, E., Conte, S., Maes, D., Tuyttens, F. A. M., & Devillers, N. (2013). Assessment of lameness and claw lesions in sows. Livestock Science, 156(1–3), 10–23.

Nalon, E., & Stevenson, P. (2019). Addressing Lameness in Farmed Animals: An Urgent Need to Achieve Compliance with EU Animal Welfare Law. Animals, 9(8), 576.

Nilsson, S. A. (1963). Clinical, morphological, and experimental studies of laminitis in cattle. Acta veterinaria scandinavica, 4 (Suppl. 1).

O'Grady, S. E. (2010a). White line disease - an update. Equine Veterinary Education, 14(1), 51–55.

Ossent, P. (1999). Subclinical bovine laminitis. Cattle Practice (United Kingdom).

Penny, R., Cameron, R., Johnson, S., Kenyon, P., Smith, H., Bell, A., Cole, J., & Taylor, J. (1980). Foot rot of pigs: the influence of biotin supplementation on foot lesions in sows. Veterinary Record, 107(15), 350–351.

Sampsize. (2003). SampSize. http://sampsize.sourceforge.net/

Shearer, J. K., & van Amstel, S. R. (2017). Pathogenesis and treatment of sole ulcers and white line disease. Veterinary Clinics of North America: Food Animal Practice, 33(2), 283–300.

Simmins, P., & Brooks, P. (1988). Supplementary biotin for sows: effect on claw integrity. Veterinary Record, 122(18), 431–435.

Smith, W., & Robertson, A. (1971). Observations on injuries to sows confined in part slatted stalls. Veterinary Record, 89(20), 531–533.

Swine Lesion Identification | Zinpro Performance Minerals | Zinpro Corporation. (2018a). https://www.zinpro.com/lameness/swine/lesion-identification.

Timmer, M. (2004). Untersuchungen zur Wirkung von Biotin auf die Klauenhornqualität von wachsenden Schweinen (Doctoral dissertation).

Tomlinson, D. J., Mülling, C. H., & Fakler, T. M. (2004). Invited Review: Formation of keratins in the bovine claw: roles of hormones, minerals, and vitamins in functional claw integrity. Journal of Dairy Science, 87(4), 797–809.

Van Riet, M. M. J., Millet, S., Aluwé, M., & Janssens, G. P. J. (2013). Impact of nutrition on lameness and claw health in sows. Livestock Science, 156(1–3), 24–35.

Varagka, N., Lisgara, M., Skampardonis, V., Psychas, V., & Leontides, L. (2016). Pathological evaluation of claw lesions in culled sows from a Greek herd. Journal of Swine Health and Production, 24(2), 72-80.

Varkenshouderij Archieven. (2020). LTO. https://www.lto.nl/sector/dier/varkenshouderij/

Webb, N., Penny, R., & Johnston, A. (1984). Effect of a dietary supplement of biotin on pig hoof horn strength and hardness. Veterinary Record, 114(8), 185–189.

Wright, A., Osborne, A., Penny, R., & Gray, E. (1972). Foot-rot in pigs: experimental production of the disease. Veterinary Record, 90(4)

Zimmerman, J. J., Karriker, L. A., Ramirez, A., Schwartz, K. J., & Stevenson, G. W. (2012). Diseases of Swine. Wiley.