

Aus dem Department für Nutztiere und öffentliches Gesundheitswesen in der
Veterinärmedizin

der Veterinärmedizinischen Universität Wien

Zentrum für Tierernährung und Tierschutzwissenschaften

(Leiter: Quendrim Zebeli)

Tail measurements in fattening pigs at three different slaughterhouses in Austria

Diploma Thesis

Veterinärmedizinische Universität Wien

vorgelegt von

Reinhold Beck

Wien, im September, 2025

Betreuer: Ass. Prof. Dr. med. vet.; Johannes Baumgartner, Dipl. ECAWBM (AWSEL)
Dr.med.vet. Kristina Maschat
Zentrum für Tierernährung und Tierschutzwissenschaften
Veterinärmedizinische Universität Wien

Begutachter: Dr.med.vet. Lukas Schwarz, Dipl.ECPHM

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Reinhold Beck

Zusammenfassung

Schwanzkupieren ist in Österreich trotz gesetzlicher Einschränkungen weit verbreitet, etwa 95 % der Schweine sind kupiert. Ziel dieses Eingriffs ist die Vorbeugung von Schwanzbeißen, gleichzeitig werden damit jedoch akute Schmerzen, Stressreaktionen und langfristige Folgen wie Neurome sowie die Einschränkung natürlicher Verhaltensweisen hervorgerufen. Schwanzbeißen selbst führt ebenfalls zu Schmerzen, Infektionen, verminderter Leistung und Schlachtkörperverwerfungen. Für eine effektive Überwachung gesetzlicher Vorgaben sind verlässliche Daten zu intakten Schweineschwänzen notwendig, da bislang weder standardisierte Messmethoden noch nationale Referenzwerte existieren.

In dieser Studie wurde eine standardisierte manuelle Messmethode mit einem eigens entwickelten Gerät unter den praktischen Bedingungen am Schlachthof etabliert. Über sechs Monate wurden an drei Schlachthöfen 5.773 Schweine von 128 Betrieben verschiedener Produktionssysteme untersucht, mit Fokus auf intakte Schwänze aus biologischer Haltung und Tierwohlprogrammen, in denen Kupieren verboten ist. Schwanzlänge und -umfang wurden gemessen, statistisch ausgewertet und mit Ergebnissen der Schlachtkörper- und Fleischuntersuchungen verknüpft.

Die mittlere intakte Schwanzlänge beträgt 33,7 cm (Median 34 cm) und liegt damit über bisher veröffentlichten Werten. Weibliche Schweine haben signifikant längere Schwänze als männliche Tiere, Schweine aus biologischer Haltung haben signifikant längere Schwänze als „mTW sehr gut“-Schweine bei vergleichbarem Schlachtgewicht.

Die Ergebnisse liefern erstmals nationale Referenzwerte für intakte Schweineschwänze in Österreich und bilden eine Grundlage für KI-gestützte, automatische Messsysteme in Schlachthöfen. Dies ermöglicht eine systematische Kontrolle des Schwanzkupierens und eine objektive Bewertung des Tierwohls.

ABSTRACT

Tail docking is widely practiced in Austria despite legal restrictions, with approximately 95% of pigs affected. The procedure is intended to reduce tail biting but raises major animal welfare concerns due to acute pain, stress responses, and long-term consequences such as neuroma formation and restriction of natural behavior. Conversely, tail biting causes pain, infections, reduced performance, and carcass condemnations. To improve monitoring and enforcement of legal requirements, reliable data on intact tail dimensions in Austrian slaughter pigs are essential, as no standardized measurement method or national reference values currently exist.

This study established a standardized manual measurement method using a newly developed device under slaughter line conditions at three Austrian abattoirs. Over six months, 5,773 pigs from 128 farms with different production methods were assessed, focusing on intact tails from organic and welfare-certified pigs where docking is prohibited. Tail length and circumference were recorded and analyzed statistically and linked to carcass and meat inspection findings.

The mean intact tail length is 33.7 cm (median 34 cm), longer than previously reported. Female pigs have significantly longer tails than males, and organic pigs show slightly longer tails than “mTW sehr gut” pigs, even at comparable carcass weights.

The results provide a reference standard for intact pig tails in Austria and a calibration basis for AI-supported automated monitoring at slaughterhouses, enabling systematic control of docking practices and improved welfare assessment.

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Abbreviations

AMA	AgrarMarkt Austria (Austrian Agricultural Market) agency for quality assurance and marketing of agricultural products
AMA-GS	AMA-Gütesiegel quality seal with requirements above the legal minimum standard
Bio	Organic farming
mTW gut	mehr Tierwohl – gut animal welfare label seal within the AMA-GS framework
mTW sehr gut	mehr Tierwohl – sehr gut animal welfare label seal within the AMA-GS framework
GMO	genetically modified organism
SD	standard deviation
MAD	mean average deviation
min	minimum value
max	maximum value
n	sample size
p	p-value (significance level)
z	z-value (standard normal distribution)
W	test statistic of the Wilcoxon rank sum test

F	ratio of variance between subjects to variance within subjects
ICC	intraclass correlation coefficient

1. Introduction and Hypothesis

1.1. Introduction and preliminary considerations

Tail docking is a generally accepted method to reduce the prevalence of tail biting. In docked pigs, signs of tail biting occur significantly less than in undocked pigs [1]. In another study there were found that pigs with docked tails are significantly less likely to show lesions on the tail (47%) than pigs with intact tails (89%) [2]. A Danish study from 2018 with three different tail docking lengths (short, medium, long) and intact tails found out that pens of pigs with short-docked tails were significantly less likely to have outbreaks of tail biting than pigs with longer docked or intact tails. Further, manipulation of pen mates' tails was observed less in the shortest docked group than in the longest docked and intact one, without any evidence of compromises in social function within the group of pigs [3].

But even with intact tails, interventions can be implemented to mitigate tail biting. Provision of small quantities of straw or alternative enrichment materials has been shown to substantially reduce the risk. Further benefits can be achieved through optimized ventilation parameters and increased space allowance [4]. Another study yielded similar results, indicating that particularly organic enrichment materials can reduce tail biting, more so when exchanged weekly. On the other hand, processed wood, plastic or metal enrichment materials showed no effect in the prevention and mitigation of tail biting, despite their frequent use for this purpose [5].

By European Council Directive 2008/120/EC, Annex I, Chapter I, "*all procedures intended as an intervention of the pigs resulting in damage to or loss of a sensitive part of the body shall be prohibited*" [6]. In "1. Tierhaltungsverordnung Anlage 5, Chapter 2.10.", Austrian legislation further defines that tail docking must not be carried out routinely and only then, when it is strictly necessary to prevent further injuries on ears and tails of other pigs. It has to be carried out with a device that cuts sharply and simultaneously cauterizes, only on piglets not older than seven days by a competent person with effective intra- and post-operative pain treatment. It is not allowed to dock more than half of the tail [7].

Despite this legislation, tail docking in Austria is still carried out routinely in the vast majority of farms, resulting in approximately 95% of all pigs kept in Austria getting their tails docked [8].

Tail docking can cause acute stress responses in piglets. Recent studies found out that after the treatment, blood cortisol levels are significantly higher in piglets who were tail docked compared to those who were sham handled, what indicates it being a highly stressful

procedure. Also behavioural differences such as lowering the head, which is commonly seen as a sign of acute pain, could be examined in piglets after docking [9]. Further the method of docking is important, as clipping the tail seems to have a longer lasting negative impact on the piglet than docking it with a cauterising iron. Those stress responses can be alleviated by the preoperative use of meloxicam, as a further study from Morrison and Hemsworth shows [10].

Sutherland et al. had similar results regarding the blood cortisol levels and the behaviour after docking the tails, supplemented by the measure of white blood cells in blood samples taken prior to and after the docking procedure, with significantly reduced white blood cell counts after the intervention [11].

There are not only immediate, acute consequences of tail docking, but also long-lasting effects, such as formation of neuromas in the docked tails. Herskin et al. could not find any neuromas in intact tails, but consistently in the tips of cauterised tails, almost regardless the left-over length of the tail at the day of docking it [12]. This can be associated with an altered nociception. Other authors published similar findings [13]. Others again came to the conclusion that there is no difference in the risk of developing neuroma between clipping and cauterizing tails, thus both of these methods potentially causing long-term animal welfare issues [14].

Even the emotional relationship between the tail-docked animals and humans can be permanently disturbed, as a French study showed [15].

On the other hand, tail biting not only directly leads to discomfort in pigs due to pain and stress, but also to considerable losses in performance, carcass rejections and premature deaths in the fattening period due to the possibility of wound infections, abscess formation and septicaemia [16].

Reasons for tail biting are manifold. Foraging and exploration behaviour, which is misdirected to the tails of other pigs, can be one explanation for tail biting. Also limited resources such as feeder space or optimal resting areas can cause aggression and tail biting. Dietary deficiencies, whether due to bad feed or due to maldigestion followed by enteric diseases, is also one of the leading causes of tail biting. Especially lack of tryptophane or sodium play a major role in the occurrence of tail biting. Genetic reasons are commonly discussed, but there is found no consistent link in pig breed and prevalence of tail biting. Between the sexes, there can be observed a difference, where male pigs are more likely to have bitten tails than females. Climatic factors, such as too high or low temperature or too much ventilation, contribute to the occurrence of tail biting [17, 18].

In a Finnish study there was found no significant difference in the prevalence of tail lesions between animals from herds from finishing farms and those from farrow-to-finish-herds [19]. As stated earlier, docking of part of the tail is prohibited to be carried out routinely, yet the vast majority of slaughter pigs is docked. In Austria, there is no superordinate inspection body to monitor docking of piglets on farms, which results in the current status. Since the year 2023, farmers are required to implement an “action plan for tail docking” in which they must record the prevalence of tail injuries. According to this plan, actions to reduce tail biting must be taken. All pig farms are required to keep documentation in form of a risk analysis and have to submit an annual livestock declaration, which includes information on tail and ear injuries, as well as a risk analysis that considers factors such as housing conditions, provision of bedding and enrichment materials, space and dietary adjustments. The risk analysis must be kept on-site at the farm, whereas the livestock declaration must be submitted online via the consumer health information system to the responsible chamber of agriculture. Tail docking or keeping docked pigs is therefore only permitted, if it is deemed an absolute necessity to prevent tail injuries. This so-called “indispensability” is given at a prevalence of more than 2 % of tail bitten or otherwise tail/ear injured pigs, which allows the farmers to carry out tail docking or to keep tail-docked pigs. Farms that are keeping docked tails also have to keep a control group of at least eight pigs with undocked tails, to evaluate the effectiveness of the actions taken. The data submitted to the chamber of agriculture is reviewed to ensure completeness and plausibility, checked if legal requirements are met and an indispensability for tail docking is given [20]. The full responsibility for recording the incidence of tail biting lies with the farmers, who have a conflict of interest and are often not objective in their observations. This requires an independent, objective control of tail lengths and the proportion of docked and/or bitten tails, and therefore, a verifiable monitoring at big slaughterhouses is suitable, as this is a quasi-bottleneck, where the vast majority of fattening pigs end up.

Literature on the definition of the tail length is scarce and mostly based on measurements of feral pigs or boars. Mostly, authors largely agree in the definition of the tail length as “the distance [length] from the tip [end] to the base [of its attachment] of the tail” [21–23] which was supplemented by “with the ventral side of the tail stretched onto a rigid ruler” from Kritas and Morrison [24]. This definition was also used by Bulens et al. [25]. Tail length varies greatly between animals of different breeds, different age/weight and different sexes. This makes studies for an explicit location indispensable, if a statement about the tail length wants to be made or is used for further steps, such as classification of tails at the abattoir. For tail length,

only Valros et al. and Herskin et al. have published numbers with 31.5 cm (SD = 2.5 cm) and 30.6 cm (SD = 0.6 cm) respectively [26, 12].

As literature on tail dimensions in non-docked slaughter pigs is scarce and average length of intact tails hasn't been studied within the Austrian pig population yet, it remains unclear how to monitor if the tail was docked correctly or at all. The lack of former studies on this topic also implies that a standardised method to measure the pig tail hasn't been established up to now, so that tail dimensions cannot be compared across different countries or studies.

The project "aWISH" (animal welfare indicators at the slaughterhouse) is a research project in eleven European countries funded by the Horizon Europe research programme, aimed at improving animal welfare standards in meat production through automated animal-based welfare indicators directly at the slaughter line. Using a variety of sensor technologies and AI-supported analytical tools, data are collected that allow conclusions to be drawn about animal welfare during the fattening period, transport and slaughter. In Austria, slaughterhouse Hüglsberger in Schwertberg, Upper Austria, takes part in this project as one of six pilot companies with the "PigInspector" installed in the slaughter line. This camera system developed by the German technology provider CLK GmbH can detect ear, skin and tail lesions on the pig and simultaneously estimates the tail length automatically [27]. The University of Veterinary Medicine in Vienna (Vetmeduni Vienna) acts as scientific co-lead.

A feasibility study for AI-supported tail length assessment at the slaughterhouse ("PigTail") funded by the Austrian Federal Ministry of Social Affairs, Health, Care and Consumer Protection, was carried out by ÖFK ("Österreichische Fleischkontrolle", Austrian meat control authority), Vetmeduni Vienna and University of Natural Resources and Life Sciences, Vienna (BOKU), basing on a part of the measurements taken for this thesis. There was stated that an automated tail length measurement system should provide continuous data in order to accurately capture the variability of tail lengths and to be able to better research the influence of different factors for tail length [28].

Against this background, this thesis aims to determine average tail measurements of Austrian slaughter pigs with intact tails, so that in future it will be possible to assess by its length whether a tail has been docked or bitten, and if so, by how much. This measurement method will subsequently serve as the gold standard for the calibration of automated, AI-supported camera systems which measure the length of the tails in the slaughter line on abattoirs. This can further solve the problem of the lack of control of tail injuries and tail docking as described above if

every pig arriving at the slaughterhouse can be categorized based on the automatically measured tail length.

Therefore, a standardized measuring method was established for this purpose, which yields reproducible figures for tail length and circumference at various points of the tail. This also made it necessary to develop a measuring device that is reliable and easy to use under the conditions at the abattoir and can acquire the precise data required.

1.2. Hypothesis

The main question of this thesis is: How long is an average intact tail of a finishing pig at an Austrian slaughterhouse?

It is hypothesized that:

- there is no significant difference in tail length between pigs from organic farms and pigs from conventional farms in animal welfare programs.
- there is no significant difference between male and female animals.
- there is a positive correlation between the length of the tail and its circumference.

2. Material und Methods

2.1. Data Collection

Data collection was performed on 23 survey days over a period of six months at three different slaughterhouses in Upper and Lower Austria (Großfurtner, St. Martin i.L.; Higersberger, Schwertberg; Dachsberger, Eggenburg).

At all three slaughterhouses, the location for taking the measurements was after scalding and bristle removal. The slaughter line speed depends on the slaughter frequency, and ranges from 30 seconds per carcass at Higersberger (approximately 1,000 pigs per day) and 12 seconds at Dachsberger and Großfurtner (approximately 2,000-2,500 pigs per day).

In Austria, almost all conventionally produced pigs have docked tails, so measurements are mostly taken from pigs produced in animal welfare labels such as “mehr Tierwohl – sehr gut” (enhanced animal welfare - excellent, in the following abbreviated as “mTW sehr gut”) or organic farming.

“mTW sehr gut” is an animal welfare label within the framework of the “AMA Gütesiegel” (AgrarMarkt Austria quality seal, in the following abbreviated as AMA-GS). The basic requirements for this label are 100% more space than legally required, ban on fully slatted floors, access to outdoor areas, GMO-free feed of European origin, enrichment material such as straw or hay, surgical castration only under general anaesthesia with the obligatory use of postoperative painkillers and the total ban on tail docking.

In addition to these requirements, organic farms must further comply with the requirements of the EU Organic Regulation (EU No 2018/848), which among other things also includes a complete ban on tail docking.

At the locations mentioned, these were therefore mainly animals from animal welfare labels such as organic farms (Großfurtner, Dachsberger) and ones from the “mTW sehr gut” program (Dachsberger, Higersberger). But also pigs from AMA-GS farms, “mehr Tierwohl – gut” (enhanced animal welfare – good, in the following abbreviated as “mTW gut”) farms and standard conventional farms were measured, as at some slaughterhouses there was no temporally delimitation between the different forms of production in the slaughter process.

For this study, both male and female pigs were measured. As the specific breed or crossbreed of the animals is neither available nor otherwise recorded, there can only be made a general assumption on the pig population in Upper and Lower Austria, where approximately 90 % of

all fattening pigs are “Ö-PIG” piglets, a crossbreed where the maternal line (“FORTUNA”, formerly known as “ÖHYB F1”) is a crossbreed of Large White and Landrace, and the paternal line is mostly a Pietrain sire from the “FELIX” or “ROCKET” line [29]. In some cases, Duroc is used as a terminal sire [30].

There was no further preselection of the pigs, every animal in the slaughter line on the survey days was measured.

2.2. Measuring device

The specific measuring device for tail pig dimensions TailSizer© was developed at the Center of Animal Nutrition and Animal Welfare Science (Haberl, Maschat and Baumgartner) of the Vetmeduni. It consists of a 3D printed plastic ring with a diameter of 71 mm and a height of 3 cm (Figure 1). The ring is 2 cm higher where the two measuring tapes are fixed. A 45 cm long piece of a metallic, stiff measuring tape is in perpendicular position to the ring to measure the length, while a second 35 cm long flexible measuring tape is in parallel position to the ring at a length of about 4 cm to measure the circumference of the tail (Figure 2 and Figure 3).

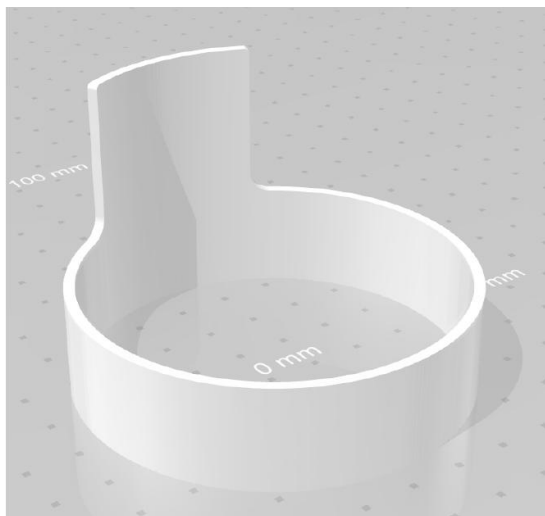


Figure 1: 3D printed plastic ring, main corpus of the tail dimension measuring device TailSizer©



Figure 2: TailSizer©, version for right handers



Figure 3: TailSizer© close up, version for left handers

2.3. Methodology

To obtain the most accurate and reproducible measurement results possible, at each slaughterhouse a location on the slaughter line was selected which was located after the scalding process but before the carcasses were split. The location after the scalding step ensures a better perceptibility of possible tail tip lesions. This is because in tails with any hair or dirt remaining, as most pigs exhibit directly after slaughter, superficial wounds, scabs or bite marks can often not be detected, and additionally, after scalding the tail skin can be inspected for healed scars or bruises [26]. The survey of the dimensions of the tail must be taken before splitting the carcasses, as in this process in many cases the tail gets cut through or completely off, making measurements impossible. In order to check the inter-rater reliability of this measurement method, an observer comparison was carried out for all parameters surveyed. Another consideration when selecting the measuring point on the slaughter line is the positioning of the camera system “PigInspector” from CLK GmbH, Germany [31].

As there the carcasses are several meters high, a framework or pedestal had to be set up so the measurements could be taken properly. All surveys were conducted in pairs. One person was responsible for measuring the dimensions with the TailSizer®, while the second person documented the measurements on paper and simultaneously recorded tail integrity, tail tip shape, and the presence of tail lesions for a subsequent study within this project.

During the measurement process, the tail is threaded through the ring, which is then pressed against the gluteal/anal region with one hand with moderate pressure (Figure 4).



Figure 4: Positioning the TailSizer©

The tail is then extended at a 90 degree angle from the animal's back with the other hand to take the length measurement. The tail is straightened along the measuring tape. The scale is read on the ventral side of the tail (Figure 5).



Figure 5: Taking the length and circumference measure

For the circumference, the second, soft measuring tape is used, which is wrapped around the tail to read the measures. The circumference is measured at the base, in the middle and at the tip to obtain the dimensions of the tail. The measurement process must be completed within a timeframe of 12 to 30 seconds, depending on the slaughter speed of the abattoir. During this time, the carcass continues to move on the slaughter line. This means that the carcass is never at rest, what, along with the fact that the consistency of the soft tissue against which the TailSizer© is pressed is not equal in all animals, limits the measurement accuracy to 0.5 cm. Also, the reproducibility of the measures taken and the inter-rater reliability would be poor if they would have been taken in subdivisions of 1 mm. The shape and size of the tail can also affect the accuracy of the measurement. Tails with kinks or crooked healed fractures cannot be fully extended, which would lead to underestimations of the actual tail length. For this reason, tails with kinks were systematically excluded from the data set.

The integrity of the tail is defined by the shape of its tip. Docked, bitten, or otherwise shortened tails characteristically have a thick, hemispherical tip (see panel C in Figure 6), whereas intact tails have a slightly flat to conical tip shape (see panel A in Figure 6), which is defined by the flattened last vertebra (Figure 7A and B). This classification is based on the system developed by Valros et al [26]. Similar to that study, some of the measured tails had their tips removed due to mechanical influence during the slaughter process (see panel B in Figure 6). Those tails were not separately recorded but listed along with all other tails with lesions at the tip (Figure 6 D, E and F). The lesions are subject of another diploma thesis from this project.

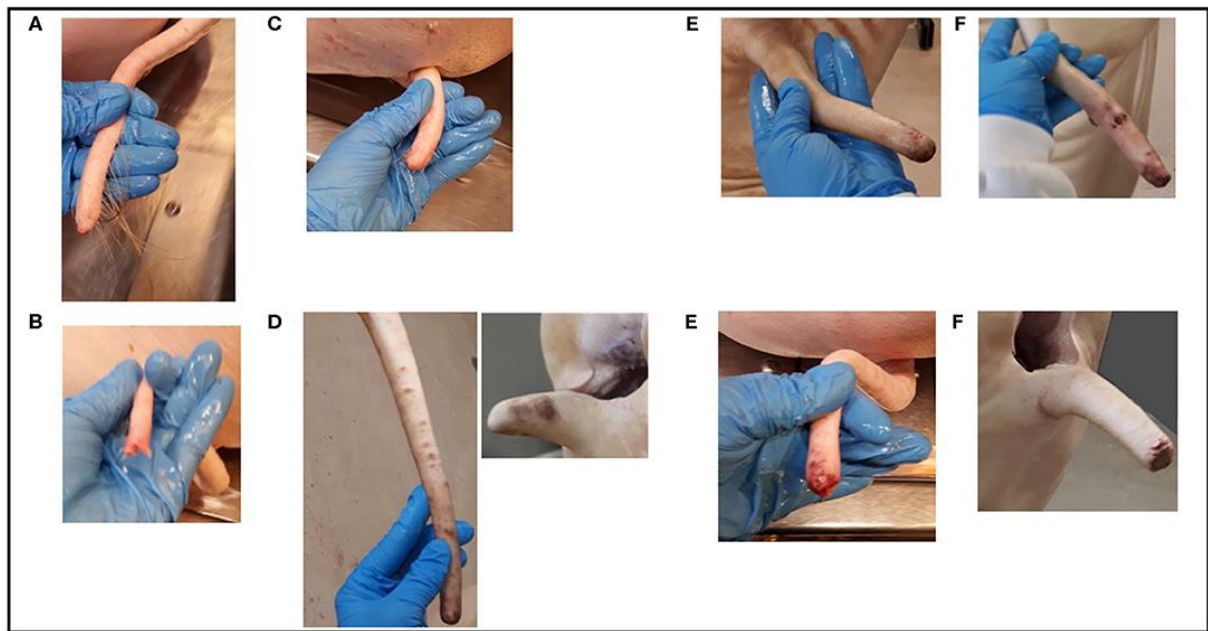


Figure 6: Representation of different pig tails for classification. A: intact tail; B: broken tail; C: healed tail; D: healed tails with bite marks; E: tails with minor acute wounds; F: tails with major acute wounds [26]

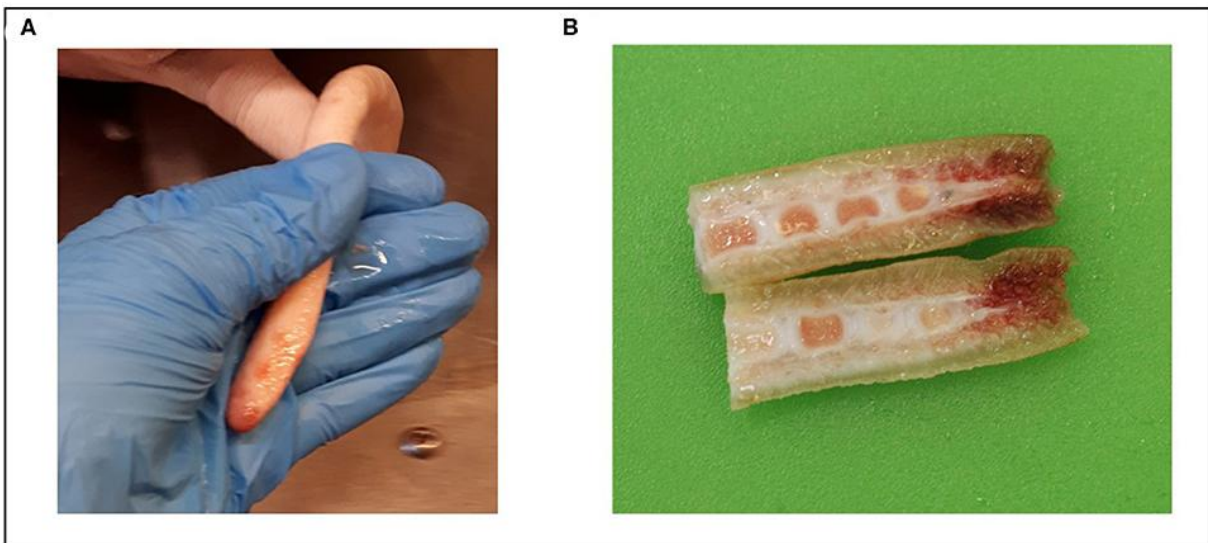


Figure 7: Tips of fully intact tails; A: flattening end of an intact tail; B: transversal cut through the end of an intact tail, flattening shape of the last vertebra depicted [26]

For the circumference at the base, the TailSizer© continued to be pressed against the anal area and the second measuring tape was wrapped around the base of the tail to be able to read the measure. For the middle circumference, the device was removed from the anal area and reapplied to the estimated middle of the tail. The same thing was done for the third circumference, therefore the measuring device was placed in the last 1 to 3 cm of the tail length.

To make a statement about a statistically relevant difference between the median tail lengths of male and female pigs, a Wilcoxon rank sum test was conducted. This test is preferred, as the variables are not normally distributed and a t-test would not give consistent results.

To look if there are any correlations between the circumferences at the base, centre and the tip of the supposedly intact tails with the length of them, spearman's rank correlation tests were performed with the data, as the correlation between those parameters is not linear, but monotonic.

For traceability reasons at the abattoir, each carcass is marked with a consecutive ID number, which was also recorded, so the findings of the post-mortem examination along with the carcass weight can be assigned to each individual animal and linked to the measurements taken in this study.

2.4. Raw data, data processing and statistics

All collected data were transferred to a Microsoft Excel file (Version 2308 Build 16.0.16731.20542; Microsoft Corporation). The preprocessing and cleaning of the data were partly carried out in Excel, while for data preparation and the statistical analyses, the software R (version 4.1.2, 'Bird Hippie'; R Core Team, 2021) and RStudio (version 2021.09.1.372, 'Ghost Orchid'; RStudio Team, 2020) along with the relevant packages were used.

All in all, records from 5,936 pigs from 130 farms were taken. This includes both intact tails as well as docked or bitten ones. Excluding those without a recorded length, there are 5,776 records left. Three outliers for which it can be assumed that there are survey errors based on the remaining data/tail measurement parameters collected as part of the diploma thesis, were further excluded, resulting in a raw data count of 5,773 from 128 farms. This is the data set which was considered for the following statistical examination.

For every production form, there is a defined norm carcass weight range, in which the weight of the slaughter pigs should be when delivered to the abattoir. Weight ranges for different production forms can be taken from the following table (Table 1).

Table 1: Norm carcass weight classes for different production forms

Production form	AMA-GS	Organic	mTW (Sehr Gut)	Standard conventional	TW (Gut)
Norm carcass weight [kg]	85–111	93–119	83–109	86–112	85–111

Excluding pigs outside of the norm carcass weight and those for which tail tip measurements were not collected, there are 4,897 pigs left.

These pigs are divided into the following forms of production: 1,028 from AMA-GS-farms, 1,025 from organic farms, 1,705 from “mTW sehr gut” farms, 114 from “TW gut” farms and 1,025 from standard conventional farms.

To get to the amount of supposedly intact tails in organic and “mTW sehr gut” farms, all tails with rounded tips were excluded, leaving a data set of 752 organic and 818 “mTW sehr gut” animals.

As organic and “mTW sehr gut” animals have different norm carcass weights, there was also taken a look at the difference between the tail lengths in the same weight class from 83 to 109 kg.

To estimate the portion of the tail which is bitten away in cases of tail biting, tails from organic and “mTW sehr gut” farms with both rounded tips and tail tip lesions were taken into the statistical analysis. This leaves a number of 79 tails where there can be assumed that they were influenced by tail biting.

All parameters are analysed using descriptive statistics, namely mean, median, standard deviation, range, variance, symmetry, skewness and kurtosis.

To compare the distribution of different parameters, the Wilcoxon rank sum test is used, as this is the method of choice if the data set is not normally distributed. The significance threshold is set at $\alpha = 0.05$. If the p-value is equal to or less than the significance threshold, the result is statistically significant, indicating a difference between the groups.

3. Results

To ensure the reliability of the manual tail measurement method, interrater agreement was assessed. Both observers measured tail lengths at the same position routinely used for tail observations on 34 non-docked pigs. Intraclass correlation coefficients (ICCs) were then calculated for the measurements. An ICC of 0.95, with 95% confidence intervals of 0.90–0.97 ($F = 38.5$; $p < 0.001$), indicates excellent agreement between the observers, therefore validating the values measured.

Over all non-docked tails in organic and “mTW sehr gut” farms in the norm carcass weight, the mean tail length is 33.66 cm (median 34 cm) with a standard deviation of 3.29 cm and a range from 15 to 45 cm. The distribution of tail lengths is shown in the following diagram (Figure 8).

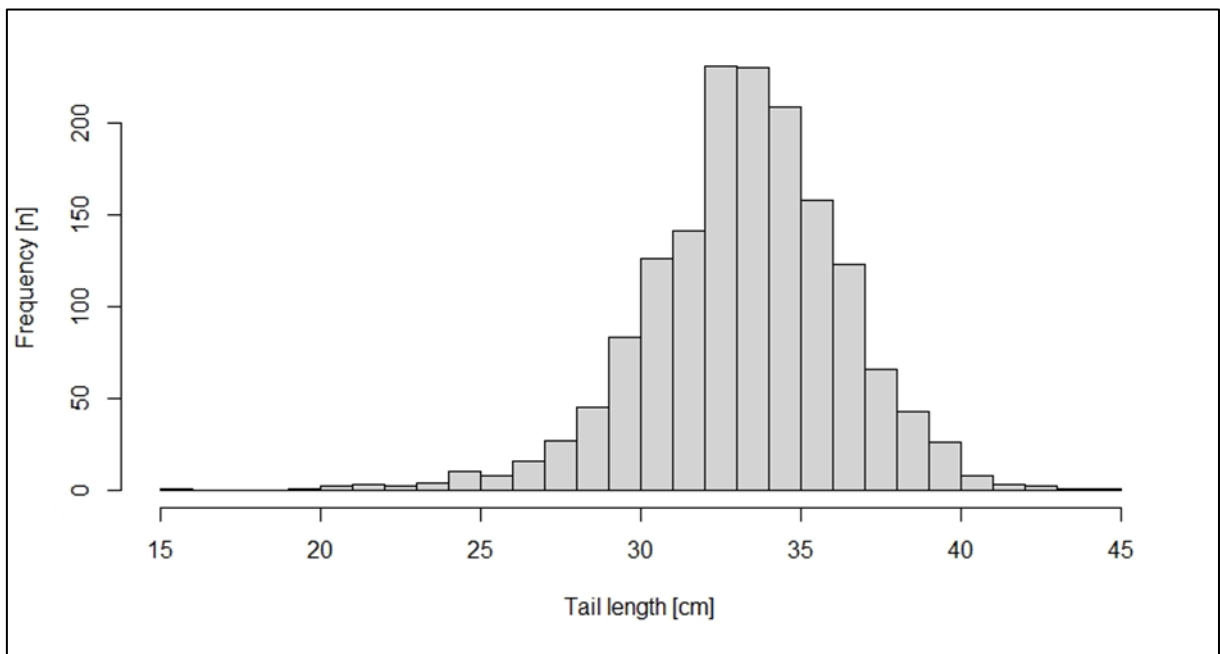


Figure 8: Histogram of tail lengths of non-docked tails

The statistical measures of tail lengths for the different production forms are shown in the table below (Table 2). Pigs from organic farms are depicted both in their norm carcass weight class and in the norm carcass weight class of “mTW sehr gut” pigs to allow for better comparison.

Table 2: Descriptive statistical figures for non-docked tails in their respective norm carcass weight classes, in cm; „all non-docked tails“ includes data sets from AMA-GS (n=92), standard conventional (n=146) and “mTW gut” (n=2)

Production form	n	mean	median	SD	MAD	min	max	range
Organic (93–119 kg)	752	34.13	34	3.18	2.97	20	45	25
Organic (83–109 kg)	578	33.63	34	3.09	2.97	20	43.5	23.5
“mTW sehr gut” (83–109 kg)	818	33.10	33	2.97	2.97	15	40.5	25.5
All non-docked tails	1,810	33.66	34	3.29		15	45	30

After performing a Wilcoxon rank sum test and a Wilcoxon Z test, it can be said that there is a significant difference between the tail lengths of pigs from organic farms and those from “mTW sehr gut” farms in their respective norm carcass weight ($W = 366342$; $p < 0.001$), with organic animals having on average an approximately 1 cm longer tail than “mTW sehr gut” animals. The values for organic animals also show a slightly higher variation, as shown in the following diagram (Figure 9).

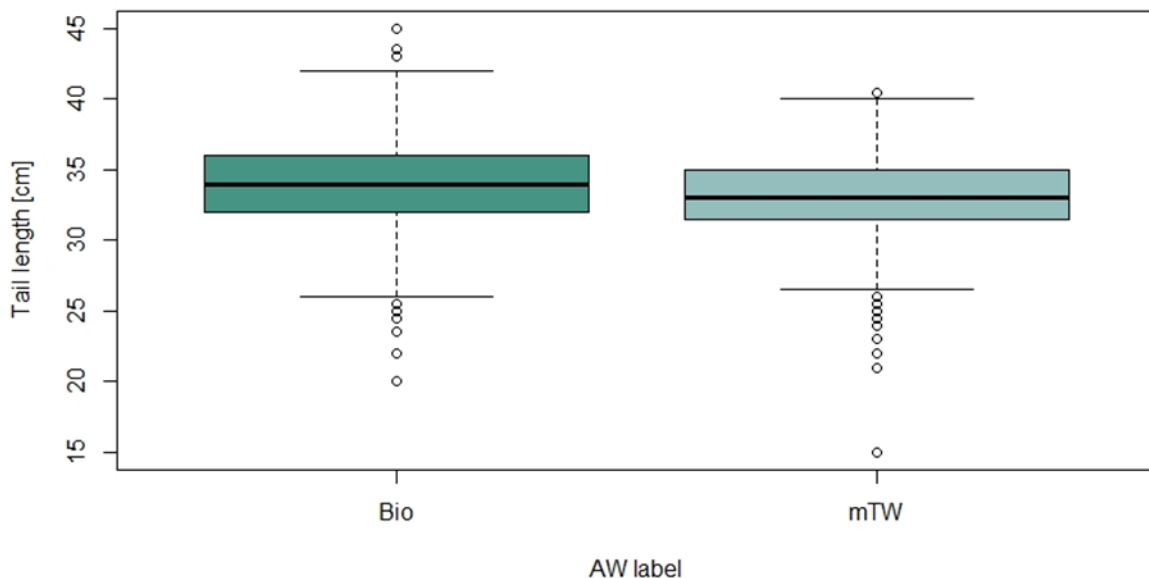


Figure 9: Boxplot of tail length distribution in organic (“Bio”) and “mTW sehr gut” (“mTW”) farms in their respective norm carcass weight class

Adjusted to the same carcass weight range (83–109 kg), the numbers for “mTW sehr gut” animals stay the same, but those for the organic animals go down. After a Wilcoxon rank sum test, there still exists a significant difference between the lengths of pigs from organic farms and those from “mTW sehr gut” farms ($p = 0.004$; $W = 257727$), but the difference is smaller, with tails from organic animals being about 0.5 cm longer than those from “mTW sehr gut” ones.

The mean length of tails which were assumed as being tail bitten is 26.65 cm, median 26.5 cm, with a standard deviation of 6.42 cm and a range from 6.5 to 39.5 cm. Consequently, it can be stated that in cases of suspected tail biting, an average of about 7 cm of the tail was bitten off, with a median of 7.5 cm, which accounts for a loss of about 20% of the average intact tail length.

Between the sexes there can be found a significant difference in tail lengths, where female pigs have consistently longer tails than male pigs, despite the average carcass weight for female animals (102.5 kg) being lower than that of males (103.7 kg).

Female animals from “mTW sehr gut” farms show a mean and median tail length more than 1 cm longer than their male counterparts. This results in a significant statistical difference ($p > 0.001$, $W = 43677$). Similar results came from animals from organic farms, where the tail length for female animals is also more than 1 cm longer than for male animals. This makes up for a statistically significant difference ($p < 0.001$, $W = 44816$) (Table 3).

Between the different abattoirs, there were also found some differences in tail length and slaughter weight. The median tail length for “mTW sehr gut” animals at abattoir Dachsberger was 1 cm shorter than at abattoir Higelsberger, which accounts for a statistically significant difference ($p < 0.001$, $W = 64.218$) (Table 3). This may partly be attributed to the difference in median slaughter weight, which was lower at abattoir Dachsberger (97.1 kg) than at Higelsberger (99.2 kg, $p > 0.001$, $W = 67.764$). This can also be supported by a weak significant positive correlation between carcass weight and tail length ($\rho = 0.11$, $p < 0.001$).

For organic animals, there was found no significant difference between abattoir Dachsberger and Großfurtner (Table 3).

Table 3: Descriptive statistical figures for tail lengths of intact tails, stratified by sex and slaughterhousees, in cm

	n	mean	median	SD	min	max
mTW ♀	364	34.02	34	2.70	23	40.5
mTW ♂	358	32.45	32.75	3.06	15	39.5
organic ♀	333	34.92	35	3.03	26	44.5
organic ♂	348	33.63	34	3.15	20	45
Dachsberger mTW	325	32.55	33	3.06	15	40
Higelsberger mTW	493	33.47	34	3.85	21	40.5
Dachsberger organic	532	34.15	34	3.25	20	45
Großfurtner organic	220	34.08	34	3.03	25	43

Between the length of the tail and the circumference at the base, there is a moderately significant positive correlation with $\rho = 0.445$, $p < 0.001$.

Between the length of the tail and the circumference at the centre, there is a weakly significant positive correlation with $\rho = 0.131$, $p < 0.001$.

Between the length of the tail and the circumference at the tip, there is no correlation with $\rho = -0.006$, $p = 0.823$.

There is also a weak to moderate significant positive correlation between the circumference at the base and the one at the centre of the tail with $\rho = 0.370$, $p < 0.001$, and a weak correlation between the circumference at the base and the one at the tip with $\rho = 0.203$, $p < 0.001$.

4. Discussion and conclusions

4.1. Measuring system

The TailSizer© system, developed by Vetmeduni, was designed to provide precise and practical measurements of pig tail dimensions under the challenging conditions of the slaughter line. It must deliver reproducible results within the short timeframe of 12 to 30 seconds, depending on the slaughter line speed. Also, the diameter of the ring makes sure that there can be made consistent measurements, as the base point of the tail is standardized. The moderately flexible metal measuring tape fits well along the ventral tail contour, allowing for precise length measurements. The flexible measuring tape positioned perpendicularly to the first one allows for reasonably accurate measurements for the larger dimensions of the tail at the base and in the middle. However, it does not permit accurate measurements in the case of very small dimensions, such as the circumference at the tip of the tail.

Pre-study trials with TailSizer© prototypes helped to further improve the usability of the measuring device. The final design was a progression of a previous model where the length scale was mounted to the inside of a transparent acrylic tube where the tail was threaded through, which had the downsides of not being able to pull the tail straight to get an exact measure and not being able to measure the circumference of the tail. The 3D printed ring in the final model allowed the user to press the device against the anal region with a consistent pressure to get comparable results for each carcass condition (i.e. different body fat percentages), while still being able to straighten the tail when measuring it.

Based on Kritas and Morrison, the measurements were taken on the ventral side of the tail [24], different to previous studies done by Valros et al. and Heinonen et al., as the dorsal side of the tail does not ensure consistent results for the length measurements and the tail can be pressed more firmly against the ruler [26, 19]. The measurement accuracy was restricted to 0.5 cm steps, mostly due to the high slaughter line speed and reasons of feasibility of reading and recording of the values.

The circumference measurements were taken with a second flexible measurement tape, which was wrapped around the base, centre and tip of the tail. The measurement accuracy again was restricted to 0.5 cm steps, which lead to a relatively great inaccuracy, especially with smaller values at the tip of the tail.

Our own experience with the TailSizer© was largely positive. Initially, some practice and acclimatization are required to obtain accurate measurements under the conditions on the

slaughter line (constantly moving carcasses, limited time frame), but after a short period, the device proves to be highly practical. Potential improvements, based on longer-term use, could include a ring on the flexible tape measure to allow it to be secured to a finger of the person taking the measurements, thereby enabling faster circumference measurements, as well as an extension of the rigid tape, since the longest tails may well exceed the 45 cm mark.

Furthermore, it should be considered whether the body of the TailSizer© needs to have a ring shape, as its primary function is simply to provide a consistent reference point on the ventral side of the tail base. With the ring shape, the tail must be threaded through the ring, which can be particularly challenging at high slaughter line speeds. As a potential improvement, a U-shaped design could be considered, eliminating the need to thread the tail through the ring — a step that offers no benefit to the user or increase in measurement accuracy.

4.2. Intact Tail length

The primary objective of this thesis was to determine the average length of an intact tail of an Austrian slaughter pig. The statistical analysis revealed a mean tail length of 33.67 cm (median 34 cm) for undocked, intact pig tails. This is slightly longer than in similar studies with 31.5 cm and 30.6 cm respectively done by Valros et al. and Herskin et al. [26, 12]. These differences may be caused by either the measuring location (ventral vs. dorsal side of the tail) or by carcass weight at slaughter (especially organic pigs are often heavier at slaughter).

These results can be used as a benchmark for further studies or projects, which aim for a classification of tails at the slaughterhouse into intact and docked/bitten, especially automatized measurements with AI-supported camera systems such as the PigInspector from CLK GmbH. Also, the proper execution of tail docking can be systematically monitored and controlled, as legislation stipulates that no more than half of the tail may be removed, assuming tail growth in a linear fashion throughout the life of the pig.

One of the hypotheses stated that there should not be a difference between intact tails, regardless the form of production. Yet, in our statistical analysis we found out that organic pigs have consistently longer tails than pigs from the “mTW sehr gut” program. The difference between the mean tail lengths of pigs from these farms may have many underlying causes. In the norm carcass weight for the respective form of production, it can be stated that organic pigs are on average heavier and larger, resulting in a longer tail. But also adjusted to the same carcass weight class, there is still a significant difference of half a centimeter between those forms of production. Several factors may account for that finding, including potential genetic

variation or slower growth resulting from organic feed regulations (no supplementary synthetic amino acids, lower-quality protein sources) which cause organic pigs of the same slaughter weight to be, on average, older at the time of slaughter. In cases of tail biting, on average 20 % of the tail length is missing at slaughter. This still leaves more average tail length than most docked pigs have, even considering that in docked pigs there can be found a big variance between different farms, most probably caused by operator characteristics during the docking process on the farm [26].

The variation in length in both bitten and docked tails does not allow any conclusions to be drawn about the categorisation of a single tail into one or the other class without a morphological examination of the tail tip for bitemarks, swelling or healed or acute lesions. This has to be considered when implementing an automatic camera-based classification system for tail lengths, so tails within a range in which both bitten and docked animals can occur are specified in the right category. However, the variation within a single delivery from a farm and between multiple deliveries from the same farm over the course of a longer period of time can indeed allow for a differentiation between docked and tail bitten animals, as groups of docked animals generally exhibit similar tail length with only slight variation within a narrow range, whereas tail-bitten batches may show considerable variation, including individual outliers towards the lower end of the scale.

The finding that female pigs have in average a significantly longer tail contradicts to existing latest literature, where there has been found no difference in tail length between the sexes, neither in piglets [32] nor later in fattening period [33]. When slaughter weight is taken into account, this difference becomes even more pronounced, as female pigs show a lower average slaughter weight than males.

Between the tail length and the circumference at the base, there is a moderately significant correlation, as it can be expected that longer tails have a thicker base.

The weakly significant correlation between the circumference at the centre and the length of the tail can mostly be attributed to a relatively high inaccuracy in taking those measures, leading to an unusually high variation in these values. This may be a result of the centre of the tail not being measured, but only eyeballed, and there could be an expected higher correlation between the length and the thickness of the tail if more exact measurements are taken. The same can be stated for the correlation between the length of the tail and the circumference at

the tip, as here the measurement inaccuracy comes into play even more due to the smaller dimensions at this segment of the tail.

4.3. Conclusions

This study provides a general overview of the dimensions of intact tails of fattening pigs at Austrian slaughterhouses and presents a manual measurement method that provides reliable, reproducible, and accurate values under slaughter line conditions.

Based on the values determined in this study, a tail length of more than 30 cm (median minus one standard deviation, rounded) can generally be considered highly indicative of an intact tail. Most tails shorter than this are either bitten or docked. However, minimal tail lengths observed for intact tails in this study were as low as 15 cm, with the shortest tails not considered outliers at approximately 25 cm. To comply with legal requirements regarding docking, a minimum length of 12,5 cm at slaughter should be maintained. Tails shorter than this already correspond to a loss of length exceeding 50% relative to the original length with high certainty.

Measurements taken manually with the TailSizer© method used in this study or a similar approach can be seen as the current gold standard for measuring tail lengths of slaughter pigs. However, manual measurement of pig tails is a highly time-consuming task, particularly when other parameters, such as tail, skin, or ear lesions, also need to be assessed simultaneously, making it almost inevitable to work in pairs at least. To measure a larger number of animals or to implement systematic monitoring of tail length at slaughterhouses, the installation of automated systems is therefore unavoidable. Several pilot projects already employ camera-based systems with AI-supported analysis, but all still require calibration and validation using manual measurement data, making the method used in this study the ground truth for all automated systems.

In a first step, priority should be given to a continuous measurement scale rather than a classification into categorical class scales. Once the susceptibility to errors is sufficiently low, advantages such as higher precision, finer differentiation and more possibilities for statistical analyses with the data collected are undeniable. In the subsequent step, data obtained on a continuous scale can be categorized into discrete classes. This might be of particular interest for providing both practical and user-friendly assessment for farmers, veterinarians and competent authorities.

Once these measurement systems are implemented on a larger scale, they could provide farms and authorities with different types of responses. On one hand, farms showing high variability in tail lengths can be flagged as potentially having tail-biting problems, enabling targeted mitigation measures in consultation with the herd veterinarian. The approach also enables evaluation of production conditions under animal welfare labels that fully prohibit tail docking and supports the allocation of incentives for farms that voluntarily refrain from docking. Conversely, it can help identify farms that systematically dock tails too short and, within the applicable legal framework, take appropriate enforcement actions. This supports the enforcement of the national monitoring of compliance with the ban on routine tail docking and the associated action plan on tail docking.

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7. Acknowledgement

The author gratefully acknowledges the support of Laura Brachmayer during data collection. Appreciation is also extended to the slaughterhouses Großfurtner, Hügelsberger, and Dachsberger, and in particular to Martin Lindinger, Rudolf Baderer, and Richard Ströbl, for their collaboration during the fieldwork. Furthermore, sincere thanks are due to the supervisors, Johannes Baumgartner and Kristina Maschat, for their preparatory work, their introduction to the topic, and their continuous guidance during data collection and the preparation of this thesis.