Universität Hohenheim

Institut für Agrartechnik

Verfahrenstechnik der Tierhaltungssysteme

apl. Prof. Dr. Eva Gallmann

Attraktives Beschäftigungsmaterial zur Reduktion von Schwanz- und Ohrschäden beim Schwein

Dissertation

zur Erlangung des Grades eines Doktors

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1. Allgemeine Einleitung

1.1 Problemstellung

Die Domestikation des Hausschweins (*Sus scrofa* domesticus) begann vor circa 9.000 Jahren. Genetischen Analysen zufolge stammt das Hausschwein vom Wildschwein (*Sus scrofa*) ab, wobei das Europäische Wildschwein (*Sus scrofa* scrofa) und das Ostasiatische Wildschwein (*Sus scrofa* vittatus) unabhängig voneinander domestiziert wurden (Giuffra et al., 2000). Erst ab dem 18. Jahrhundert kam es zu einer Zusammenführung der domestizierten Formen (Giuffra et al., 2000). Die Zuchtgeschichte von Schweinen, bei der schon immer die Fleischproduktion im Mittelpunkt stand, begann Ende des 18. Jahrhunderts in England (William und Simianer, 2011). Im Laufe der Industrialisierung wuchs der Wohlstand der Bevölkerung stetig an, wodurch gleichzeitig die Nachfrage nach (Schweine-)Fleisch anstieg. Dies hatte ab der Mitte des 20. Jahrhunderts eine Intensivierung der Landwirtschaft und somit auch der Schweinehaltung zur Folge.

Infolge der Domestikation und Zucht auf einige bestimmte Merkmale entstanden beim Hausschwein (Jensen, 2014; Price, 2002; Röhrs und Kruska, 1969), wie auch bei anderen domestizierten Nutztierarten (z.B. Dudde et al., 2018; Hare et al., 2002; Jensen, 2014; Price, 2002), Unterschiede zu den wilden Vorfahren hinsichtlich der Anatomie, der Physiologie und des Verhaltens. Des Weiteren stellt heute die durch die Domestikation und insbesondere durch die Intensivierung der Landwirtschaft veränderte Haltungsumwelt einen Unterschied zwischen dem Haus- und Wildschwein dar. Das Verhaltensrepertoire hat sich jedoch auch nach der Domestikation und Jahren der Zucht nicht wesentlich geändert (Jensen, 1986; Stolba und Wood-Gush, 1989), die Häufigkeiten des Auftretens einzelner Verhaltensweisen jedoch schon. Schweine, die in einer restriktiven und reizarmen Haltungsumwelt untergebracht werden, können ihre natürlichen Verhaltensweisen, wie das intrinsische Explorationsverhalten, nicht oder nur zu einem gewissen Maße ausüben, was zu Stress oder Frustration bei den Tieren führen kann. Anhand sogenannter „Coping-Strategien“ (Bewältigungsstrategien) versuchen sich Tiere an Stressoren aus der Haltungsumwelt anzupassen (Folkman und Lazarus, 1988; Koolhaas et al., 1999). Dabei besitzen domestizierte Schweine individuelle Strategien, um auf Stress in der Haltungsumwelt zu reagieren (Hessing et al., 1993). Wenn den Tieren die Anpassung an auftretende Stressoren nicht gelingt, können Verhaltensanomalien entstehen. Die beim Hausschwein bekannteste Verhaltensanomalie ist das Schwanzbeißen. Es tritt vermehrt dann auf, wenn Schweine in einer reizarmen Umwelt, beispielsweise in konventionellen Ställen mit Spaltenböden, gehalten werden, kann jedoch zahlreiche Ursachen haben (Brunberg et al., 2016; Schrøder-Petersen und Simonsen, 2001). Von Schwanzbeißen ist dann die Rede, wenn ein Schwein den Schwanz eines anderen Schweines mit dem Maul aufnimmt und daran kaut, sodass daraus Wunden hervorgehen können (D'Eath et al., 2014; Day et al., 2002; Schrøder-Petersen und Simonsen, 2001; Schrøder-Petersen et al., 2010). Diese Verhaltensanomalie tritt besonders häufig bei Hausschweinen in konventionellen Haltungssystemen auf, wurde aber auch bei Schweinen unter ökologischen Haltungsbedingungen beobachtet (Hansson et al., 2000). Bisher sind keine Studien bekannt, die Schwanzbeißen bei Wildschweinen nachweisen, wodurch die Verhaltensanomalie ein Problem der Haltung domestizierter Schweine zu sein scheint. Schwanzbeißen hat sowohl für das Tier selbst, als auch für den Tierhalter Folgen. Bei Schweinen, die Opfer von Schwanzbeißen werden, können unmittelbare Verletzungen entstehen sowie Schmerzen und Einschränkungen des Wohlbefindens. Für den Tierhalter kann ein starkes Auftreten von Schwanzbeißen zu wirtschaftlichen Verlusten führen, aufgrund einer erhöhten Mortalität oder einer verringerten Qualität des Schlachtkörpers. Eine bislang oftmals präventiv angewandte Maßnahme gegen Schwanzbeißen bei Schweinen ist das Kupieren des Schwanzes, was in der Europäischen Union gesetzlich verboten und aus Tierschutzgründen kritisch zu betrachten ist. Daher müssen Verfahren gefunden werden, wie unkupierte Schweine artgerecht gehalten werden können und wie anhand einer Anreicherung der Haltungsumwelt artspezifisches Verhalten, wie das Explorationsverhalten, gefördert werden kann. Bestens geeignet sind dafür Haltungssysteme mit Langstroheinstreu (Bolhuis et al., 2005; Fraser et al., 1991; Peeters et al., 2006; Van de Weerd et al., 2006). Jedoch werden mit einem Anteil von 91,8% die meisten Schweine in Deutschland auf Spaltenböden gehalten (BMEL, 2010). In diesen Haltungssystemen können langfaserige Materialien Probleme hinsichtlich der Entmistung verursachen, indem Rohrleitungen verstopfen. Es besteht somit die Notwendigkeit, Beschäftigungsmaterialien zu finden, die das Explorationsverhalten von Schweinen steigern und gleichzeitig mit dem Güllesystem konventioneller Ställe kompatibel sind.

In dieser Arbeit wurde konventionell gehaltenen, unkupierten Schweinen in der Aufzucht und Mast anhand eines Beschäftigungsturms mit Wühlbereich die Möglichkeit geboten, ihr natürliches Explorationsverhalten auszuüben, indem ihnen in unterschiedlichen Wechselintervallen verschiedene organische und güllekompatible Beschäftigungsmaterialien angeboten wurden. Dabei wurden unter anderem neuartige Beschäftigungsmaterialien untersucht, die hinsichtlich Struktur und Aroma variierten. Die Explorationszeit der Tiere an den Beschäftigungstürmen wurde anhand von „Ultra High Frequency Radio-Frequency Identification" (UHF-RFID) kontinuierlich über die gesamte Haltungsdauer erfasst und ausgewertet, was in anderen Studien in dieser Form bisher erst selten durchgeführt wurde. Ziel dabei war die Identifikation von attraktivem Beschäftigungsmaterial für Schweine, das zu einem Anstieg der Explorationszeit führt und nachhaltig attraktiv bleibt. Somit sollte das als attraktiv identifizierte Beschäftigungsmaterial zur Reduktion von Schwanz- und Ohrschäden beitragen.

1.2 Kenntnisstand

1.2.1 Verhalten und Sinnesleistung von Schweinen

Das Explorationsverhalten von Schweinen dient sowohl dem Auffinden von Nahrung, als auch zur Erkundung des Lebensraumes (Day et al., 1995), was die Wichtigkeit dieses Verhaltens untermauert. In Freilandhaltung verbringen domestizierte Schweine über 54 % der Tageslicht-Zeit mit dem Ausüben von Explorationsverhalten (Rodríguez-Estévez et al., 2009). Schweine zählen zu den sogenannten Makrosmaten, die sich durch einen sehr gut ausgeprägten Geruchssinn auszeichnen. Der Geruchssinn wird zur Futtersuche, dem Erkennen fremder Artgenossen, dem Aufspüren von Fressfeinden und zur Festlegung territorialer Grenzen genutzt (Kittawornrat und Zimmerman, 2011). Darüber hinaus haben Schweine einen gut ausgeprägten Geschmackssinn. Sie bevorzugen süßen Geschmack (Baldwin, 1976; Glaser et al., 2000; Hellekant und Danilova, 1999; Kennedy und Baldwin, 1972; Tinti et al., 2000) und vermeiden bitteren Geschmack (Nelson und Sanregret, 1997; Tinti et al., 2000). Diese Geschmackspräferenzen könnten den Vorteil bieten, dass energiereiche Nahrung bei der Futtersuche bevorzugt aufgenommen wird und bittere Nahrung, die mit giftigen Pflanzenteilen assoziiert sein könnte (Glendinning, 1994; Li und Zhang, 2014), vermieden wird. Sowohl der Geruchs- als auch der Geschmackssinn spielen neben der mit zahlreichen Nerven besetzten Rüsselscheibe bei der Nahrungssuche eine besonders große Rolle. Indem Schweine mit ihrem Rüssel die obere Bodenschicht durchwühlen, spüren sie über ihr Riechorgan fressbare Bestandteile auf, die sie mit der Rüsselscheibe ertasten. Der Rüssel von Schweinen ist daher anatomisch besonders markant, während die Augen vergleichsweise klein erscheinen. Das Sehvermögen von Schweinen ist weniger gut ausgeprägt und durch den höheren Anteil von Stäbchen im Vergleich zu Zapfen (Braekevelt, 1983) an das Sehen in der Dämmerung angepasst. Wildschweine adaptieren ihre Aktivitätsphase abhängig von Störungen durch den Menschen (z.B. während der Jagdsaison oder in der Nähe von Wohngebieten) an die Hell- bzw. Dunkelphase (Ohashi et al., 2012). Im Laufe der Domestikation hat sich der Tagesrhythmus der Hausschweine an den des Menschen angepasst, weshalb sie ihre Hauptaktivität am Tag zeigen (Fraser et al., 1991; Lyons et al., 1995; Olsen et al., 2000). Schweine kommunizieren durch verschiedene Laute miteinander, die sich je nach Situation (Tallet et al., 2013) und Emotion (Düpjan et al., 2008; Schrader und Todt, 1998) voneinander unterscheiden. Dies setzt ein gutes Hörvermögen von Schweinen voraus, was ihnen das Hören im Bereich von 42 Hz bis 40.500 Hz ermöglicht (Heffner und Heffner, 1990). Dadurch hören sie im selben Frequenzbereich wie zum Beispiel der Mensch, nehmen jedoch zusätzlich auch höhere Frequenzen wahr.

1.2.2 Risikofaktoren für Schwanzbeißen

Nach aktuellem Stand der Forschung liegen im Schwein bereits **tierbezogene Risikofaktoren** (Rasse, Wachstum, Geschlecht, Gesundheit) für Schwanzbeißen vor, welche in Tabelle 1.1 dargestellt sind. Zusätzlich stellt aber auch die **Haltungsumwelt** (Fütterung, Platzangebot, Gruppengröße, Klima, Management/Haltung und Zugang zu Beschäftigungsmaterial) ein Risikofaktor für das größte Verhaltensproblem in der Schweinehaltung dar (Tabelle 1.2). Auf die Risikofaktoren für Schwanzbeißen wird im folgenden Abschnitt eingegangen.

Dabei wird die Haltungsumwelt als Risikofaktor unter Berücksichtigung der Unterschiede zwischen Haus- und Wildschwein betrachtet.

1.2.2.1 Tierbezogene Risikofaktoren beim Schwein

Die gezielte Zucht auf bestimmte Merkmale setzt den Einsatz bestimmter **Rassen** voraus, die unterschiedliche Prävalenzen für Schwanzbeißen besitzen. In einem Vergleich waren Schweine der Rasse Yorkshire häufiger Opfer von Schwanzbeißen als die der Rasse Landrasse (Sinisalo et al., 2012). Wohingegen bei der Landrasse im Vergleich zu Large White häufiger Schwanzbeißen auftrat (Breuer et al., 2005) und die Rasse Duroc mehr Beißverhalten an Buchtengenossen zeigt, als Landrasse und Large White (Breuer et al., 2003). Die Heritabilität von Schwanzbeißen bei der Landrasse ist mit 0,27 moderat vorhanden (Breuer et al., 2005). Darüber hinaus wurde festgestellt, dass Schwanzbeißen mit Leistungsparametern korreliert (Breuer et al., 2005). So neigen magere Schweine der Rasse Landrasse eher zu Schwanzbeißen als fette (Breuer et al., 2005) und bei Schweinen mit geringer Rückenspeckdicke wurde vermehrt Schwanzbeißen festgestellt im Vergleich zu Schweinen mit erhöhter Rückenspeckdicke (Moinard et al., 2003). Oft werden in der Ferkelerzeugung Piétrain Eber eingesetzt, die einen hohen Magerfleischanteil und eine geringe Fettauflage vererben. Aufgrund von Verbrauchererwartungen sollte ein Schlachtkörper diese Eigenschaften mitbringen, jedoch wird dadurch Schwanzbeißen begünstigt. Ein weiteres Zuchtziel sind hohe tägliche Zunahmen, wodurch das **Wachstum** und gleichzeitig der Stoffwechsel der Schweine ansteigt. Ursinus et al. (2014) fanden heraus, dass hohe Gewichte, ein schnelles Wachstum und große Wurfgrößen das Schwanzbeißen bei Schweinen begünstigen. Die Autoren vermuten einen Zusammenhang mit der verwendeten Genetik (Landrasse-Kreuzung) und dass die Selektion auf diese drei Merkmale eine Zunahme von Verhaltensänderungen verursacht haben könnte. Eine mögliche Erklärung für den Zusammenhang zwischen Wachstum und Schwanzbeißen könnte zudem ein hoher metabolischer Umsatz sein (Ursinus et al., 2014), der den Stoffwechsel der Tiere belastet. Große Würfe gehen außerdem meist mit geringen Einzeltiergewichten und geringen Zunahmen einher. Beattie et al. (2007) stellten bei Ferkeln, die vermehrt

Schwanzbeißen zeigten, geringere Zunahmen von der Geburt bis zum Absetzen und geringere Absetzgewichte fest, als bei Ferkeln, die wenig Schwanzbeißen zeigen. Sie vermuten, dass Schweine, die vermehrt Schwanzbeißverhalten ausführten, ein Nährstoffdefizit aufwiesen, was zu einem erhöhten Futtersuchverhalten führte, das gegen Artgenossen gerichtet wurde. Neben Leistungsparametern kann auch das **Geschlecht** der Schweine einen Einfluss auf die Prävalenz von Schwanzbeißen haben, wobei Untersuchungen zu unterschiedlichen Ergebnissen kamen. In Schrøder-Petersen et al. (2010) trat Schwanzbeißen bei Schweinen mit kupierten Schwänzen häufiger in gemischtgeschlechtlichen Gruppen als in getrenntgeschlechtlichen Gruppen auf. In gemischtgeschlechtlichen Gruppen wurde das Beißverhalten tendenziell vermehrt gegen das entgegengesetzte Geschlecht gerichtet, dabei zeigten die weiblichen Tiere mehr Beißverhalten als die kastrierten männlichen Tiere, jedoch konnte kein signifikanter Unterschied zwischen den Geschlechtern festgestellt werden (Schrøder-Petersen et al., 2010). Im Gegensatz dazu beobachteten Hunter et al. (2001) bei Schweinen mit unkupierten Schwänzen mehr Schwanzbeißen in getrenntgeschlechtlichen Gruppen, während bei Schweinen mit kupierten Schwänzen kein Unterschied zwischen den getrennt- und gemischtgeschlechtlichen Gruppen festzustellen war. Zudem waren kastrierte männliche Schweine in gemischtgeschlechtlichen Gruppen häufiger Opfer aber auch Täter von Schwanzbeißen als weibliche Schweine (Van de Weerd et al., 2005). Zonderland et al. (2010) fanden bei Untersuchungen mit unkupierten Schweinen heraus, dass in Gruppen mit ausschließlich weiblichen Tieren schneller eine 40% Grenze von am Schwanzbeißen betroffenen Schweinen erreicht wurde als in rein männlichen und gemischtgeschlechtlichen Gruppen. Ein schlechter **Gesundheitsstatus** von Schweinen kann die Prävalenz für Schwanzbeißen erhöhen. So sind Atemwegserkrankungen, welche unter dem Procine Respiratory Disease Complex (PRDC) zusammengefasst werden, oder eine hohe Mortalität abgesetzter Ferkel Risikofaktoren für das Auftreten von Schwanzbeißen (Moinard et al., 2003). Die Gesundheit der Schweine hängt eng mit der Haltungsumwelt der Tiere zusammen, worauf im nächsten Kapitel eingegangen wird.

Tabelle 1.1 Übersicht der tierbezogenen Risikofaktoren für Schwanzbeißen beim Hausschwein.

Parameter	**Risiko für Schwanzbeißen**	**Literatur**
Rasse	Yorkshire > Landrasse	Sinisalo et al. (2012)
	Landrasse > Large White	Breuer et al. (2005)
	Duroc > Landrasse, Large White	Breuer et al. (2003)
Leistungsparameter	Mager	Breuer et al. (2005)
	Geringe Rückenfettdicke	Moinard et al. (2003)
	Hohes Gewicht, schnelles Wachstum, große Würfe	Ursinus et al. (2014)
	geringe Zunahmen, geringes Absetzgewicht	Beattie et al. (2007)
Geschlecht	Gemischtgeschlechtlich (kupiert)	Schrøder-Petersen et al. (2010)
	Getrenntgeschlechtlich (unkupiert)	Hunter et al. (2001)
	Opfer: Kastraten > weibliche Schweine Täter: Kastraten > weibliche Schweine	Van de Weerd et al. (2005)
Gesundheitsstatus	Atemwegserkrankungen Mortalität abgesetzter Ferkel	Moinard et al. (2003)

1.2.2.2 Haltungsumwelt-bezogene Risikofaktoren

Die Haltungsumwelt der Schweine nimmt direkten Einfluss auf die Möglichkeit, arttypisches Verhalten zu zeigen und somit auch auf deren Wohlergehen. Haltungsumwelt-bezogene Faktoren, die einen Risikofaktor für Schwanzbeißen darstellen, sind in Tabelle 1.2 dargestellt. So zeigen abgesetzte Ferkel reduzierte Zunahmen sowie vermehrt Krankheitssymptome, wenn sie mehrmals täglich einer Zugluft mit einer Luftgeschwindigkeit von durchschnittlich 0,99 m/s ausgesetzt waren (Scheepens et al., 1991). Des Weiteren wird ein Zusammenhang zwischen Zugluft und Schwanzbeißen vermutet (D'Eath et al., 2014). Diese Erkenntnisse zeigen, dass das **Klima** in der Schweinehaltung eine große Rolle spielt. Zudem zeigte sich auf Betrieben, bei denen die Ammoniakkonzentration in den Ställen über 10 ppm lag, eine höhere Prävalenz für Schwanzbeißen als Betriebe die unterhalb dieser Grenze lagen (Scollo et al., 2016). Scollo et al. (2017) wiesen sogar bereits bei Ammoniakkonzentrationen über 2,7 ppm eine höhere Prävalenz von Schwanzbeißen nach. Zudem wurden mit steigenden Temperaturen (zwischen 23 und 30°C) in den Aufzuchtbuchten eine Zunahme der Prävalenz von Schwanzbeißen während der Mast festgestellt (Smulders et al., 2008).

Tabelle 1.2 Der Haltungsumwelt von Hausschweinen zugeordnete Parameter, die einen Risikofaktor für Schwanzbeißen darstellen und Kennwerte der Haltungsumwelt von Haus- und Wildschweinen.

Parameter	**Wildschwein**		**Hausschwein**		
	Kennwert	**Literatur**	**Kennwert**	**Risikofaktor**	**Literatur**
Klima	Abhängig von der Saison			NH_3 > 10 ppm NH_3 > 2,7 ppm	Scollo et al. (2016) Scollo et al. (2017)
				Hohe Temperaturen (Aufzucht)	Smulders et al. (2008)
Fütterung	Omnivore Ernährung	Rodríguez-Estévez et al. (2009)	Alleinfutter (Phasen-fütterung)		
				Trockenfütterung > Nassfütterung	Smulders et al. (2008)
				Einzelplatz-Fütterung oder Bodenfütterung > Futterautomaten mit zwei oder mehr Futterplätzen	Hunter et al. (2001)
	Futteraufnahme: 11,3 % der Beobachtungszeit, Futtersuche: 11,3 % der Beobachtungszeit (Scan sampling über ein Jahr)	Blasetti et al. (1988)	Fressdauer: 67,0 min pro Tier und Tag		Hyun et al. (1997)
			68,8 min pro Tier und Tag		Brown-Brandl et al. (2013)
Management und Haltung	Wald sowie daran angrenzende Felder und Wiesen	Dardaillon (1986), Massei und Genov (2004)	Voll- oder Teilspalten bei 91,8 % der Haltungsplätze		BMEL (2010)
				Hoher Anteil an Spaltenboden	Smulders et al. (2008)
	Säugezeit: 9-14 Wochen	Newberry und Wood-Gush (1985)	Absetzen i.d.R. 4 Wochen nach der Geburt		
				Frühes Absetzen (12 Tage nach der Geburt	Gonyou et al. (1998)
				Heterogene Gewichte	Scollo et al. (2016)
	Revier: 104,4 ha	Lemel et al. (2003)	0,4 m^2 (bei 30-50 kg), 0,65 m^2 (bei 95-110 kg)		RL 2008/120/EG (2008)
				Hohe Besatzdichte	Scollo et al. (2016)
	Gruppen bis zu 23 Tiere	(Dardaillon, 1988)		Kein Einfluss der Gruppengröße	Schmolke et al. (2003)
Zugang zu Beschäfti-gungs-material	Exploration (Futtersuche und Erkundung des Lebensraums)	Day et al. (1995)	Kein Beschäftigungs-material		Beattie et al. (1995) Fraser et al. (1991) Hunter et al. (2001)
			Beschäftigungs-material als limitierte Ressource		Van de Perre et al. (2011)

Eine Folge des durch die Zucht auf Wachstumsleistung erhöhten Stoffwechsels der Tiere war die Anpassung und Optimierung der **Fütterung**. Hauptbestandteil heutiger Futtermittel sind Getreidesorten, wie Weizen oder Gerste, und Leguminosen, wie Soja, die durch Mineral- und Proteinadditive ergänzt werden. Das Verfüttern tierischer Proteine an Nutztiere ist gesetzlich verboten (VO (EG) 999/2001). Dabei zeigten Untersuchungen mit freilebenden Iberico Mastschweinen, dass neben einer großen Menge an pflanzlichem Futter (Eicheln, Gras, Sträucher, Beeren, Stroh, Wurzeln, Hölzer, Pilze) auch tierische (Aas, wirbellose Tiere, Knochen) oder anorganische (Erde, Sand, Holzkohle, Steine) Bestandteile in der omnivoren Ernährung von Schweinen eine Rolle spielen (Rodríguez-Estévez et al., 2009). Es wird vermutet, dass bei Futtermitteln mit einem geringen Proteingehalt, in denen Aminosäuren ergänzt wurden, die Menge und Qualität des Proteins unzureichend für eine normale Entwicklung von Schweinen war und dadurch Schwanzbeißen begünstigen konnte (Brunberg et al., 2016). Bei der Darreichung standardisierter Futtermittel können außerdem individuell auftretende Nährstoffbedürfnisse nicht gedeckt werden.

Dabei zeigen gerade Schweine in Buchten mit Schwanzbeißen eine geringere Aminosäuren-Konzentration im Blut, was auf eine geringere Nährstoffabsorption oder geringere Futteraufnahme durch erhöhten Stress zurückzuführen sein könnte (Palander et al., 2013). In der Schweinehaltung wird in der Regel eine Trocken- oder Nassfütterung eingesetzt. In einem Vergleich stellten Smulders et al. (2008) jedoch fest, dass eine Trockenfütterung gegenüber einer Nassfütterung das Risiko für Schwanzbeißen erhöht. Ebenso wurde bei einem Vergleich mehrerer Betriebe ein erhöhtes Risiko für Schwanzbeißen bei der Verwendung von Einzelplatz-Futterautomaten oder Bodenfütterung ermittelt, während die Verwendung von Futterautomaten mit zwei oder mehr Futterplätzen im Vergleich ein geringeres Risiko darstellten (Hunter et al., 2001). Dieser Trend lässt sich auch aus der negativen Korrelation zwischen der Anzahl an Futterplätzen in der Aufzucht und der Prävalenz für Schwanzschäden ableiten (Smulders et al., 2008). Schweine haben eine große Motivation, ihr Verhalten zu synchronisieren (Docking et al., 2008; Hsia und Wood-Gush, 1983; Zwicker et al., 2015), weshalb eine Einzeltierfütterung dem natürlichen Verhalten von Schweinen nicht entspricht und zu einer Konkurrenz um die erwünschte Ressource führen kann (Young und

Lawrance, 1994). In Gefangenschaft lebende Wildschweine verbrachten 11,9 % der Beobachtungszeit mit der Futteraufnahme und 11,3 % mit Wühlen (Blasetti et al., 1988). Durch die Vorlage auf den Bedarf abgestimmter Futtermittel verkürzt sich die Zeit der Futtersuche und -aufnahme in den heutigen Haltungssystemen jedoch enorm. So liegt die durchschnittliche Dauer der Futteraufnahme von Mastschweinen bei 67,0 min pro Tier und Tag (Hyun et al., 1997), wobei diese mit dem Alter der Tiere ansteigt (Brown-Brandl et al., 2013).Neben der Fütterung haben sich auch **Management** und **Haltung** im Laufe der Zeit verändert. Die Landwirtschaftszählung im Jahr 2010 ergab, dass in Deutschland 91,8 % der Haltungsplätze für Schweine mit Voll- oder Teilspaltenböden ausgestattet sind (BMEL, 2010). Arttypisches Verhalten wie Wühlen, Futtersuche oder Erkunden der Umwelt können in solchen Haltungssystemen nicht ausreichend ausgeübt werden. Dadurch kann das Auftreten von Verhaltensanomalien begünstigt werden, wie die positive Korrelation zwischen dem Anteil an Spaltenboden in einer Bucht und dem Risiko für Schwanzbeißen untermauert (Smulders et al., 2008). Eine weitere Managementmaßnahme, die die Prävalenz von Schwanzbeißen beeinflusst, ist das Absetzen der Ferkel. Hausschweine werden in der Regel mit einem Alter von vier Wochen abgesetzt und von der Sau entwöhnt, wobei die Säugezeit domestizierter Schweine in einer semi-natürlichen Haltungsumwelt zwischen neun und 14 Wochen (Newberry und Wood-Gush, 1985) liegt und bei frei lebenden domestizierten Schweinen selbst 18 Wochen nach der Geburt noch beobachtet wurde (Jensen und Recén, 1989). Gonyou et al. (1998) stellten fest, dass Schweine mit einem Alter von 12 Wochen mehr Kauverhalten an ihren Buchtengenossen zeigen, wenn sie 12 Tage nach der Geburt abgesetzt wurden, als wenn das Absetzen nach 21 Tagen stattfand. Schwanzbeißen konnte jedoch auch bei den Ferkeln mit einer längeren Säugezeit nicht verhindert werden. Zu diesem Ergebnis kamen auch Naya et al. (2019), die die Säugezeit von vier auf fünf Wochen erhöhten. Abgesetzte Ferkel werden in der Regel in gemischten Gruppen mit gleichalten Tieren aufgezogen. Dabei wirken sich einheitliche Gewichte auf Buchtenebene reduzierend auf Schwanzbeißen aus (Scollo et al., 2016). Die Zeit nach dem Absetzen stellt eine kritische Phase für die Prävalenz von Schwanzbeißen dar, hier wird die Verhaltensanomalie am häufigsten beobachtet (Abriel und Jais, 2013; Blackshaw, 1981; Jans-Wenstrup, 2018; Schrøder-Petersen et al., 2010; Veit et al., 2016).

Es wird vermutet, dass sich frei lebende Wildschweine in einem Gebiet von 104,4 ha (was 1.044.000 m^2 entspricht) aufhalten, wo sie während der Aktivitätsphase durchschnittlich Strecken von 7,2 km zurücklegen (Lemel et al., 2003). Die Mindestanforderungen für das **Platzangebot** von Schweinen in der Endmast (85 kg bis 110 kg Lebendgewicht) beträgt 0,65 m^2 (Richtlinie 2008/120/EG, 2008), wodurch domestizierte Hausschweine im Vergleich zu frei lebenden Wildschweinen einen deutlich eingeschränkteren Lebensraum besitzen. Scollo et al. (2016) fanden heraus, dass eine hohe Besatzdichte das Risiko für Schwanzbeißen erhöht. Neben dem Platzangebot wird dem Hausschwein auch die **Gruppengröße** und -zusammensetzung vorgegeben, wobei Schmolke et al. (2003) bei einem Platzangebot von 0,76 m^2 pro Schwein keinen Einfluss der Gruppengröße (10, 20, 40 oder 80 Schweine pro Bucht) auf die Prävalenz von Schwanzbeißen feststellen konnte. Die Gruppengröße ist meist ähnlich der freilebender Wildschweine, die in Gruppen von bis zu 23 Tieren zusammenleben (Dardaillon, 1988). Während die Gruppengröße bei Wildschweinen abhängig von der Jahreszeit, dem Alter und Geschlecht der Gruppenmitglieder variiert (Dardaillon, 1988), wird die Gruppenzusammensetzung der Hausschweine vom Haltungssystem vorgegeben und bleibt meist über die Aufzucht und über die Mast hinweg konstant.

Bei Untersuchungen zum Verhalten domestizierter Hausschweine unter natürlichen Bedingungen stellte sich eine große Übereinstimmung zum Wildschwein heraus (Jensen, 1986; Stolba und Wood-Gush, 1989), was indiziert, dass sich durch die Domestikation die Verhaltensweisen von Schweinen nicht sehr stark verändert haben. Die Haltungsumwelt von Hausschweinen steht jedoch in großem Kontrast zum Lebensraum der Wildschweine. Die meisten der aufgeführten Risikofaktoren stehen in engem Zusammenhang mit den Unterschieden des Habitats zwischen Haus- und Wildschwein und stellen einen Stressor für das domestizierte Hausschwein dar. Dabei wirken meist mehrere Stressoren gleichzeitig auf die Tiere ein, weshalb Schwanzbeißen ein multifaktorielles Problem darstellt. Bis zu einem gewissen Grad können Schweine auftretenden Stress bewältigen. Es wird jedoch angenommen, dass Schweine versuchen, auftretenden Stress, mit dem sie nicht umgehen können, durch Schwanzbeißen zu kompensieren (Schrøder-Petersen und Simonsen, 2001).

1.2.2.3 Beschäftigungsmaterialien in der Haltungsumwelt

Haben Schweine keinen **Zugang zu Beschäftigungsmaterial**, steigert dies die Prävalenz für das Beißen von Buchtengenossen (Beattie et al., 1995; Fraser et al., 1991; Hunter et al., 2001). Dabei können Beschäftigungsmaterialien, die bei Schweinen sehr beliebt sind, eine Konkurrenz um die Ressource auslösen, was ebenfalls das Risiko für Schwanzbeißen erhöhen kann (Van de Perre et al., 2011). Auf den Einsatz von Beschäftigungsmaterial als Maßnahme gegen Schwanzbeißen wird in Kapitel 6 eingegangen.

Durch das Angebot an Beschäftigungsmaterialien kann die Haltungsumwelt der Schweine angereichert werden, wodurch das Explorationsverhalten gesteigert und manipulatives Verhalten, wie Schwanzbeißen, reduziert werden kann (Beattie et al., 1995; Bolhuis et al., 2005). In der Praxis kommen häufig langlebige Materialien zum Einsatz, da diese selten erneuert oder ausgetauscht werden müssen und somit Material- und Arbeitskosten sparen. Jedoch stellte sich heraus, dass Beschäftigungsmaterialien für Schweine besonders gut geeignet sind, wenn sie die Eigenschaften veränderbar, kaubar, essbar, neuartig manipulierbar oder riechbar besitzen (Docking et al., 2008; Fraser et al., 1991; Jensen und Pedersen, 2007; Studnitz et al., 2007; Trickett et al., 2009; van de Weerd und Day, 2009). Organische Beschäftigungsmaterialien erfüllen diese Eigenschaften und werden von Schweinen in einem direkten Vergleich gegenüber nicht-organischen Materialien bevorzugt (Scott et al., 2006, 2009). Besonders zu empfehlen ist dabei der Einsatz von Langstroh als Einstreu (Bolhuis et al., 2005; Fraser et al., 1991; Peeters et al., 2006; Van de Weerd et al., 2006). Bei der Bereitstellung von Beschäftigungsmaterialien müssen gleichzeitig die baulichen Gegebenheiten eines Stalles berücksichtigt werden. Dabei stellt der Einsatz langfaseriger Materialien in Ställen mit Spaltenböden oft eine Herausforderung bei der Entmistung dar, weshalb für den Einsatz in konventionellen Ställen Alternativen zu langfaserigen Beschäftigungsmaterialien angeboten werden müssen. Eine solche Alternative könnten Beschäftigungsmaterialien mit fressbaren Zusätzen darstellen, die bei Schweinen höhere Explorationsdauern im Vergleich zu Materialien ohne fressbaren Zusatz erzielten (Jensen und Pedersen, 2007; Zwicker et al., 2013). Möglicherweise können dadurch naturnahe Gegebenheiten der Futtersuche imitiert werden. Des Weiteren bevorzugten Schweine Torf, Pilzkompost und

Sägemehl gegenüber Sand, Holzrinde und Stroh als Beschäftigungsmaterial (Beattie et al., 1998). Demnach scheinen Schweine Beschäftigungsmaterialien zu präferieren, die eine ähnliche Textur wie Erde haben (Jensen et al., 2008). Darüber hinaus bevorzugen Schweine pelletiertes Beschäftigungsmaterial gegenüber gehäckselten Materialien und Rindenkompost (Zwicker et al., 2013). Auch olfaktorische Reize können Präferenzen für Beschäftigungsmaterialien bei Schweinen auslösen. So zeigten Schweine eine klare Präferenz für Seile, die mit Knoblauchöl aromatisiert wurden, im Vergleich zu Seilen ohne Aroma (Blackie und de Sousa, 2019). Wie wichtig beim Einsatz von Beschäftigungsmaterialien für Schweine die Neuartigkeit ist, zeigt die kurze Zeit der Habituation (Trickett et al., 2009; Van de Perre et al., 2011), die bereits wenige Stunden nach der Bereitstellung von Beschäftigungsmaterialien eintreten kann (Apple und Craig, 1992). Habituation beschreibt dabei einen Prozess der verminderten Reaktion auf einen Reiz (z.B. verminderte Exploration von Beschäftigungsmaterial) und ist von einer Gewöhnung, also der Adaption an eine Reizsituation zu unterscheiden (Birbaumer, 1975). Die Habituation von Schweinen an Beschäftigungsmaterialien kann jedoch durch einen wöchentlichen Wechsel (Van de Perre et al., 2011) oder durch das wechselnde Aromatisieren von Beschäftigungsmaterialien (Nowicki et al., 2015) gesenkt werden. Des Weiteren eignete sich eine regelmäßige Vorlage von frischem Stroh, um das Interesse von Schweinen aufrechtzuerhalten (Bolhuis et al., 2005) oder das erneute Aromatisieren von Seilen, um das Interesse von Schweinen zu steigern (Blackie und de Sousa, 2019).

1.3 Formen von Schwanzbeißen

Wie vorausgehend erörtert, können in konventionellen Haltungssystemen vielerlei Stressoren auf Schweine einwirken. Schweine versuchen aufkommende Stressoren durch sogenannte Coping Strategien zu bewältigen. Gelingt die Adaption an den Stress nicht, können Verhaltensanomalien, wie Schwanzbeißen, Belly Nosing, Ohrbeißen oder Leerkauen auftreten. Schweine haben unterschiedliche Anpassungsstrategien an die von der Haltungsumwelt ausgelösten Stressoren. Bolhuis et al. (2005) teilten Schweine anhand eines sogenannten „Backtests“ in stark-reagierend (HR) und schwach-reagierend (LR) ein. Bei Verhaltensbeobachtungen zu unterschiedlichen Zeitpunkten nach dem Absetzen fanden die Autoren heraus, dass sich HR-Schweine eher aggressiv gegenüber ihren Artgenossen verhielten, sie kämpften, bissen und zeigten Kopfschlagen. LR-Schweine äußerten hingegen eher manipulatives Verhalten, wie Belly Nosing, Schwanz- oder Ohrenbeißen. Diese Erkenntnis deckt sich mit der Einteilung von Prunier et al. (2020), die das Beißverhalten von Schweinen nach Simonsen (1990) in „aggressiv" und „nicht-aggressiv" einteilten. Demnach wird „aggressives" Beißen durch Konkurrenzverhalten oder limitierte Ressourcen hervorgerufen und betrifft den vorderen Bereich des Körpers (Nacken und Schultern). Schwanzbeißen hingegen wird als „nicht-aggressives" Verhalten gewertet, das auftritt, wenn Schweine ihr Erkundungsverhalten nicht ausreichend befriedigen können und dies stattdessen an Buchtengenossen ausüben. Dabei beginnt Schwanzbeißen zunächst mit einem Bewühlen oder leichten Bekauen von Körperteilen, wie dem Schwanz der Artgenossen, was Fraser (1987) als „pre-Injury stage" des Schwanzbeißens bezeichnet. Dieses Bekauen wird von den Buchtengenossen meist toleriert und kann zu kleinen Wunden führen, was dann aufgrund einer hohen Affinität von Schweinen zu Blut in die „injury stage" übergeht (Fraser, 1987). Taylor et al. (2010) beschreiben zwei weitere Formen des Schwanzbeißens, die als „sudden-forceful" (plötzlich und heftig) und als „obsessiv" bezeichnet werden. Das „sudden-forceful" Schwanzbeißen tritt dann auf, wenn einem Schwein der Zugang zu einer gewünschten Ressource nicht möglich ist und es aufgrund von Frustration aggressives, kräftiges Beißen der Schwänze seiner Artgenossen zeigt (Taylor et al., 2010). Beim „obsessiven" Schwanzbeißen verfolgt ein Schwein scheinbar zwanghaft die Schwänze der Buchtengenossen und beißt kraftvoll zu, sobald die Möglichkeit dazu besteht (Taylor et al., 2010).

1.4 Auswirkungen von Schwanzbeißen

Die Auswirkungen von Schwanzbeißen können vielfältig sein. Sie betreffen die Gesundheit und das Wohlergehen der Schweine, indem sie oberflächliche Hautdurchbrechungen verursachen und im Extremfall zum Tod eines Tieres führen können. Die Folgen von Schwanzbeißen bedeuten somit auch ökonomische Verluste für den Landwirt. Der Schwanz des Schweines ist vollständig mit Nerven durchzogen (Simonsen et al., 1991), weshalb durch Schwanzbeißen beim gebissenen Tier Schmerzen hervorgerufen werden. Darüber hinaus können durch das Eintreten von Krankheitserregern in offene Wunden Entzündungen am Schwanz entstehen, wodurch als Sekundärinfektion oft die Lungen der Tiere betroffen sind (Kritas und Morrison, 2007; Munsterhjelm et al., 2013; Schrøder-Petersen und Simonsen, 2001). Als weitere Folge von Schwanzbeißen können sich Abszesse bilden (Kritas und Morrison, 2007; Li et al., 2017; Marques et al., 2012), die durch Verletzungen des Muskelgewebes hervorgerufen werden (Schrøder-Petersen und Simonsen, 2001) und zur Verwerfung des Schlachtkörpers führen können. Des Weiteren wird Schwanzbeißen mit einer erhöhten Mortalität und mit Störungen des Bewegungsapparats (Marques et al., 2012), sowie geringen Zunahmen der gebissenen Tiere in Verbindung gebracht (Marques et al., 2012; Sinisalo et al., 2012). Letzteres könnte in Folge einer reduzierten Futteraufnahme entstehen (Munsterhjelm et al., 2015; Wallenbeck und Keeling, 2013). Einen Einfluss von Schwanzbeißen auf die Futterverwertung und den Anteil an rotem Fleisch am Schlachtkörper konnte jedoch nicht festgestellt werden (Sinisalo et al., 2012). Aus den dargestellten gesundheitlichen und ökonomischen Folgen und unter Berücksichtigung des Tierwohls ist es erforderlich, dem Schwanzbeißen durch geeignete Maßnahmen vorzubeugen und entgegenzuwirken.

1.5 Maßnahmen gegen Schwanzbeißen

1.5.1 Kupieren

Die heute in der Praxis gängigste Methode, um Schwanzbeißen bei Schweinen zu vermeiden, ist das Kupieren eines Teilstückes des Schwanzes, was in der Europäischen Union grundsätzlich verboten ist. Aufgrund einer Ausnahmegenehmigung ist das Kupieren eines Teilstückes des Schwanzes jedoch erlaubt, um Schäden am Tier zu vermeiden (Richtlinie 2008/120/EG, 2008). Diese Ausnahmegenehmigung führt dazu, dass 77 % der Schweine in der Europäischen Union routinemäßig kupiert werden (De Briyne et al., 2018). Das Kupieren des Schwanzes kann das Risiko für Schwanzbeißen reduzieren, es jedoch nicht gänzlich verhindern (Hunter et al., 2001; Larsen et al., 2018; Lee et al., 2016).

Durch das Kupieren des Schwanzes werden Nerven verletzt, die Neurome und somit Nervenschmerzen verursachen können (Devor und Rappaport, 1990; Simonsen et al., 1991). Unter Berücksichtigung von Tierwohlaspekten sollten daher nicht-invasive Maßnahmen gegen das Auftreten von Schwanzbeißen eingesetzt werden, mit denen die Ursachen der Verhaltensanomalie behoben werden, anstatt deren Folgen entgegenzuwirken. Eine Möglichkeit, wie durch das Fördern von arttypischem Verhalten Schwanzschäden reduziert werden können, ist der Einsatz von Beschäftigungsmaterial.

1.5.2 Beschäftigungsmaterial als Maßnahme gegen Schwanzbeißen

Schweine besitzen eine hohe intrinsische Motivation zur Exploration, die im engen Zusammenhang mit der Futtersuche (Day et al., 1995) und somit dem Wühlen, Kauen und Beißen steht. In Ställen ohne Umweltreize und ohne die Möglichkeit zur Exploration, stellen die Artgenossen oft die einzige veränderbare Variable dar. Es wird daher vermutet, dass das Bekauen und Beißen von Artgenossen mit einem nicht erfüllten Bedürfnis des Explorationsverhaltens und der Futtersuche einhergeht (Beattie et al., 2007; Wood-Gush und Vestergaard, 1989). Aus diesem Grund ist das Bereitstellen von geeigneten Beschäftigungsmaterialien eine wichtige Maßnahme, um den Schweinen artspezifische Verhaltensweisen zu ermöglichen und Schwanzschäden zu reduzieren. Die von Schweinen präferierten Beschäftigungsmaterialien wurden bereits in Kapitel 1.2.2.3 beschrieben. In verschiedenen Studien wirkte sich der Einsatz bestimmter Beschäftigungsmaterialien zudem positiv auf die Prävalenz von Schwanzbeißen aus. Diese werden in Tabelle 1.3 aufgeführt. Gegenüber Buchten, in denen Schweine ohne Beschäftigungsmaterialien gehalten wurden, konnte aufgrund einer Anreicherung der Haltungsumwelt eine Reduktion von Schwanzschäden erzielt werden (Bolhuis et al., 2005; Day et al., 2008; Larsen et al., 2018; Petersen et al., 1995). Vor allem Stroh wurde in diesem Zusammenhang häufig untersucht. Dabei stellte sich heraus, dass bei Schweinen, die auf Stroheinstreu gehalten wurden, weniger Schwanzschäden auftraten als bei Schweinen, die auf

Spaltenböden gehalten wurden, unabhängig von dem Angebot eines Plastikspielzeugs (Scott et al., 2007; Scott et al., 2009). Pedersen et al. (2014) berechneten zur Reduktion von Schwanzschäden eine optimale Strohmenge von 387g (± 10 g) pro Mastschwein und Tag. Dabei konnte in bisherigen Studien kein Unterschied der Darreichungsform von Stroh (Langstroh, gehäckseltes Stroh, Strohpellets) auf die Prävalenz von Schwanzschäden gefunden werden (Day et al., 2008; Lahrmann et al., 2015; Zwicker et al., 2013). Im direkten Vergleich konnte mit Beschäftigungsmaterialien wie Grassilage (Holinger et al., 2018) oder Maissilage (Jensen et al., 2010) sogar einen größeren Effekt auf die Reduktion von Schwanzschäden erreicht werden als mit dem Einsatz von Stroh. Bei Untersuchungen, in denen Schweinen mehrere Beschäftigungsmaterialien simultan (Telkänranta et al., 2014) oder in alternierender Reihenfolge (Trickett et al., 2009; Van de Perre et al., 2011) angeboten wurden, wurde ebenfalls ein positiver Effekt auf die Prävalenz von Schwanzschäden festgestellt. Jedoch treten Schwanzschäden bei einigen Untersuchungen unabhängig vom eingesetzten Material auf (Scott et al., 2006; Veit et al., 2016; Zwicker et al., 2013).

Der Einfluss auf Schwanzschäden wurde bereits anhand von zahlreichen Beschäftigungsmaterialien untersucht. Jedoch wird dabei oftmals bereits beobachtetes Beißverhalten oder aufgetretene Verletzungen als Grundlage zur Beurteilung der Eignung als Maßnahme gegen Schwanzbeißen herangezogen. Zur Vermeidung unnötiger Schmerzen, Leiden oder Schäden am Tier (TierSchG, 1972), sind Methoden zu bevorzugen, die bereits einen Schritt vorher ansetzen. Bei Schweinen zeigen sich Verhaltensänderungen bereits mehrere Tage vor dem Auftreten von Schwanzbeißen (Larsen et al., 2019; Munsterhjelm et al., 2015). Diese Verhaltensänderungen könnten durch den Einsatz automatisierter Verfahren frühzeitig erkannt werden, um bereits vor dem Auftreten von Symptomen dagegen vorzugehen.

Tabelle 1.3 Überblick über untersuchte Beschäftigungsmaterialien und deren Auswirkungen auf die Explorationszeit und Schwanzschäden

Material	Alter	Durchschnitts-gewicht (Beginn)	Kupiert	Material mit der meisten Exploration	Material mit den geringsten Schwanzschäden/ Manipulationen[1]	Literatur
Bucht ohne oder mit Langstroh (3,5 kg Stroh täglich)	ab 4 Wochen (Aufzucht)	7,23 -7,33 kg	kupiert	mit Stroh	Mit Stroh	Bolhuis et al. (2005)
4 kg Langstroh (F) oder halb-gehäckseltes Stroh (H) oder gehäckseltes Stroh (C) pro Tag oder kein Stroh (N)	(Mast)[2]	28.3 kg	keine Angabe	Gehäckseltes Stroh (meistes Durchpflügen) Langstroh (meistes Herauszupfen)	Langstroh und halb-gehäckseltes Stroh	Day et al. (2008)
Grassilage oder Langstroh in Raufe (max. 1x täglich)	(Mast)[2]	25 kg	nicht kupiert	Grassilage	Nicht signifikant	Holinger et al. (2018)
Maissilage (ca. 350 g) oder gehäckseltes Stroh (90 g), täglich pro Tier und Tag	(Mast)[2]	etwa 30 kg	keine Angabe	Maissilage	Maissilage (p=0,06)	Jensen et al. (2010)
Langstroh oder gehäckseltes Stroh (100 g pro Tier und Tag)	(Mast)[2]	33 kg	kupiert	Nicht signifikant	Nicht signifikant	Lahrmann et al. (2015)
Stroh (150 g pro Tier und Tag) oder kein Stroh	(Mast)[2]	30 kg	kupiert & nicht kupiert	Nicht erfasst	Mit Stroh	Larsen et al. (2018)
Stroheinstreu ohne oder mit Raufutter (Silage aus Hafer, Wicke und Lupine oder Silage aus Gerste und Erbsen oder Silage aus Klee und Gras oder grünes Grasmehl oder Heu aus Klee und Gras oder Futterrüben)	15 Wochen	57,8 kg	keine Angabe	Silage aus Hafer, Wicke und Lupine	Nicht signifikant	Olsen et al. (2000)
Langstroh (10, 500 oder 1000 g pro Tier und Tag)	(Mast)[2]	30 kg	kupiert	nicht erfasst	1000 und 500 g	Pedersen et al. (2014)
Langstroh (10, 80, 150, 220, 290, 360, 430 oder 500 g pro Tier und Tag)	(Mast)[2]	30 kg	kupiert	nicht erfasst	387 g (± 10 g) pro Tier und Tag (Optimum)	Pedersen et al. (2014)
Stroh, Holzstämme und Zweige oder kein Material	4 Wochen (bis Woche 18)	keine Angabe	nicht kupiert	Nicht differenziert	Mit Material	Petersen et al. (1995)
Stroheinstreu ohne weitere Materialien oder mit Plastik Spielzeug, Vollspalten mit Plastikspielzeug (hängend oder auf dem Boden)	12 Wochen (Mast)	35 kg	keine Angabe	Stroheinstreu > Plastikspielzeug, Plastikspielzeug hängend (p=0,052)	Mit Stroh	Scott et al. (2009)

Stroheinstreu ohne Plastikspielzeug oder Stroheinstreu + Plastikspielzeug oder Vollspalten + Plastikspielzeug oder Vollspalten + 4 Plastikspielzeuge	12 Wochen (Mast)	35 kg	keine Angabe	Stroheinstreu > Plastikspielzeug	Mit Stroh (p=0,06)	Scott et al. (2007)
Stroheinstreu mit oder ohne Bite-Rite oder Vollspalten + Bite-Rite oder Vollspalten + Zuckerrübenschnitzel	12 Wochen (Mast)	35 kg	keine Angabe	Stroheinstreu > Bite-Rite, Zuckerrübenschnitzel > Bite-Rite	Nicht signifikant	Scott et al. (2006)
Strohkorb, Metallkette und Holzspähne ohne zusätzliches Material oder mit Birkenholz oder mit Polyäthylen-Rohrkreuze oder mit zwei Kreuzen aus Metallketten oder mit allen drei Materialien zusätzlich	8 Wochen	Keine Angabe	nicht kupiert	Birkenholz, Polyäthylen-Rohrkreuze oder alle drei Materialien	Holz oder alle drei Materialien simultan	Telkänranta et al. (2014)
Seil, Holz, alternierend Seil-Holz alternierend Holz-Seil, simultan Seil und Holz	4 Wochen	8,89 - 10,90 kg	keine Angabe	Seil und Holz simultan	Seil oder alternierend Seil-Holz	Trickett et al. (2009)
7 Materialien im wöchentlichen Wechsel: Gummistange, Gummiball, gelbes Band, orangenes Seil, gelber Gartenschlauch, lila Band und grauer Gartenschlauch im Vgl. zu Kette (Kontrolle)	10 Wochen (Mast)	20 kg	keine Angabe	Tag 0: orangenes Seil Tag 5: orangenes Seil (ohne sign. Unterschied zu lila Band und grauer Gartenschlauch)	7 Materialien im wöchentlichen Wechsel (im Vgl. zu Kette)	Van de Perre et al. (2011)
Stroheinstreu ohne zusätzliches Material oder mit Bite-Rite oder mit Strohautomat oder mit aromatisiertem Futter oder mit aromatisiertem Wasser	7-8 Wochen	55 kg	nicht kupiert	Stroheinstreu	Stroheinstreu (ohne sign. Unterschied zu Strohraufe und aromatisiertem Futter)	Van de Weerd et al. (2006)
Kein Material oder getrocknete Maissilage oder Luzerne-Heu (2x täglich ab der 2. Lebenswoche)	ab 2. Lebenswoche (LW) bis Ende Aufzucht	Ø Geb.-Gewicht: 1,4 kg Ø Absetzgewicht: 8 kg (4. LW)	nicht kupiert	Nicht signifikant	Nicht signifikant	Veit et al. (2016)
gehäckseltes Stroh (Einstreu) gehäckseltes Stroh mit Maiskörnern (Einstreu) gepresster Strohblock im Spender gehäckseltes Stroh in Raufe (im dreiwöchigen Wechsel)	(Mast)[2]	30 kg	nicht kupiert	Tag 2: gehäckseltes Stroh mit Maiskörnern	Nicht signifikant	Zwicker et al. (2013)
geäckseltes Stroh (Einstreu) gehäckseltes *Miscanthus giganteus* (Einstreu) Strohpellets im Spender Rindenkompost im Trog (im dreiwöchigen Wechsel)	(Mast) [2]	30 kg	nicht kupiert	Tag 2: Strohpellets	Nicht signifikant	Zwicker et al. (2013)

[1] darunter Schwanzbeißen, [2] keine Altersangabe

1.6 Elektronische Verhaltensüberwachung

Seit einigen Jahren steigen in Deutschland, aber auch in anderen europäischen Ländern die Bestandszahlen in der Schweinehaltung an (Roguet und Rieu, 2014; Winter et al., 1998). Um bei steigenden Tierzahlen die Gesundheit und das Wohlergehen des Einzeltiers gewährleisten zu können, spielt die elektronische Datenerfassung und Tierüberwachung eine zunehmende Rolle. Bereits kleine Verhaltensänderungen können ein Indikator für Krankheiten oder vermindertes Wohlbefinden von Schweinen sein. So sind eine geringe Aktivität oder eine reduzierte Futteraufnahme Anzeichen für Erkrankungen (Ahmed et al., 2015; Escobar et al., 2007; Reiner et al., 2009). Eine weit verbreitete Methode das Verhalten von Tieren zu überwachen sind Videoaufnahmen. Sie können genutzt werden, um mit sogenannten „deep learning“ Verfahren oder „Kinect-Tiefensensoren“ Programme darauf zu trainieren, die Position von Schweinen innerhalb einer Bucht zu erfassen (Riekert et al., 2020), liegende von aktiven Schweinen zu unterscheiden (Lee et al., 2016; Riekert et al., 2020) oder sogar aggressives Verhalten zu identifizieren (Lee et al., 2016).

Eine weitere Möglichkeit, die Position von Schweinen zu erfassen, um Rückschlüsse auf deren Aktivität zu ziehen, ist die Verwendung von Radiofrequenz-Identifikations (RFID) Systemen (Naguib und Krause, 2020). Gegenüber videobasierter Datenerfassung auf Gruppenebene bietet die UHF-RFID den Vorteil einer automatisierten und tierindividuellen Datenerfassung. Die UHF-RFID kommt dabei im Vergleich zu sogenannten „deep learning“ Verfahren ohne ein Anlernen und das Programmieren von Algorithmen aus. UHF-RFID-Systeme beruhen auf einer kontaktlosen Kommunikation zwischen einem Lesegerät und einem Transponder über eine dazwischengeschaltete Antenne. Dabei werden sogenannte „Hotspots“ (z.B. Futtertrog, Tränke, Beschäftigungsautomat) mit einer UHF-RFID-Antenne ausgestattet, die mit passiven UHF-RFID-Transpondern ausgestattete Schweine im Bereich ihres Lesefeldes erkennen. Es gibt niederfrequente (LF, 125 - 135 kHz), hochfrequente (HF, 13.56 MHz) und ultrahochfrequente (UHF, 860 MHz (EU)) RFID-Systeme (Ruiz-Garcia und Lunadei, 2011). Im Vergleich zu UHF-Systemen sind LF- und HF-Systeme störungsfreier gegenüber äußeren Einflüssen wie Wasser oder Metallabschirmung und -reflektion. Die kurze Lesereichweite ist ein Nachteil von

LF-RFID (20 cm – 100 cm) und HF-RFID-Systemen (10 cm – 150 cm) gegenüber UHF-RFID-Systemen (300 – 1500 cm) (Ruiz-Garcia und Lunadei, 2011). Des Weiteren können bei LF-Systemen keine gleichzeitigen Lesungen mehrerer Transponder stattfinden, weshalb sie oft an Abrufstationen zur Einzeltierfütterung eingesetzt werden. An Futterautomaten mit mehreren Fressplätzen kommt die LF-RFID an ihre Grenzen. Dabei können gerade hier Änderungen in den Verhaltensmustern erfasst werden. Für die gleichzeitige Erfassung mehrerer Tiere sind UHF-RFID-Systeme besonders gut geeignet. Die Störanfälligkeit gegenüber äußeren Einflüssen kann jedoch zu fehlerhaften Lesungen und damit zu Messungenauigkeiten führen (Adrion et al., 2018). Abhängig von der an der RFID-Antenne anliegenden Leistung und dem Aggregieren einzelner Ereignisse konnte jedoch bereits eine Sensitivität des UHF-RFID-Systems von bis zu 90 % erzielt werden (Adrion et al., 2015). Durch die hohe Übereinstimmung zwischen RFID-Daten und Videoauswertungen, bewerteten die Autoren das untersuchte UHF-RFID-System als vielversprechende Methode zur Entwicklung von Systemen zur Überwachung der Gesundheit und Aktivität von Schweinen. Inzwischen wurde die UHF-RFID-Technik in der Schweinehaltung bereits für den Einsatz zur Gesundheitsüberwachung erprobt. So zeigten Schweine, bei denen Lahmheit oder Husten diagnostiziert wurde, einen Rückgang der mittels UHF-RFID erfassten Besuchsdauer am Futtertrog im Vergleich zu gesunden Artgenossen (Kapun et al., 2016).

1.7 Elektronische Früherkennung von Schwanzbeißen

Das Bevorstehen eines Ausbruchs von Schwanzbeißen kann sich bei Schweinen anhand von Verhaltensänderungen, wie einer erhöhten Aktivität oder einer reduzierten Futteraufnahme bemerkbar machen (Larsen et al., 2019; Wallenbeck und Keeling, 2013). Das automatisierte Erkennen und Erfassen dieser Verhaltensänderungen kann zur Früherkennung von Schwanzbeißen beitragen. Wallenbeck und Keeling (2013) werteten Futterdaten von Schweinen in Buchten mit und ohne Schwanzbeißen aus. Dabei stellten sie fest, dass die durchschnittlich aufgenommene Futtermenge pro Tier und Woche und die durchschnittlichen Besuche an der Futterstation pro Tier und Tag in den Buchten mit Schwanzbeißen tendenziell geringer war im Vergleich zu Buchten, in denen kein Schwanzbeißen beobachtet wurde. Diese Unterschiede traten bereits mehrere Wochen vor dem Ausbruch von Schwanzbeißen auf, waren jedoch nicht in allen Wochen signifikant. Die automatische Erfassung von Futterdaten könnte somit eine Früherkennung von Schwanzbeißen ermöglichen (Wallenbeck und Keeling, 2013). Eine Woche vor dem Ausbruch von Schwanzbeißen stellten Larsen et al. (2019) ein geringeres objektbezogenes manipulatives Verhalten von unkupierten Schweinen in Buchten mit Schwanzbeißen fest, während die allgemeine Aktivität zunahm. Die Autoren ordneten die Erfassung der Objektmanipulation als vielversprechende Methode zur Früherkennung von Schwanzbeißen bei unkupierten Schweinen ein, empfahlen jedoch eine kontinuierliche anstatt einer sequenziellen Datenauswertung zur Identifikation abweichender Verhaltensweisen im Tagesverlauf.

Larsen et al. (2018) fanden heraus, dass die Haltung des Schwanzes unkupierter Schweine Aufschluss darüber gibt, ob eine Verletzung am Schwanz vorliegt. Dabei wurden in Buchten mit einem Schwanzbeißgeschehen mehr eingezogene Schwänze beobachtet als in Buchten ohne Schwanzbeißen. Sie untersuchten die Schweine in einem Zeitraum von drei Tagen bevor Schwanzschäden auftraten, empfahlen jedoch, diesen Zeitraum zu verlängern und die Erfassung der Schwanzhaltung zu automatisieren. Ein Verfahren zur automatischen Erfassung der Schwanzhaltung von Schweinen wurde unter der Verwendung von 3D-Kameras und Bildverarbeitungsalgorithmen von D'Eath et al. (2018) getestet. Anhand des verwendeten Algorithmus wurden in den Buchten mit Schwanzbeißen bereits eine Woche vor den ersten Symptomen mehr abgesenkte Schwänze erfasst als in den Buchten ohne Schwanzbeißen. Eingezogene Schwänze wurden von dem entwickelten Algorithmus zu 88,4% der ausgewerteten Zeit korrekt erfasst, während abgesenkte Schwänze zu 53,4% korrekt erkannt wurden. D'Eath et al. (2018) lieferten damit ein Echtzeitverfahren, mit dem erste Voraussetzungen geliefert wurden, um anhand der Schwanzhaltung ein Schwanzbeißgeschehen auf Buchtenebene vorherzusagen.

Die UHF-RFID wurde im Bereich der Schweinehaltung bereits auf ihre Einsatzfähigkeit getestet (2015; Adrion et al., 2018; Kapun et al., 2016) und würde erste Voraussetzungen für den Einsatz in der Schweinehaltung erfüllen. Jedoch fehlen bisher Untersuchungen zur Validität von UHF-RFID-Systemen bei der kontinuierlichen Erfassung von Verhaltensdaten, um eine Einschätzung über die Vorhersagegenauigkeit von Schwanzbeißen geben zu können.

1.8 Fragestellung und Hypothesen

Im Verbundprojekt „Label-Fit“ (Schweinehaltung fit für das Tierschutzlabel: Integrierte Entwicklung von Haltungs- und Verfahrenstechnik zur Transformation konventioneller Ställe) sollten Lösungsansätze gefunden werden, wie bereits bestehende konventionelle Ställe dahingehend verändert werden können, dass sie an der Vermarktung unter dem Tierschutzlabel des Deutschen Tierschutzbundes teilnehmen können. Berücksichtigt wurden in dem Projekt die Anforderungen des Tierschutzlabels an die Haltung von Schweinen, was unter anderem ein erhöhtes Platzangebot, eine Strukturierung der Buchten, den Zugang zu Beschäftigungsmaterial und das Halten unkupierter Schweine beinhaltete. Die im Verbundprojekt beteiligten Projektpartner bearbeiteten in fünf Teilprojekten (TP) Fragestellungen hinsichtlich Buchtenstrukturierung (TP 1), organischem Beschäftigungsmaterial (TP 2) und Entmistung beim Einsatz organischer Beschäftigungsmaterialen (TP 3) und entwickelten Lösungsansätze zur Implementierung in der Praxis. Begleitend dazu erfolgte die Überprüfung der Praxistauglichkeit (TP 4). Die Ergebnisse aller Teilprojekte wurden anschließend unter Berücksichtigung des Tierwohls und der Ökonomie bewertet (TP 5).

Die vorliegende Arbeit befasst sich mit Teilprojekt 2. Hier sollte organisches Beschäftigungsmaterial identifiziert werden, das für Aufzucht- und Mastschweine besonders attraktiv ist, das Explorationsverhalten langfristig aufrechterhält und somit im Optimalfall bei unkupierten Schweinen Schwanz- und Ohrschäden reduziert. Als Messgröße wurde dabei die Explorationsdauer der Schweine mit diesen Beschäftigungsmaterialien herangezogen. Die Verwendung der Beschäftigungsmaterialien sollte dabei in konventionellen Ställen mit Spaltenböden realisierbar sein. Die Vorlage der güllekompatiblen und organischen Beschäftigungsmaterialien erfolgte daher über einen speziell für das Vorhaben entwickelten Beschäftigungsturm mit Wühlbereich und integrierter UHF-RFID-Technik zur Erfassung der Beschäftigungszeit von Schweinen. Durch die Vorlage von Beschäftigungsmaterial, das im Wühlbereich von den Schweinen untersucht und bewühlt werden konnte, sollte das arttypische Explorationsverhalten gefördert werden. Da eine Steigerung der Exploration eine Reduktion von manipulativem Verhalten an Artgenossen bewirkt, sollte gleichzeitig eine Reduktion von Schwanz- und Ohrschäden erreicht werden.

Die in dieser Arbeit durchgeführten wissenschaftlichen Untersuchungen wurden in vier Kapitel unterteilt (Kapitel 2-5). Dabei wurde zunächst überprüft, welche gleichzeitig zur Verfügung gestellten organischen Beschäftigungsmaterialien Schweine in zwei getrennt voneinander durchgeführten Wahlversuchen präferieren (Kapitel 2; (Kauselmann et al., 2020a)), um einen Anhaltspunkt für weitere Langzeituntersuchungen zu erhalten. Im ersten Wahlversuch wurden unterschiedlich strukturierte Beschäftigungsmaterialien untersucht, mit denen bei der Exploration der Tastsinn der Rüsselscheibe angesprochen werden sollte. Dabei wurde die Hypothese aufgestellt, dass Schweine anhand ihrer Beschäftigungszeit Präferenzen für bestimmte Materialien und Strukturen zeigen. Da das Explorationsverhalten bei Schweinen in engem Zusammenhang mit der Nahrungssuche steht, wurden die Präferenzen für fressbare Zusätze in gehäckseltem Stroh getestet. Dabei wurde vermutet, dass Schweine vermehrt Stroh mit einem fressbaren Zusatz gegenüber dem Stroh ohne Zusatz erkunden.

Ausgehend von den Resultaten des ersten Wahlversuchs wurde die Beschäftigungsdauer von Schweinen beim Einsatz unterschiedlich strukturierter Materialien in einer Langzeituntersuchung überprüft (Kapitel 3; (Kauselmann et al., 2021)). Unter Berücksichtigung der schnellen Habituation von Schweinen an Beschäftigungsmaterialien, stand dabei die Frage im Mittelpunkt, ob Schweine auch über die Aufzucht und Mast hinweg Präferenzen für alternierend angebotene Beschäftigungsmaterialien mit unterschiedlichen Strukturen zeigen. Dabei wurde die Hypothese aufgestellt, dass Schweine ausgehend von dem zuvor durchgeführten Wahlversuch auch während einer Langzeituntersuchung Präferenzen für bestimmte Materialien und Strukturen zeigen.

Des Weiteren erfolgte eine Untersuchung, ob die Attraktivität von gehäckseltem Stroh als Basismaterial durch die Zugabe von Mais als fressbaren Zusatz gesteigert werden kann und gleichzeitig Schwanzschäden reduziert werden können (Kapitel 4; (Kauselmann et al., 2020b)). Ausgehend von den Ergebnissen des zweiten Wahlversuchs wurde vermutet, dass sowohl Aufzucht- als auch Mastschweine in einer Langzeituntersuchung ein stärkeres Explorationsverhalten für gehäckseltes Stroh mit einem fressbaren Zusatz im Vergleich zu gehäckseltem Stroh ohne fressbaren Zusatz zeigen. Darüber hinaus wurde vermutet, dass die Steigerung der Exploration mit einer Reduktion von Schwanz- und Ohrschäden einhergeht.

Zudem sollte die Präferenz von Schweinen für verschieden aromatisierte Strohpellets und deren Auswirkung auf den Status des Schwanzes überprüft werden (Kapitel 5; (Kauselmann et al., accepted 2021)). Dabei wurde die Frage untersucht, ob die Attraktivität von Strohpellets anhand eines olfaktorischen Reizes in Form von alternierend ausgetauschten Aromen für die Makrosmaten gesteigert werden kann. Es wurde vermutet, dass Schweine bestimmte Aromen präferieren und anhand einer gesteigerten Explorationszeit eine Reduktion von Schwanz- und Ohrschäden erreicht werden kann.

Abschließend werden in der allgemeinen Diskussion (Kapitel 6) die Erkenntnisse aller wissenschaftlichen Untersuchungen zusammengeführt.

2. Short-term choice of fattening pigs for additional plant-based materials

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Abstract

A major problem in conventional pig production systems is the occurrence of abnormal behaviours such as tail biting. Tail biting is a multifactorial problem, but it seems that a lack of proper enrichment materials prevents the animals from performing normal species-specific behaviour, e.g., rooting, nosing or chewing, and thus increases the prevalence of tail biting. The aim of this study was to identify plant-based enrichment material and nutritive additives that are attractive to pigs and that can be used as enrichment in practice. Therefore, we carried out two choice tests to investigate (i) which plant-based enrichment materials, differing in structure and flavour, pigs prefer and (ii) what kind of nutritive additives can be used to further increase the attractiveness of plant-based enrichment materials. In each choice test, pigs had the choice of six offered options. Pigs were tested individually in their familiar environment in an arena for 150 s. The first choice test revealed that pelletized materials, i.e., lucerne pellets and straw pellets, were preferred over all other options tested (Friedman test, $n = 55$, $p<0.001$). In the second choice test, the pigs' interest was highest for the largest nutritive additive, i.e., maize kernels, compared to the other options tested (Friedman test, $n = 65$, $p<0.001$). When choosing enrichment materials for pigs, structure, size and flavour should be considered. Pelletized plant-based enrichment materials or non-pelletized materials with nutritive additives can be recommended to stimulate exploration. Further studies should examine the interval at which enrichment material needs to be altered to keep pigs' interest at a high level.

Keywords: Enrichment material; Fattening pigs; Choice test; Tail biting; *Sus scrofa* domesticus

Highlights

- We measured pigs' preference for different plant-based enrichment materials.
- Structure matters: Pigs prefer pelletized materials over chopped and powdered ones.
- Size and flavour matters: Maize kernels in straw were most attractive for pigs.
- Structure, size and flavour should be considered by choosing enrichment material.
- Adding nutritive additives can further stimulate exploration and interest of pigs.

1 Introduction

Tail biting is a common problem in conventional pig production systems. The causes are multifactorial (Brunberg et al., 2016; Schrøder-Petersen and Simonsen, 2001). However, it is often assumed that one of the most important risk factors for the occurrence of tail biting is the lack of appropriate enrichment materials hampering the pigs from performing species-specific exploration and foraging behaviour, such as rooting, nosing, and chewing (EFSA, 2014; Špinka, 2017; Stolba and Wood-Gush, 1980; Wood-Gush and Vestergraad, 1989). Plant-based or non-plant-based materials are used as enrichment materials to facilitate exploration. Plant-based enrichment materials such as straw are often deemed incompatible with slurry systems. Therefore, farmers often provide durable, non-plant-based enrichment materials to pigs, e.g., metal chains or plastic items, to distract the animals and to lower the risk for the occurrence of tail biting. Furthermore, non-plant-based materials are often low cost and require lower time investments. However, these materials mostly have only short-term enrichment effects, as rearing, fattening and finishing pigs habituate relatively quickly to them (Scott et al., 2006, 2009). To achieve long-term enrichment effects that may be better suited to reducing the risk of tail biting, the respective enrichment materials probably need specific characteristics. It has been shown that growing and fattening pigs show high levels of exploration towards plant- or non-plant-based enrichment materials that are compound, changeable, manipulable, chewable, edible or odorous (Fraser et al., 1991; Jensen and Pedersen, 2007; Studnitz et al., 2007; Van de Perre et al., 2011; Van de Weerd et al., 2003). Most plant-based materials fulfil these specific requirements and are thus recommended as the most suitable enrichment materials for pigs.

When given a choice, finishing pigs prefer plant-based materials over non-plant-based materials (Scott et al., 2009). In a choice test, growing pigs preferred pens littered with peat, mushroom compost and sawdust compared to pens littered with sand, wood bark, straw, and non-littered concrete floor (Beattie et al., 1998). These results suggest that pigs favour textures similar to earth. This was supported by a study in which eighteen materials from six categories were examined in a choice test (Jensen et al., 2008).

Plant-based materials can be provided in different ways to pigs, which is closely related to the management of the stable. In existing conventional housings with fully slatted floors, long materials, such as hay or straw, can plug the slurry system once they have passed through a slatted floor. Thus, for reasons of practicability, smaller materials, which may be chopped or pelletized, should be used. These smaller materials also bear the advantage that they can be automatically dispensed into the pens. The attractiveness of plant-based materials for growing and finishing pigs can be further increased by using different nutritive additives (Jensen and Pedersen, 2007; Zwicker et al., 2013). Nutritive additives obviously increase the rooting behaviour of pigs by imitating natural conditions in which pigs root to find food and by enhancing the reward of rooting. The feed intake of pigs is influenced by the nutrient composition (Kyriazakis and Emmans, 1995; Whittemore et al., 2001), which affects the flavour and taste of the feed (Mizushige et al., 2007; Mori et al., 1991). This suggests that different nutritive additives may cause differences in the pigs' preference and thus in the time they spend exploring and ingesting it.

In our study, we further investigated two successive short-term choice tests: (i) which plant-based enrichment materials, differing in structure and flavour, do pigs prefer; and (ii) what kind of nutritive additives can be used to further increase the attractiveness of plant-based enrichment materials?

2 Methods

2.1 Animals

We used crossbred fattening pigs (German Piétrain x German Hybrid) that had not been tail docked as piglets. Each pig was familiar with daily human contact and ear tagged for individual identification.

In choice test 1, a total of 57 animals (29 females, 28 castrated males) were tested individually. At the time of the choice test (July 2017), the animals had an age of 21 weeks and weighed an average of 81.4 kg (±6.9 kg SD). No animals were familiar with any of the materials used in the first choice test prior to testing. In the second choice test, a total of 67 animals (38 females, 29 castrated males) were tested individually. At the time of the choice test (January 2018), the animals had an age of 18 weeks and an average weight of 66.1 kg (±12.2 kg SD). The animals had prior experience with chopped straw and, in addition, were fed squeezed oats as piglets (i.e., at the age of 1–28 days).

2.2 Housing and feeding

Animals were housed in a forced ventilation stable at the Bildungs- und Wissenszentrum Boxberg (LSZ), Germany. All pens had 15 m^2 floor space (5 m × 3 m) with fully slatted floors and were equipped with a sisal rope and a piece of wood hanging on metal chains. The animals had free access to water from four nipple drinkers and were fed *ad libitum* with pellet concentrate in two separate phases (with feed conversion at an average weight of 80 kg). Further details on the content in feed are provided in the electronic supplementary material. In the first choice test, the pigs were fed with feed of the second phase. In the second choice test, the pigs had not yet reached the average weight for feed change. Feed was provided with a single feeder (i.e., one feeder per pen).

In the first choice test, animals from a total of six pens (from two barns) with eight to eleven pigs per pen were used. In the second choice test, animals from a total of eight pens (from two barns) with seven to ten pigs per pen were used. In the second test, the pens in the rearing and fattening barns were additionally equipped with a round material dispenser in the middle of the pen, which was filled with different enrichment materials, i.e. chopped hay, chopped straw, straw pellets and lucerne pellets (Table 1). The materials were offered in alternating order, of which only straw was used as basic material in the choice test.

Table 1 Description of the enrichment materials tested in choice tests 1 and 2.

Material	Description	Dimension
Choice test 1		
Control (C)	Empty trough	
Chopped straw (CS)	Barley straw, chopped	length approximately 10 mm to 100 mm
Chopped hay (CH)	Hay of the first harvest, chopped	length approximately 10 mm to 100 mm
Powdered lignocellulose (LC)	Lignocellulose	powdered
Straw pellets (SP)	Barley straw, pressed in pellets	width approximately 8 mm, length approximately 5 mm to 15 mm
Lucerne pellets (LP)	Lucerne hay (*Medicago sativa*), pressed in pellets	width approximately 8 mm, length approximately 5 mm to 15 mm
Choice test 2		
Chopped straw (C)	Barley straw, chopped	length approximately 10 mm to 100 mm
Maize kernels (MK)	C + maize kernels, whole grain	width approximately 9 mm, length approximately 11 mm, height approximately 5 mm [a]
Black raisins (RA)	C + organic black raisins	width approximately 9 mm, length approximately 14 mm, height approximately 5 mm [a]
Grated carrots (GC)	C + fresh organic carrots, grated into slices immediately before use in the choice test	width and length approximately 20 mm, height approximately 1 mm [a]
Squeezed oats (SO)	C + oat, squeezed grain	width approximately 6 mm, length approximately 9 mm, height approximately 1 mm [a]
Wheat kernels (WK)	C + wheat kernels, whole grain	width approximately 4 mm, length approximately 7 mm, height approximately 3 mm [a]

[a] C (chopped straw dimensions) see above

2.3 Choice test

2.3.1 Arena

For the choice tests, an arena was installed inside each home pen of the respective pigs. The arena had an area of 126 cm × 103 cm (length x width) (Fig. 1). The walls of the arena were 97 cm high, and the door of the arena was 110 cm high. The lower part of the walls and of the door consisted of opaque plastic (62 cm high) and three horizontally mounted tubular metal bars above. Thus, the animals had visual, acoustic and olfactory contact with their pen-mates during the entire choice test but were not directly bothered by them. Furthermore, they did not have to leave their home pen. At the front end of the arena, there was an experimental trough (98.4 cm × 22.0 cm) with six identical chambers (22.0 cm × 16.4 cm) for the test materials. The content of the chambers was not visible to the pigs outside the arena due to the opaque plastic walls. A camera (Edimax IC-9110W, H.264 codec, Edimax Technology Co., Ltd, Taiwan) was installed above the experimental trough at a height of 2.0 m. The door at the back of the arena could be opened to let in and to release the respective test pig.

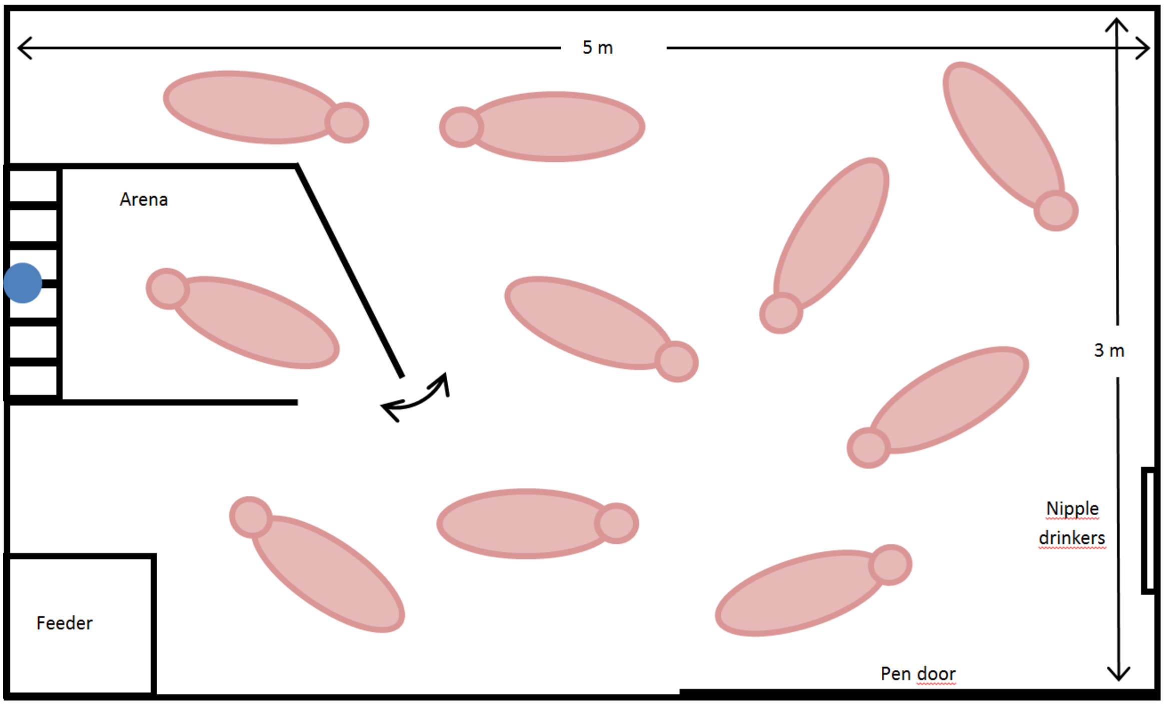

Fig. 1. Schematic drawing of the arena installed in the pen (5 m × 3 m) for the duration of the choice tests. Above the experimental trough with six chambers, a camera (blue filled circle) was attached at the ceiling.

2.3.2 Plant-based enrichment materials and nutritive additives

In the first choice test, plant-based enrichment materials differing in structure and flavour were provided simultaneously to the pigs in the chambers of the experimental trough. The order of the material was randomly altered between individuals. The six chambers were filled with either lucerne pellets (LP), straw pellets (SP), chopped hay (CH), chopped straw (CS), powdered lignocellulose (LC) or remained empty as a control (C) (Table 1).

In the second choice test, different nutritive additives to chopped straw were provided in the six chambers of the experimental trough. Therefore, chopped straw was mixed with either maize kernels (MK), raisins (RA), grated carrots (GC), squeezed oats (SO), wheat kernels (WK) or, as a control, only the chopped straw without any additive (C) was offered (Table 1). Again, the order of the nutritive additives in the chambers was altered randomly between individuals.

2.3.3 Testing procedure and data acquisition

Both choice tests were carried out according to the same procedure. The arena was built in a pig's home pen immediately before the respective choice test started (Fig. 1). In the first choice test, 0.5 l of the respective material was filled in each chamber of the experimental trough. In the second choice test, 0.5 l of chopped straw and 0.12 l of the respective nutritive additives were filled in each chamber. The door at the back of the arena was opened by the observer. Individual pigs entered the arena voluntarily or were gently guided by the observer. Animals that were not willing to cooperate and thus to enter the arena were not forced and thus not tested (n=1 in the first choice test, n=4 in the second choice test). Once all legs of a pig were inside the arena, the door was closed, the recording time started, and the observer left the room. The duration of recording was 150 s during which the test pigs could freely explore the different chambers of the experimental trough, and the entire test was video recorded for further analysis. After the brief choice test time, the observer re-entered the room, opened the door at the back of the arena and released the pig. The experimental trough was removed, and a new cleaned and prepared experimental trough was placed in the arena for the next voluntary test pig.

From the video recordings, we analysed the duration of exploration of the respective chambers (snout inside a chamber) by using Mangold INTERACT (version 17.0.2.13). Animals that did not explore the chambers during the test phase (n = 2 in each of the two choice tests) were not considered for further analysis.

2.4 Statistical anslysis

From these video recordings, the total duration each animal spent at each of the tested enrichment materials (including the controls) was calculated, and for each material, the relative duration at the material was calculated (duration at a specific material / total duration at the experimental trough).

The statistical analyses were performed using R 3.5.2 (R Core Team, 2018) and the package agricolae (De Mendiburu, 2019). The relative durations the pigs spent at the different choice options were compared with a Friedman test for both choice tests. In the case of a significant effect, we used Fisher´s least significant difference test for pairwise post hoc comparisons between the different choice options.

3 Results

3.1 First choice test – Materials differing in structure and flavour

The relative duration of the time the pigs spent exploring the different chambers of the experimental trough differed between the respective enrichment materials (Friedman test, n = 55, Chi^2 = 113.7, df = 5, P<0.001, Fig. 2a). Post hoc pairwise comparisons revealed that the animals spent significantly longer durations exploring lucerne pellets (LP) and straw pellets (SP) compared to the other three enrichment materials (i.e., chopped hay, chopped straw and lignocellulose) offered (see Fig. 2a). The shortest explored option was the control (i.e., the empty chamber).

On average, for 27.5 % (i.e., 41.4 s ± 19.81 SD) of the 150 s observation time, the pigs made a choice by putting their snout in one of the chambers of the experimental trough.

3.2 Second choice test – Different nutritive additives

The different nutritive additives significantly affected the relative duration that pigs spent exploring the chambers of the experimental trough (Friedman test, n = 65, $Chi^2 = 44.1$, df = 5, P<0.001, Fig. 2b). Post hoc pairwise comparisons revealed that maize kernels (MK) as a nutritive additive were explored significantly longer than grated carrots (GC), squeezed oats (SO), wheat kernels (WK) and the control (C) (Fig. 2b). The chambers including wheat kernels (WK) and control chambers (C) were explored significantly shorter than the other additives.

In the second choice test, the animals spent 40.7 % (i.e., 60.4 s ± 17.48 SD) of the observation time exploring the choice chambers.

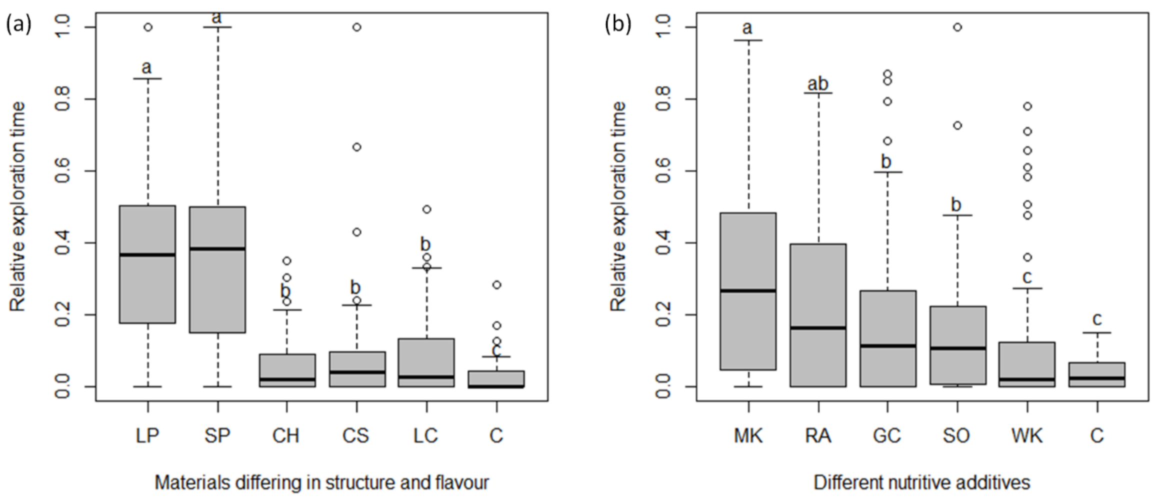

Fig. 2. (a) Boxplots of the relative duration the tested pigs explored materials differing in structure and flavour, i.e., lucerne pellets (LP), straw pellets (SP), chopped hay (CH), chopped straw (CS), lignocellulose (LC) or control (C), in choice test 1. (b) Boxplots of the relative duration the tested pigs spent with chopped straw that was enriched with different nutritive additives, i.e., maize kernels (MK), raisins (RA), grated carrots (GC), squeezed oats (SO), wheat kernels (WK) and control (C), in choice test 2. Different letters above the bars indicate significant differences.

4 Discussion

Our results show that in a short-term choice test, pigs prefer particular kinds of plant-based enrichment materials. In the first choice test focusing on the structure and flavour of the materials, we found that the pigs preferred lucerne pellets and straw pellets the most. In the second choice test examining the enriching nature of nutritive additives, we found that pigs prefer maize kernels as the most attractive nutritive additive.

The strong preference for lucerne pellets and straw pellets in contrast to chopped hay, chopped straw and lignocellulose is in line with earlier studies. After two days of offering, straw pellets were more often explored by finishing pigs in comparison to chopped straw, chopped *Miscanthus giganteus* and bark compost (Zwicker et al., 2013). Although pellets so far have not been well investigated as plant-based enrichment material for pigs, they meet some of the properties suggested to stimulate exploration: they are changeable, destructible, and manipulable, as they can be minced by the pigs into smaller pieces to eat them (Studnitz et al., 2007). However, it should be mentioned here, that in our study, we did not test larger structured materials, such as long straw, which is well examined as a plant-based enrichment material for reducing and preventing tail biting in pigs from weaning to finishing (Bolhuis et al., 2005; Fraser et al., 1991; Larsen et al., 2018; Van de Weerd et al., 2006). The reason is that such materials can bear practical problems for the slurry system and thus have a lower practicable impact for its use in existing commercial stables.

Feeding experiments have shown that weaned pigs prefer special kinds of structures, for example, pelletized feed to mashed diets, both composed of the same ingredients (Solà-Oriol et al., 2008). The results of these food preference tests suggest that pigs seem to make their choices i.a. based on the structure of the offered food or edible plant-based enrichment material. In line with the findings on the structural preferences of pigs, in our test, they explored the straw pellets longer than the chopped straw. However, even the less preferred materials were explored longer by the pigs compared to the empty control. This confirms that pigs clearly distinguish between different options for edible plant-based enrichment materials.

Thus, the results of the first choice test suggest that pelletized material seems to be a suitable possibility to provide plant-based enrichment material to pigs in housing systems with slatted floors and a slurry system. In contrast to long structured materials such as straw, the pellets decompose into small pieces when falling into the slurry. The relatively high production costs for pellets may be counterbalanced by technical options to automatically dispense pellets to the pens, which reduces labour costs compared to long structured materials offered manually.

In the second choice test, we focused on making plant-based enrichment material more attractive by nutritive additives. We used chopped straw as the basis, although it was not the most preferred material in the first choice test. The reason for this is that straw is inexpensive and often available on farms compared, for example, to pelletized plant-based materials. Thus, it may represent the most practicable possibility for farmers starting with new enrichment. In our choice test, maize kernels in chopped straw were most attractive to pigs, while wheat kernels and the control were least interesting. Additionally, Zwicker et al. (2013) found that maize kernels mixed with cut straw were more attractive for finishing pigs compared to cut straw without additives (Zwicker et al., 2013). The pigs did not spend much time with the squeezed oats. This may be because the pigs already had experience with oats before the test. Novel materials increase the interest of pigs more than familiar materials (Trickett et al., 2009; Van de Perre et al., 2011; Zonderland et al., 2003; Zwicker et al., 2013). The low interest for the control, i.e., the straw without any further nutritive additive, shows that most of the offered nutritive additives lead to a significant increase in exploration and thus are positively stimulating the pigs. The only exception was wheat kernels, which are smaller than maize kernels.

Taken together, our results and previous findings (Haskell et al., 1996; Jensen and Pedersen, 2007; Olsen et al., 2000; Studnitz et al., 2007; Young et al., 1994; Zwicker et al., 2013) support the idea that edible additives increase attractiveness of rootable plant-based enrichment materials by stimulating both exploration and foraging. Complex enrichment materials with different components are highly recommended for pigs (Jensen and Pedersen, 2007; Olsen et al., 2000; Studnitz et al., 2007). Holm et al. (2008) found in a direct comparison that *ad libitum* fed pigs prefer enrichment material that is rootable and edible (sand with carrots) or only edible (carrots) over exclusive rootable (sand) material. These findings confirm the preference of pigs to explore enrichment materials with food rewards. Nevertheless, it is assumed that pigs explore their environment not only to find food, but also because of intrinsic motivational reasons (Day et al., 1995), what underpins the importance of access to suitable enrichment materials adapted to the pigs and their housing systems.

Interestingly, in both choice tests, the pigs explored the materials that were larger/thicker in size longer compared with the smaller/thinner materials. In the first choice test, pellets were preferred compared to chopped and powdered material. In the second choice test, maize kernels were preferred compared to grated carrots, squeezed oats and wheat kernels, as well as grated carrots and squeezed oats compared to wheat kernels (Table 1). Larger materials may be better suited for manipulation and rooting by pigs. These findings are confirmed by a study, which found piglets to prefer feed pellets with a diameter of 12 mm to pellets with a diameter of 2 mm (Van den Brand et al., 2014). Furthermore, pigs prefer fodder beets to roughage when the most complex whole crop silage (of oats, vetch and lupine) was omitted (Olsen et al., 2000). Otherwise, the roughage with the most components was preferred (Olsen et al., 2000). Apart from the structure, the materials offered in our choice tests differ in their nutrient composition, which influences both the palatability (Mizushige et al., 2007; Mori et al., 1991), the feed intake (Kyriazakis and Emmans, 1995; Solà-Oriol et al., 2008, 2011; Whittemore et al., 2001) and probably also the pleasure of consumption (Figueroa et al., 2019) of pigs. In a previous study cut straw with maize was preferred to cut straw, straw in a rack and, a compressed straw block (Zwicker et al., 2013). Nevertheless, in a second test with pellets, chopped straw, chopped *Miscanthus giganteus* and bark compost, the pellets as biggest material in size were preferred (Zwicker et al., 2013). Also complexity, texture, smell (Olsen et al., 2000) and taste (Figueroa et al., 2019; Olsen et al., 2000) affect the time pigs manipulate and consume materials.

Surprisingly, the durations of exploration differed between the two choice tests. In the first choice test, pigs only spent on average 27.5 % of the test time exploring the chambers of the experimental trough, whereas in the second choice test, they explored the chambers on average 40.7 % of the test time. These differences may result from the more attractive materials offered in choice test 2, i.e., a plant-based material plus a nutritive additive. This difference is even more remarkable as the pigs in the second choice test had already been exposed to chopped straw (the basic material offered in the choice test) and squeezed oats in their normal housing condition. An alternative explanation might be the different ages of the tested pigs. Older pigs spent less time manipulating straw offered on the solid floor of pens compared to younger pigs (Jensen et al., 2015). However, in that study the materials were continuously offered and behaviour of pigs was observed twice, in young (40 kg) and old (80 kg) pigs. Thus, the lower use in older pigs may have resulted from habituation rather than from age of pigs. In our short-term choice tests, the difference in age (21 weeks in the first choice test and 18 weeks in the second choice test) was quite small. Irrespective of the differences in the duration, the amount of exploration time was quite low, i.e., the pigs spent less than half of their time in the arena exploring the materials. However, not only the materials but also the arena, which they also explored, were new for the animals.

In both choice tests, we tested short-term preferences. Further studies are required to examine the long-term attractiveness of plant-based material and nutritive additives and how attractiveness can be maintained over longer periods of time. It has been shown that rearing, fattening and finishing pigs lose their interest in enrichment materials when they are offered for a long time (Trickett et al., 2009; Van de Perre et al., 2011; Zonderland et al., 2003; Zwicker et al., 2013). The changes of exploration behaviour over time depends on the given materials (Trickett et al., 2009; Zwicker et al., 2013), the order in which different materials were given (Trickett et al., 2009; Zwicker et al., 2013) and the feeding regime (Zwicker et al., 2013). Some studies showed that materials that were highly explored in short-term were still quite attractive over long-term (Trickett et al., 2009; Zonderland et al., 2003; Zwicker et al., 2013). Thus, possibilities to maintain attractiveness are, for example, to use materials preferred by the pigs, to change the offered enrichment materials from time to time or to change the nutritive additives at certain intervals. With the knowledge about the animals´ preference for enrichment materials, future studies are required that aim to find solutions to provide these materials in a way that they remain attractive and available for a long time especially in stables with slatted floors. One solution might be to use high-adjustable material dispensers with a rooting area that offer enough space for several pigs and can be filled with different structured materials both automatically or by hand.

Our two choice tests with pigs revealed insights about preferences for plant-based enrichment materials differing in structure, flavour, and nutritive additives. The result of our first choice test suggests that it is important to consider the structure and size of enrichment materials, as well as the flavour. Pelletized materials, such as straw pellets, were most attractive to pigs in our test. However, pellets are the most expensive materials. As suggested by the result of our second choice test, even less attractive (but less expensive) material can be made much more attractive by nutritive additives, such as maize kernels. With our choice tests, we can give a recommendation for the use of plant-based enrichment materials, which are preferred by pigs and can be used in already existing stables with slatted floors. However, alternative housing systems and management tools, where straw can be used without posing a risk for the slurry system, exist and have to be considered to further improve welfare in pigs.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Beattie, V.E., Walker, N., Sneddon, I.A., 1998. Preference testing of substrates by growing pigs. Anim. Welfare 7, 27–34.

Bolhuis, J.E., Schouten, W.G.P., Schrama, J.W., Wiegant, V.M., 2005. Behavioural development of pigs with different coping characteristics in barren and substrate-enriched housing conditions. Appl. Anim. Behav. Sci. 93 (3-4), 213–228. https://doi.org/10.1016/j.applanim.2005.01.006.

Brunberg, E.I., Rodenburg, T.B., Rydhmer, L., Kjaer, J.B., Jensen, P., Keeling, L.J., 2016. Omnivores going astray: a review and new synthesis of abnormal behavior in pigs and laying hens. Front. Vet. Sci. 3, 57. https://doi.org/10.3389/fvets.2016.00057.

Day, J.E.L., Kyriazakis, I., Lawrence, A.B., 1995. The effect of food deprivation on the expression of foraging and exploratory behaviour in the growing pig. Appl. Anim. Behav. Sci. 42, 193–206.

De Mendiburu, F., 2019. Agricolae: Statistical Procedures for Agricultural Research. R Package Version 1.3-0. Retrieved from. https://CRAN.R-project.org/package=agricolae.

EFSA, E.F.S.A., 2014. Scientific opinion concerning a multifactorial approach on the use of animal and non-animal based measures to access the welfare of pigs. EFSA J. 611, 1–13.

Figueroa, J., Frias, D., Sola-Oriol, D., Tadich, T., Franco-Rossello, R., Nunez, V., Dwyer, D.M., 2019. Palatability in pigs, the pleasure of consumption. J. Anim. Sci. 97 (5), 2165–2174. https://doi.org/10.1093/jas/skz085.

Fraser, D., Phillips, P.A., Thompson, B.K., Tennessen, T., 1991. Effect of straw on the behaviour of growing pigs. Appl. Anim. Behav. Sci. 30, 307–318.

Haskell, M.J., Terlouw, E.M.C., Lawrance, A.B., Erhard, H.W., 1996. The relationship between food consumption and persistence of post-feeding foraging behaviour in sows. Appl. Anim. Behav. Sci. 48, 249–262.

Holm, L., Jensen, M.B., Pedersen, L.J., Ladewig, J., 2008. The importance of a food feedback in rooting materials for pigs measured by double demand curves with and without a common scaling factor. Appl. Anim. Behav. Sci. 111 (1-2), 68–84. https://doi.org/10.1016/j.applanim.2007.05.013.

Jensen, M.B., Pedersen, L.J., 2007. The value assigned to six different rooting materials by growing pigs. Appl. Anim. Behav. Sci. 108 (1-2), 31–44. https://doi.org/10.1016/j.applanim.2006.10.014.

Jensen, M.B., Studnitz, M., Halekoh, U., Pedersen, L.J., Jørgensen, E., 2008. Pigs' preferences for rooting materials measured in a three-choice maze-test. Appl. Anim. Behav. Sci. 112 (3-4), 270–283. https://doi.org/10.1016/j.applanim.2007.07.012.

Jensen, M.B., Herskin, M.S., Forkman, B., Pedersen, L.J., 2015. Effect of increasing amounts of straw on pigs' explorative behaviour. Appl. Anim. Behav. Sci. 171, 58–63. https://doi.org/10.1016/j.applanim.2015.08.035.

Kyriazakis, I., Emmans, G.C., 1995. The voluntary feed intake of pigs given feeds based on wheat bran, dried citrus pulp and grass meal, in relation to measurements of feed bulk. Br. J. Nutr. 73 (2), 191–207. https://doi.org/10.1079/bjn19950023.

Larsen, M.L.V., Andersen, H.M., Pedersen, L.J., 2018. Which is the most preventive measure against tail damage in finisher pigs: tail docking, straw provision or lowered stocking density? Animal 12 (6), 1260–1267. https://doi.org/10.1017/S175173111700249X.

Mizushige, T., Inoue, K., Fushiki, T., 2007. Why is fat so tasty? Chemical reception of fatty acid on the tongue. J. Nutr. Sci. Vitaminol. 53, 1–4.

Mori, M., Kawada, T., Ono, T., Torii, K., 1991. Taste preference and protein nutrition and L-amino acid homeostasis in male sprague-dawley rats. Physiol. Bahav. 49, 987–995.

Olsen, A.W., Vestergaard, E.M., Dybkjaer, L., 2000. Roughage as additional rooting substrates for pigs. Anim. Sci. 70, 541–545.

R Core Team, 2018. R: A Language and Environment for Statistical Computing. Retrieved from. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Schrøder-Petersen, D.L., Simonsen, H.B., 2001. Tail biting in pigs. Vet. J. 162 (3), 196–210. https://doi.org/10.1053/tvjl.2001.0605.

Scott, K., Taylor, L., Gill, B.P., Edwards, S.A., 2006. Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems. Appl. Anim. Behav. Sci. 99 (3-4), 222–229. https://doi.org/10.1016/j.applanim.2005.10.013.

Scott, K., Taylor, L., Gill, B.P., Edwards, S.A., 2009. Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems 3. Hanging toy versus rootable toy of the same material. Appl. Anim. Behav. Sci. 116 (2–4), 186–190. https://doi.org/10.1016/j.applanim.2008.07.002.

Solà-Oriol, D., Roura, E., Torrallardona, D., 2008. Feed preference in pigs: effect of cereal sources at different inclusion rates. J. Anim. Sci. 87 (2), 562–570. https://doi.org/10.2527/jas.2008-0949.

Solà-Oriol, D., Roura, E., Torrallardona, D., 2011. Feed preference in pigs: effect of selected protein, fat, and fiber sources at different inclusion rates. J. Anim. Sci. 89 (10), 3219–3227. https://doi.org/10.2527/jas.2011-3885.

Špinka, M., 2017. Advances in Pig Welfare. Woodhead Publishing.

Stolba, A., Wood-Gush, D.G.M., 1980. Arousal and exploration in growing pigs in different environments. Appl. Anim. Ethol. 6 (4), 382–383.

Studnitz, M., Jensen, M.B., Pedersen, L.J., 2007. Why do pigs root and in what will they root? Appl. Anim. Behav. Sci. 107 (3–4), 183–197. https://doi.org/10.1016/j.applanim.2006.11.013.

Trickett, S.L., Guy, J.H., Edwards, S.A., 2009. The role of novelty in environmental enrichment for the weaned pig. Appl. Anim. Behav. Sci. 116 (1), 45–51. https://doi.org/10.1016/j.applanim.2008.07.007.

Van de Perre, V., Driessen, B., Van Thielen, J., Verbeke, G., Geers, R., 2011. Comparison of pig behaviour when given a sequence of enrichment objects or a chain continuously. Anim. Welfare 20, 641–649.

Van de Weerd, H.A., Docking, C.M., Day, J.E.L., Avery, P.J., Edwards, S.A., 2003. A systematic approach towards developing environmental enrichment for pigs. Appl. Anim. Behav. Sci. 84 (2), 101–118. https://doi.org/10.1016/s0168-1591(03)00150-3.

Van de Weerd, H.A., Docking, C.M., Day, J.E.L., Breuer, K., Edwards, S.A., 2006. Effects of species-relevant environmental enrichment on the behaviour and productivity of finishing pigs. Appl. Anim. Behav. Sci. 99 (3-4), 230–247. https://doi.org/10.1016/j.applanim.2005.10.014.

Van den Brand, H., Wamsteeker, D., Oostindjer, M., 2014. Effects of pellet diameter during and after lactation on feed intake of piglets pre- and postweaning. J. Anim. Sci. 92, 4145–4153. https://doi.org/10.2527/jas2014-7408.

Whittemore, E.C., Emmans, G.C., Tolkamp, B., Kyriazakis, I., 2001. Tests of two theories of food intake using growing pigs - 2. The effect of a period of reduced growth rate on the subsequent intake of foods of different bulk content. Anim. Sci. 72, 361–373.

Wood-Gush, D.G.M., Vestergraad, K., 1989. Exploratory behavior and the welfare of intensively kept animals. J. Agric. Ethics 2, 161–169.

Young, R.J., Carruthers, J., Lawrence, A.B., 1994. The effect of a foraging device (the Edinburgh football) on the behaviour of pigs. Appl. Anim. Behav. Sci. 39, 237–247.

Zonderland, J.J., Vermeer, H.M., Vereijken, P.F.G., Spoolder, H.A.M., 2003. Measuring a pig´s preference for suspended toys by using an automated recording technique. Agric. Eng. Int Manuscript BC 01010.

Zwicker, B., Gygax, L., Wechsler, B., Weber, R., 2013. Short- and long-term effects of eight enrichment materials on the behaviour of finishing pigs fed ad libitum or restrictively. Appl. Anim. Behav. Sci. 144 (1-2), 31–38. https://doi.org/10.1016/j.applanim.2012.11.007.

3. Effect of plant-based enrichment materials on exploration in rearing and fattening pigs (*Sus scrofa* domesticus)

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Abstract

When pigs cannot perform innate species-specific behaviours (e.g. rooting or chewing), behavioural disorders, like tail biting, can occur. However, it seems that various enrichment materials enhance the pigs to perform exploration behaviour and therefore can help to reduce and prevent tail biting. The aim of this study was to identify such highly explored plant-based enrichment material for undocked pigs during rearing and fattening. Furthermore, we evaluated the impact of the offered enrichment materials on tail length and injuries. Therefore, we continuously recorded the individuals' exploration durations in 20 groups by using an ultra-high-frequency radio-frequency identification system, installed at material dispensers. Lucerne pellets (LP), straw pellets (SP), chopped hay (CH) and chopped straw (CS) were offered in a systematically alternating order for two-week sections, respectively. At weaning and at days of material change (i.e. eight times in total), animals were weighed and scored for tail length losses and tail injuries. For analysis, the changes in tail length compared to the previous section were calculated as Δ-tail-length losses. Our study revealed that the different offered plant-based enrichment materials affected the duration of exploration behaviour (e.g. rooting, nosing or chewing) during rearing (4 groups, LME, $p < 0.0001$) and fattening (16 groups, LME, $p < 0.0001$). In piglets, exploration duration was higher for pelletized materials (LP, SP) than for chopped materials. Fattening pigs explored materials of hay (CH) more often compared to straw-based materials (CS, SP). Daily weight gains of rearing pigs were affected by the type of enrichment material offered in the respective section (LME, $p < 0.0001$). The highest daily weight gains were achieved when CH was offered. Exploration duration during rearing and fattening was affected by section (LME, both $p < 0.0001$ for rearing and fattening). Exploration duration during rearing was highest in section 4 and continuously increased from the first section to the last section during fattening. During rearing, the plant-based enrichment materials affected tail injuries (GLMM, $p < 0.0001$) and Δ-tail-length losses tended to be affected (GLMM, $p = 0.057$). Fewest tail injuries and Δ-tail-length losses occurred when SP was offered. During fattening, section affected tail injuries (GLMM, $p = 0.01$). Most injuries occurred during sections 1 and 2. Our results show that pigs of different ages seem to prefer different plant-based enrichment materials. High exploration durations do not

necessarily maintain intact tails if material is changed biweekly. However, exploration durations can be maintained at high levels from rearing through fattening period by regularly alternating the provided plant-based enrichment materials.

Keywords: pellets, chopped material, UHF RFID, continuous monitoring, weight gain

Highlights

- We aim to identify plant-based materials that increase exploration and reduce tail damages in pigs.
- During rearing, lucerne & straw pellets were most explored and thus most attractive.
- During fattening, preferences changed and most exploration was guided to chopped hay.
- Attractiveness of plant-based material is depending from age, nutrition or flavour.
- High exploration durations at any material do not necessarily maintain intact tails.

1. Introduction

The living conditions of commercial swine are very different from that of free-living wild swine, which have many possibilities to perform species-specific behaviours. Since domesticated pigs still have the need to perform species-specific behaviours (Fraser, 1983; Stolba and Wood-Gush, 1984, 1989), the prevalence of behavioural disorders can be enhanced if the housing environment does not provide the respective resources to perform highly motivated behaviours. A major behavioural disorder in domestic pigs is the occurrence of tail biting (e.g. Beattie et al., 1995; Bolhuis et al., 2005; Fraser et al., 1991; Petersen et al., 1995), which mainly occur during rearing (Blackshaw, 1981; Schrøder-Petersen et al., 2010; Veit et al., 2016) and can be reduced but not fully prevented in pigs by docked tails (Hunter et al., 2001; Larsen et al., 2018; Li et al., 2017). This is why most of the pigs in the European Union have docked tails, although routine tail docking is legally prohibited by law (Anonymous, 2008). Tail biting is assumed to be strongly related to sensory stimulation and the motivation to forage (Wood-Gush and Vestergaard, 1989). Despite this potential underlying motivation, many other factors, like e.g. genetic, growth, health, feed, space availability or climate, can contribute to the prevalence of tail biting (Brunberg et al., 2016; Schrøder-Petersen and Simonsen, 2001). Injured tails from biting can lead to health problems in pigs and can also cause economic losses (Špinka, 2018), due to reduced daily weight gains during fattening (Marques et al., 2012; Sinisalo et al., 2012) or even death of pigs. Provision of suitable enrichment material, enabling the pigs to explore, to forage and to root, is assumed to reduce the prevalence of tail biting (EFSA, 2014; Hunter et al., 2001; Larsen et al., 2018; Špinka, 2018). However, specifications for providing enrichment materials for pigs is regulated differently depending on the region (van de Weerd and Ison, 2019). In the European Union, provision of enrichment material is defined by the Council Directive 2008/120/EC (2008). To sustainably stimulate explorative behaviour in pigs, enrichment material must fulfil certain characteristics. It should be changeable, manipulable, chewable, edible and/or odorous (Fraser et al., 1991; Jensen and Pedersen, 2007; Studnitz et al., 2007; Van de Perre et al., 2011; Van de Weerd et al., 2003). Plant-based materials can very well match all of these requirements. Especially straw is well known to have positive effects on the prevalence of behaviour problems such as tail biting from weaning to finishing pigs (Bolhuis et al., 2005; Fraser et al., 1991; Hunter et al., 2001; Peeters et al., 2006; Van de Weerd et al., 2006). However, in commercial housing systems with slatted floors some plant-based enrichment materials can cause technical problems with the slurry system. As 87% of the weaning pigs and 91% of the growing and finishing pigs in the European Union are kept on slatted floors (EFSA, 2007), most pigs receive durable non-plant-based enrichment materials to avoid technical problems and to lower time investments and costs on the farms. However, pigs tend to habituate to durable enrichment materials faster than to straw (Scott et al., 2006). In common pig housings with fully slatted floor pelletized plant-based enrichment material may help to solve this conflict of interest between animals' requirements and farmers' technical prerequisites as they may fulfil most or even all of the characteristics for sustainably interesting enrichment material and – due to its fine structure, they can disperse in the slurry system. If pigs are given the choice, they prefer pelletized plant-based materials over chopped and powdered materials (Kauselmann et al., 2020a; Zwicker et al., 2013) and this may be a suitable alternative to non-pelletized plant-based materials, like straw.

In the present long-term study, we investigated in undocked, commercially housed rearing and fattening pigs how different structured plant-based enrichment materials affect exploration durations, measured as time individual pigs stayed at the dispenser of enrichment material. Furthermore, we explored potential relationships between the type of enrichment material offered, recorded tail length losses and injuries. We hypothesized that the offered enrichment materials specifically affect the duration of exploration behaviour in pigs, what in turn may have an impact on the occurrence of abnormal behaviour, like tail biting.

2. Methods

2.1 Animals and housing

For the study we used the pigs of two successive trials that included both the rearing and fattening period, respectively. Due to technical modifications within the first rearing period, these data were not included in the analysis. However, piglets from this first rearing period received the same treatment as piglets from the second trial. Thus, we used a total of 192 crossbred female and castrated male pigs (German Piétrain x German Hybrid; trial 1: 42 females and 54 castrated males; trial 2: 43 females and 53 castrated males). Pigs of both sexes were randomly allocated to the pens. The study was conducted from September 2017 to March 2018 at the Bildungs- und Wissenszentrum Boxberg (LSZ), Germany. The pigs were housed in forced ventilated barns, had not been tail docked and were familiar to daily human contact. The day before weaning (day 28), piglets were weighed and ear tagged with two identical numbered ultra-high-frequency radio-frequency identification (UHF RFID) tags (MS Tag Round UHF, MS Schippers, Netherlands) with a diameter of 3 cm, one per ear for individual animal identification. At an age of 28 days the piglets (7.8 kg ± 2.0 kg S.D.) were weaned and transferred from the farrowing pens to the rearing barn where they were randomly allocated to four identical rearing pens with 15 m^2 (5m × 3m) floor space (0.6 m^2 per animal; Fig. 1b) for 24 piglets each. The rearing pens were continuously numbered (4 rearing penIDs in total, which were considered as random nesting factors in the analysis). Pens had 7.5 m^2 slatted plastic floors with 38.5% perforation, 3.0 m^2 slatted concrete floors with 17.0% perforation and 4.5 m^2 partly slatted concrete floors with 7.0% perforation under a heated covering. Piglets had *ad libitum* access to water from two nipple drinkers and two drinking bowls (Suevia, 92 R) per pen and were fed *ad libitum* with mashed food from an automatic mash feeder (2.4:1 animal : feeding place ratio). After two weeks of rearing, food composition was altered (for detailed information see electronic supplementary Table 1). Since the farm participates in the German volunteer program to improve welfare “Initiative Tierwohl” (ITW), all pens have been equipped with additional enrichment material at any time, i.e. two sisal ropes, a piece of wood hanging on metal chains and a scrubber bar, according to the respective ITW-program specifications. After seven weeks of rearing, animals weighed 30.3 kg (± 6.6 kg S.D.) on average and were moved to the fattening pens. As mentioned above, exploration durations were recorded for one trial (96 pigs) during rearing. However, pigs of both trials received the same treatment during rearing and were used in fattening. Thus, in both trials, pigs of the four rearing groups were split randomly in two halves and the resulting eight groups of 12 pigs, respectively, were allocated to the fattening pens, i.e. pigs remained in groups with familiar peers. Thereby all pigs within a given group received the same treatment prior to fattening.

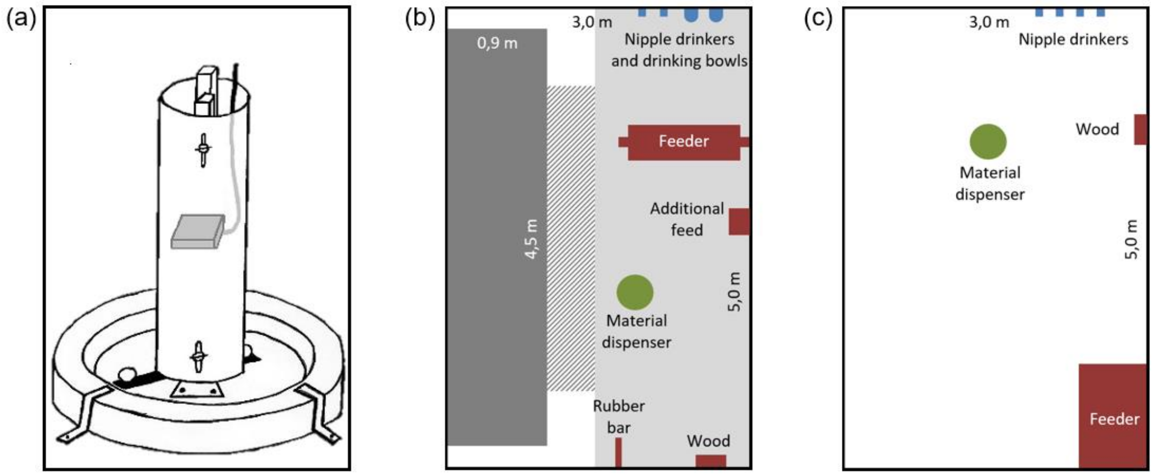

Fig. 1. Schematic drawing of a (a) material dispenser with UHF RFID antenna (grey), (b) rearing pen and (c) fattening pen with partly slatted concrete floor with 7% perforation (lined), slatted concrete floor with 17% perforation (white), slatted plastic floor with 38.5% perforation (light grey) and heated covering (dark grey).

Fattening pens had 15 m^2 (5 m × 3 m) floor space resulting in 1.1 m^2 per animal (Fig. 1c). The fattening pens were continuously numbered (16 fattening penIDs in total, which were considered in the respective analyses as random nesting factors). The floor of pens had concrete slats with 17% perforation. Pigs had free access to water from four nipple drinkers in each pen and were fed *ad libitum* with pelleted concentrate from a single feeder. Food composition changed at an average weight of 80 kg, i.e. at an age of about 18 weeks (after about seven weeks of fattening; for detailed information about food composition see the electronic supplementary Table 1). As explained above, the fattening pens had to be equipped with additional enrichment materials at any time, i.e. two sisal ropes and a piece of wood hanging on metal chains, due to the participation in the above mentioned ITW program. Data collection stopped after eight weeks of fattening. At this time, pigs of trial 1 weighed 92.6 kg (± 10.6 kg S.D.) at an age of 20 weeks. This first trial started in the second week of fattening because in the first week we validated the RFID data based on video recordings (see below). Pigs of trial 2 were 19 weeks old and weighed 78.5 kg (± 13.7 kg S.D.).

2.2. Plant-based enrichment material and data collection

During the seven weeks of rearing and the eight weeks of fattening, four different enrichment materials were successively offered in a systematically altering biweekly order (two-week sections). From now on, the two-week sections in which a material was offered will be referred to as “section”. Thus, resulting in four sections in rearing and fattening, while the fourth section in the rearing period lasted one week. Sections, i.e. when enrichment materials were altered, were considered as repeated measurements. Thereby, in each of the four rearing pens a different material was offered at the same time. During fattening, each of the different materials were simultaneously provided in two of eight pens. As materials we used lucerne pellets (LP), straw pellets (SP), chopped hay (CH) or chopped straw (CS) (Table 1). All materials were offered by identical material dispensers (described below). We took exploration duration of individual pigs to the different enrichment materials into account for the analysis, with section as repeated measure and to take the non-independency of these repeated measures PenID was considered as random factor (see details in the statistical methods). At the beginning of rearing and fattening, as well as on the days of material change (every section, i.e. two weeks), pigs were individually weighted. Furthermore, on days of material change also the tail status (injuries and losses of tail length) of each pig was recorded according to the “Deutscher Schweine Boniturschlüssel” (DSBS). Accordingly, tail injuries were recorded in four categories: (0) no injuries, (1) superficial perforation of the skin, punctually or in the form of a line, (2) deeper perforation of the skin, maximum as large as the diameter of the tail at the respective point, and (3) deeper perforation of the skin, larger than the diameter of the tail at the respective point. Tail length was recorded in five categories: (0) full/natural length, i.e. tails with intact and complete tassel; as tails grow initially with age, the length losses of more than one-third/two-thirds were assessed with reference to the length of currently existing intact tails of the penmates. (1) length loss up to one-third, i.e. also minimal losses at the tassel were included, (2) length loss up to two-thirds, (3) length loss more than two-thirds and (4) total loss with a maximum of 1 cm leftover for piglets in the rearing and 2 cm leftover for pigs in the fattening. However, it should be noted that in category 1 often only losses of a small part of the tail tip were observed and category 4 was never recorded.

Table 1. Description and dimension of the enrichment materials tested.

Plant-based enrichment material	Description	Dimension
Chopped straw (CS)	Barley straw, chopped	length about 10 mm to 100 mm
Chopped hay (CH)	Hay of the first harvest, chopped	length about 10 mm to 100 mm
Straw pellets (SP)	Barley straw, pressed in pellets	width about 8 mm, length about 5 mm to 15 mm
Lucerne pellets (LP)	Lucerne hay (*Medicago sativa*), pressed in pellets	width about 8 mm, length about 5 mm to 15 mm

All rearing and fattening pens were equipped with identical round material dispensers (Fig. 1a-c) with a 100 cm high storage tube and a diameter of 25 cm through which plant-based enrichment materials were offered. Depending on the material, the storage tube of the material dispenser was slightly adjusted, i.e. the gap on the ground of the dispenser had a width of 1.5 cm when lucerne pellets and straw pellets were offered and 2.4 cm when chopped straw and chopped hay were offered. Between the storage tube and the mat underneath a 25 cm long, 5 cm wide and 0.8 cm thick movable bolt of plastic with a ball (diameter 5.5 cm) at both ends was installed (Fig. 1a and Supplementary Fig. 1). Thus, the animals had to manipulate the ground of the dispenser by moving the bolt in order to get access to the material. The storage tube of the round material dispensers in the rearing and fattening pens were manually-filled regularly so that the pigs always had material to their disposal according to the study plan. A 10 cm high cement ring with an inner diameter of 63 cm was used to create a rooting area around the storage tube on the floor. The cement ring and the mat underneath prevent the material from falling through the slatted floor. To calculate dispenser place ratios, recommendations for feeding places were used (18 cm for rearing pigs and 33 cm for fattening pigs) (Averberg et al., 2018). Thus, animal:dispenser place ratio was 1.7:1 in the rearing pens and 1.5:1 in the fattening pens. Inside the storage tube of each material dispenser, a dust- and waterproof UHF RFID antenna (Kathrein MiRa ETSI) was installed horizontally at a height of 50 cm above the floor in order to read the individual RFID ear tags from the pigs next to the material dispenser and, thus, probably were using the material. The durations of animal visits were recorded continuously (24 h a day) from rearing to fattening. Further details about the study plan and quantity of used enrichment materials were given in the electronic supplementary material (supplementary table 2 and 3).

Housing and management of the animals was in compliance with German legislation (TierSchNutztV, 2017) for farm animals. As described above, space allowance and access to offered enrichment material exceeded the legal requirements. All animals were visually inspected during daily routines. The data acquisition was performed in accordance with the laws of Germany at that time and did not require specific approval. The data was recorded on a licensed farm that produces, rears, fattens and markets pigs (VVVO-Number: 08 128 0140 538). Pigs from the study were marketed after the study.

2.3. Validity of the used RFID system for measuring exploration behaviour

Prior to the study, we tested the conformity between the RFID data and video recordings of the exploration of the material dispensers by using different antenna output powers according to Adrion et al. (2018). Videos of pigs exploring at the material dispenser were evaluated by using the software INTERACT (version 17.0.2.13, Mangold International GmbH, Germany). On videos, the inner area of the cement ring was defined as the area where exploration with the respective material appeared. Thus, exploration was defined as, when the snout of a pig protruded over the inner edge of the cement ring. For validation of the RFID measured exploration we distinguished four categories considering Maselyne et al. (2016): A pig was recorded in the exploration area via video and RFID (RP). A pig was recorded in the exploration area via video but not recorded by RFID (WN). A pig was recorded outside the exploration area via video and by RFID (RN). A pig was recorded outside the exploration area via video and inside the exploration area by RFID (WP). To calculate the sensitivity and specifity, the following formulae were used:

$$Sensitivity\ (\%) = \frac{\text{RP}}{\text{RP + WN}} * 100 \quad (1)$$

$$Specifity\ (\%) = \frac{\text{RN}}{\text{RN + WP}} * 100 \quad (2)$$

Considering rearing and fattening, sensitivity and specifity were highest with an antenna output power of 22.4 dBm. Best conformity between the RFID data and video recordings were achieved when RFID recordings with a maximum pause time of 30 s between two readings of a pig were summarized. With this setting, we reached a sensitivity (1) of 70.7% for dispensers in the rearing pens and of 79.3% in the fattening pens. The calculated specifity (2) was 99.4% for the material dispensers in the rearing pens and 99.5% in the fattening pens (see the electronic supplementary material for further details).

Using a software (Phenobyte GmbH & Co. KG., Germany) each animal was assigned to an identification number, the tag number, its pen and the respective antenna. Whenever the antenna perceived an individual UHF RFID tag, the reader collected the date and time of the beginning and the end of the event. These recordings were done continuously throughout the entire rearing and fattening periods. All collected data were transmitted to a database. Short breaks of recorded data were counted as exploration time; in case a certain recording of an UHF RFID tag was interrupted for less than 30 s (maximum pause time) this recording still was counted as one visit at the dispenser. Thus, readings that were missing due to transponders covered by pen mates could be bridged.

2.4. Statistical analysis

We used average weekly individual pigs' exploration behaviour for further analysis, i.e. data from 96 piglets during rearing (as described above, in rearing only trial 1 was considered) and, after a total of three losses due to illness during rearing period, during fattening data from 95 pigs (42 females and 53 castrated males) from trial 1 and data from 94 pigs (42 females and 52 castrated males) from trial 2 were included in the analyses. All animals were continuously numbered and this number was considered as animalID in the models (see below). The pens in rearing and fattening were also continuously numbered (penID) to be included in the models (see below).

We checked whether or not sex of the pigs had an effect on tail biting as there are contradictory findings (e.g. Brunberg et al., 2011; Hakansson et al., 2020; Zonderland et al., 2010, 2011). We found no effect of sex on tail length in rearing

(p = 0.78) or fattening (p = 0.94) and thus do not consider that additional factor in the analysis.

For analysis of the exploration duration pigs spent with the material dispenser we calculated the exploration duration for each individual pig in the following scale [duration of exploration / week] for each section. Data were separately analyzed for the rearing and the fattening period in a repeated measures (sections, i.e. 2-week-intervals) mixed model, respectively. We show the detailed hierarchical model structure for the rearing and fattening in the electronic supplement (Supplementary Fig. 2 and 3). The data were log (log (x+1)) transformed in order to achieve a normal distribution of the residuals, checked by visual inspection of the Q-Q plot. We used a linear mixed effect model (LME) with the explanatory variables (i) type of plant-based enrichment material provided in the material dispenser (4-level factor), (ii) sectionID to account for repetitions, (iii) body weight measured at the end of the respective section and (iv) all two-way interactions. As multiple exploration measures from the pigs were not independent over repeated measures and between penmates, we considered animalID within penID as nesting random factors. In case of a significant effect of enrichment material on pigs' exploration durations, we calculated post hoc pairwise t-tests, respectively.

The daily weight gain for a respective two-week section was calculated for each pig and was analyzed separately for rearing and fattening. We respectively used a LME with the explanatory variables (i) type of plant-based enrichment material provided in the material dispenser (4- level factor), (ii) sectionID and (iii) the two-way interactions. Random factors were again animalID and penID. Post hoc pairwise comparisons (t-test) were calculated for the factor section, in case that significant effects appeared.

To assign the length losses of the tails to the enrichment material offered during each section, we calculated Δ-tail length for each pig and section. For example if one pig had a tail length of category 0 at the beginning of section 1 and of category 1 after section 1, Δ-tail length was 1 (0-1) for section 1. If the same pig still had a tail length of category 1 after section 2 and a tail length of category 2 after section 3, Δ-tail length was 0 (1-1) for section 2 and 1 (2-1) for section 3. The scores for the Δ-tail length as well as the score of skin injuries at the tails were analyzed during both rearing and fattening in generalized linear mixed models (GLMM's) with Poisson distribution, using (i) type of plant-based enrichment material provided in the dispenser, (ii) section and (iii) their interaction as explanatory variable. animalID within penID were considered as nesting random factor. Due to convergence problems caused by many zero values, the scores for tail injuries and Δ-tail length were transformed ((tail injuries+1) and (Δ-tail length+1)) and interactions between the enrichment material and section could not be considered in the model to analyze injuries at the tails. The p-values for the GLMM's were calculated using the package car (Fox and Weisberg, 2019).

All analyses were calculated with R 3.3.1 (R Core Team, 2019) using the package nlme (Pinheiro et al., 2019), lme4 (Bates et al., 2015) and car (Fox and Weisberg, 2019).

3. Results

3.1. Effects of plant-based materials during rearing of piglets

The exploration durations rearing pigs spent at the material dispenser differed significantly between the offered plant-based enrichment materials (LME, factor material, $F_{3, 261} = 65.1$, $p < 0.0001$). Post hoc pairwise comparisons showed that rearing pigs spent significantly more time exploring lucerne pellets (LP) and straw pellets (SP), compared to chopped hay (CH) and chopped straw (CS) (for all four comparisons $p < 0.001$). Additionally, they spent significantly more time exploring CH than with CS ($p = 0.01$). Median exploration durations ranged from 63.7 min (CS) to 131.3 min (LP) per week and animal during the rearing period. Exploration duration of piglets was affected by section (LME, factor section, $F_{3, 261} = 30.6$, $p < 0.0001$) and was highest in section 4. There were significant interactions between enrichment material and weight of the pigs (LME, $F_{3, 261} = 4.2$, $p < 0.01$). Exploration durations were recorded at a low level for CS and CH (between 6.9 and 239.8 min per pig and week), but evenly distributed across weights of the pigs. Higher levels of explorations were recorded when LP (between 11.7 and 503.6 min per pig and week) or SP (between 11.7 and 473.1 min per pig and week) was offered. Most exploration durations were recorded in pigs of higher weights for LP and in pigs of lower weights for SP. In addition, section and enrichment material significantly interacted (LME, $F_{9, 261} = 3.7$, $p < 0.001$, Fig. 2a-d). During section 1 and 2, piglets explored SP most and LP was preferred during section 3 and 4.

The most activity at the dispensers was recorded between 9:00 and 19:00 with a peak in the afternoon. During this time, in average 11.0 min exploration per pig was measured, which represents 74.8% of activity at the material dispenser.

The daily weight gains of piglets were affected by the enrichment materials (LME, factor material, $F_{3, 268} = 22.1$, $p < 0.0001$) and by section (LME, section, $F_{3, 268} = 717.6$, $p = 0.0001$). The interaction between enrichment material and section was also significant (LME, $F_{9, 268} = 4.7$, $p < 0.0001$). Daily weight gains continuously increased from section 1 to section 4 and were highest for CS and LP in section 1, CH in section 2, LP in section 3 and CH in section 4. During the seven weeks of rearing, piglets reached a daily weight gain of 483.4 g (±113.6 g S.D.). Detailed information on the weights of the pigs were given in the supplementary table 4.

The different plant-based enrichment materials did not affect the Δ-tail length, however, there was a tendency (GLMM, factor material, $n = 378$, $\chi^2_3 = 7.5$, $p = 0.057$; Fig. 3a). Category 0 was most frequently scored in 91.5% of the tails when SP was offered. Whereby, after CS was offered, the examination of the tails showed the most tail length losses (43.2% category 1 and 4.2% category 2). There were no differences in Δ-tail lengths (GLMM, factor section, $n = 378$, $\chi^2_3 = 5.4$, $p = 0.1$; Fig. 3b) between the sections.

The severity of injuries at the tails were affected by the different plant-based enrichment materials (GLMM, factor material, $n = 378$, $\chi^2_3 = 21.6$, $p < 0.0001$, Fig. 4a). During the whole test, most of the scored tails had no injuries (category 0). After SP was offered, 91.5% of the tails showed category 0. The most injuries of category 3 (19.1%) were scored after LP was offered. There was a significant difference of tail injuries between the sections (GLMM, factor section, $n = 378$, $\chi^2_3 = 7.9$, $p < 0.05$, Fig. 4b). The severity of injuries of the tails decreased from section 1 to section 2 and increased again from section 2 to section 4. The interaction between material and section was significant (GLMM, $n = 378$, $\chi^2_9 = 72.5$, $p < 0.0001$). Most injuries of the tails occurred when CS was offered in section 1, when CH was offered in section 2 and 3 and when LP was offered in section 4. In all four sections, the percentage of pigs with injuries at the tails were low when SP was offered.

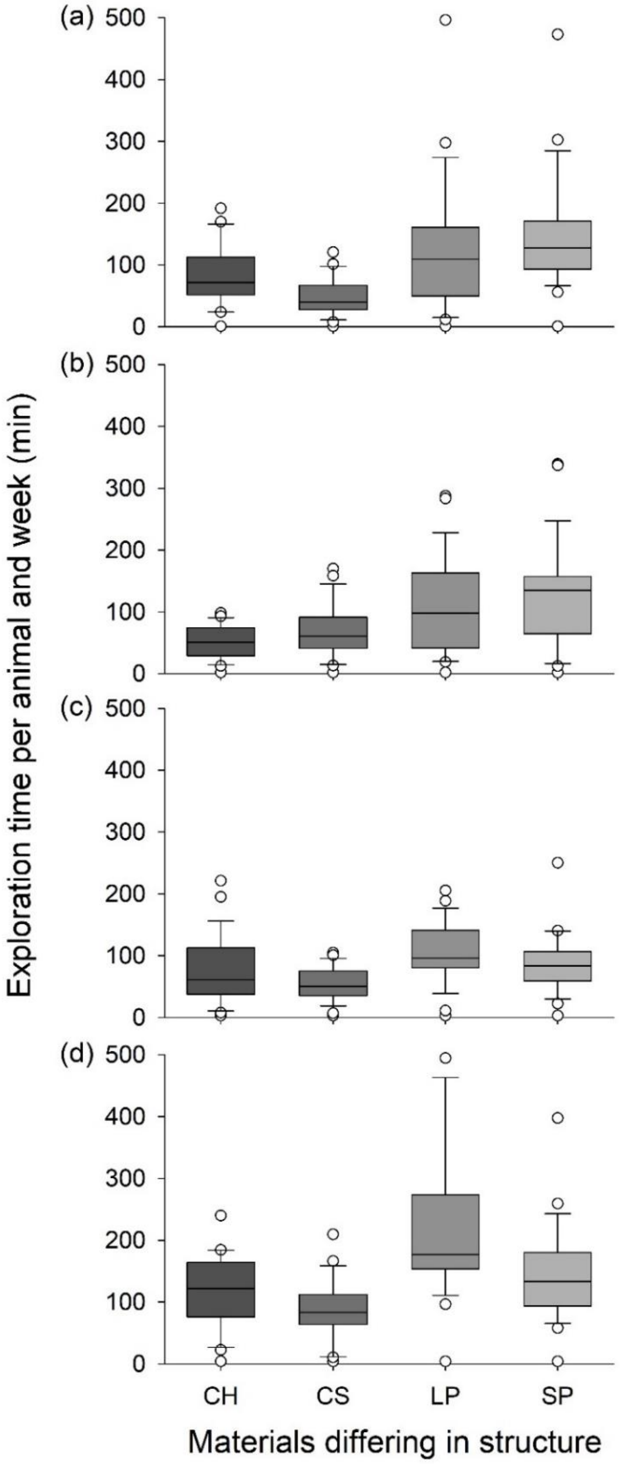

Fig. 2. Median exploration duration (boxplots) per animal and week at the material dispenser, filled with chopped hay (CH), chopped straw (CS), lucerne pellets (LP) and straw pellets (SP) during (a) section 1,(b) section 2,(c) section 3 and (d) section 4 in the rearing period. Boxplots show the median, quartiles and outliers, i.e. data point that lie outside the 10th and 90th percentiles.

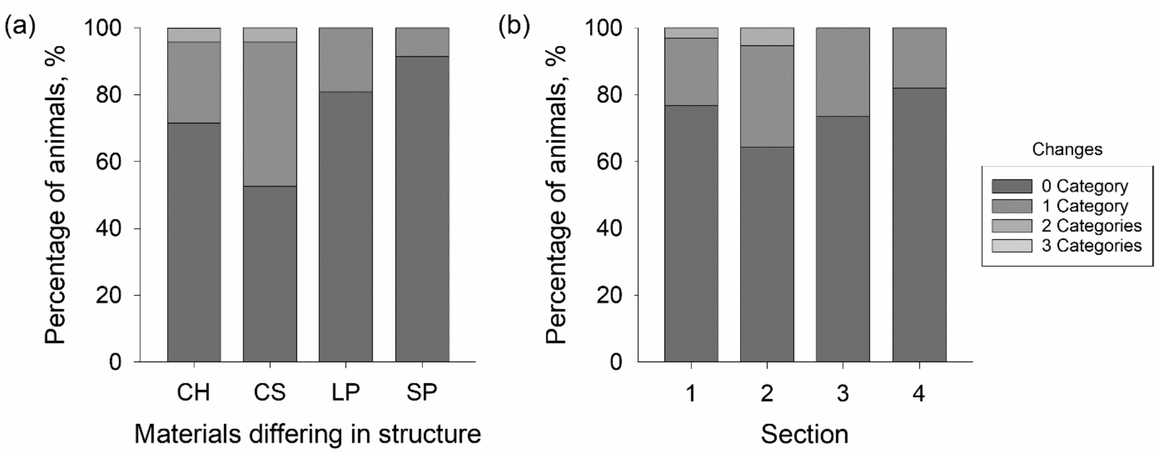

Fig. 3. Percentage of Δ-tail length during rearing period (a) after chopped hay (CH), chopped straw (CS), lucerne pellets (LP) and straw pellets (SP) were offered and (b) in the two-week sections (1 to 4) of observation.

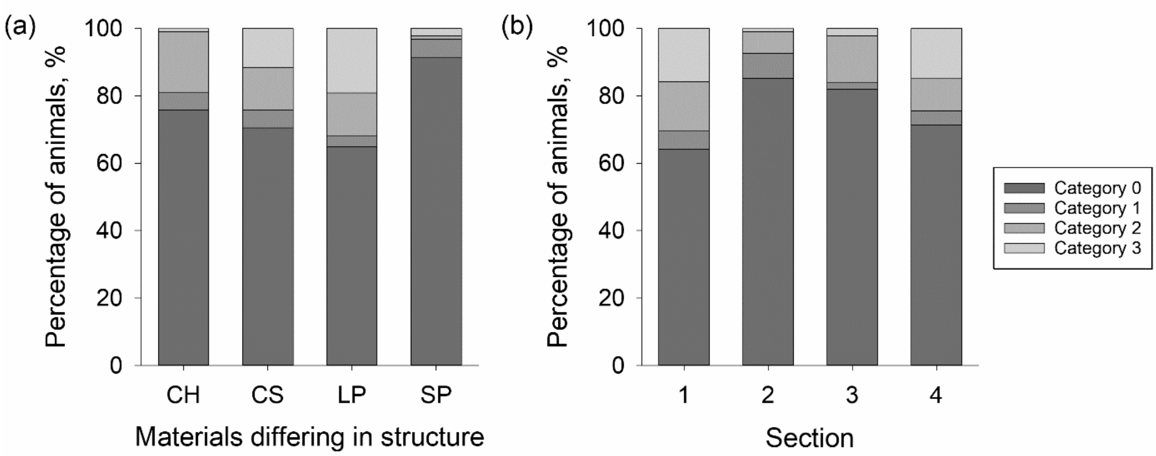

Fig. 4. Percentage of scored tail injuries during rearing period ((0) no injuries, (1) superficial perforation of the skin, punctually or in the form of a line, (2) deeper, planar perforation of the skin, maximum as large as the diameter of the tail at the respective point, (3) deeper, planar perforation of the skin, larger than the diameter of the tail at the respective point) (a) after chopped hay (CH), chopped straw (CS), lucerne pellets (LP) and straw pellets (SP) were offered and (b) in the two-week sections (1 to 4) of observation.

3.2. Effects of plant-based materials during fattening of pigs

The different plant-based enrichment materials affected the exploration duration of fattening pigs at the material dispenser (LME, factor material, $F_{3, 501} = 15.8$, $p < 0.0001$, Fig. 5). Post hoc pairwise comparisons revealed that pigs spent significant more time exploring at the material dispenser when CH was offered, compared to CS and SP (both $p < 0.05$), but not between the other materials. Median exploration durations ranged from 192.7 min (SP) to 270.7 min (CH) per week and animal. Exploration durations of pigs were affected by section (LME, factor section, $F_{3, 501} = 129.9$, $p < 0.0001$) and continuously increased from section 1 to section 4($p < 0.05$ for all comparisons). Also weights of animals influenced exploration duration of pigs (LME, factor weight, $F_{1, 501} = 26.9$, $p < 0.0001$). The pigs with intermediate weights showed highest exploration durations, while pigs with higher or lower weights showed less exploration. Significant interactions also occurred between enrichment material and weight (LME, $F_{3, 501} = 4.3$, $p < 0.01$). For all four enrichment materials, highest exploration durations per pig and week were recorded in pigs with intermediate weights, while pigs with lower or higher weights showed less exploration. However, when CH was offered exploration durations were positively related to higher weights. There was a significant interaction between enrichment material and section (LME, $F_{9, 501} = 2.4$, $p < 0.05$). During all four sections CH was explored most by the fattening pigs. Besides CH, LP was explored with a similar intense in sections 1 and 4 and CS in section 2.

During fattening, the most activity at the material dispenser was recorded between 9:00 and 19:00 with a peak in the afternoon. During this time, in average 32.6 min exploration per pig was measured, which represents 80.9 % of daily activity at the material dispenser.

The daily weight gains of fattening pigs were affected by the section (LME, section, F3, 419 = 207.2, P = 0.0001) and continuously increased from section 1 to section 4. Post hoc pairwise comparisons revealed significant differences between all sections ($p < 0.001$ for all comparisons). There was no effect of the material on the daily weight gains (LME, material, $F_{3, 419} = 1.3$, $p = 0.3$). Pigs reached a daily weight gain of 1001.0 g (±113.6 g S.D.) during the first nine weeks of fattening in the first trial (data collection started in the second week of fattening) and of 835.2 g (±134.8 g S.D.) during the first eight weeks of fattening in the second trial.

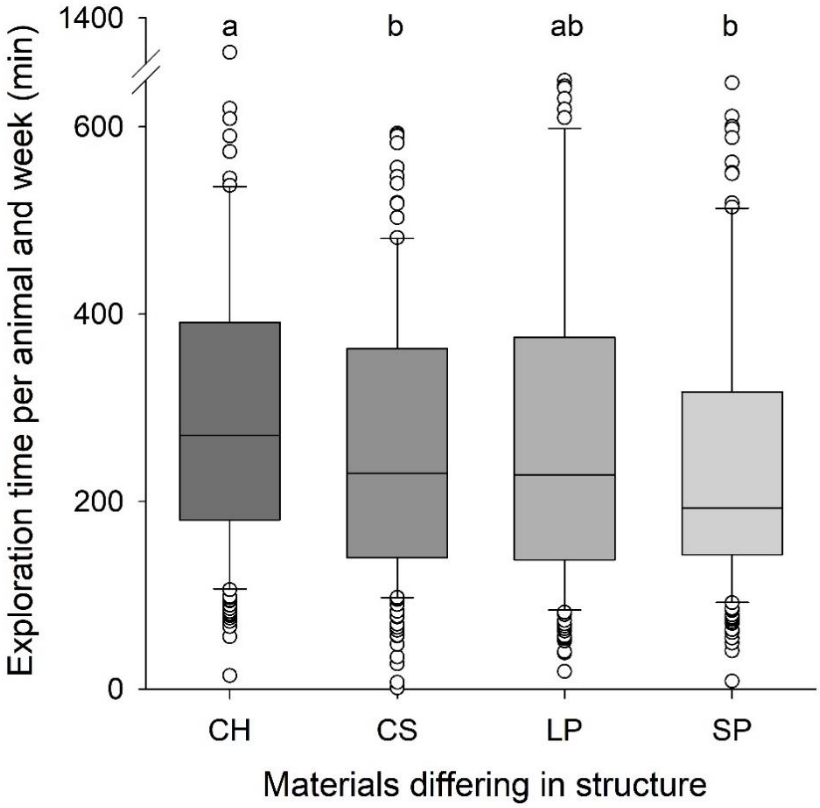

Fig. 5. Median exploration duration (boxplots) per animal and week at the material dispenser, filled with chopped hay (CH), chopped straw (CS), lucerne pellets (LP) and straw pellets (SP) during fattening period. Different letters indicate significant differences.

The percentage of Δ-tail lengths were neither affected by the different plant-based enrichment materials (GLMM, factor material, n = 704, χ^2_3 = 1.3, p = 0.7) nor by the sections (GLMM, factor section, n = 704, χ^2_3 = 2.1, p = 0.6). New scored tail length losses ranged from 9.7% when CH was offered to 4.5% when SP was offered.

The offered plant-based enrichment materials did not affect the percentage of injuries at the tails of the pigs (GLMM, factor material, n = 704, χ^2_3 = 5.5, p = 0.1). With 82.9% (CH) to 89.8% (LP), most tails were classified in category 0. Injuries at the tails of the pigs were affected by section (GLMM, factor section, n = 704, χ^2_3 = 14.2, p < 0.01). Most injuries occurred during section 1 and section 2.

4. Discussion

Our results show that pigs intensively explored the offered plant-based enrichment materials but at different extents. Furthermore, exploration of particular plant-based enrichment materials differed between the rearing and fattening phase. Piglets preferred pelletized materials of either lucerne (LP) or straw (SP), while fattening pigs favoured chopped materials, such as hay (CH) for exploration. We also found differences in length losses and injuries of tails in rearing and fattening. During rearing, length losses tended to be different between the plant-based enrichment materials. Piglets showed the most new scored length losses when chopped materials were offered such as chopped straw (CS) or chopped hay (CH) compared to times when pelletized materials were provided (LP and SP). This pattern was not as clear in tail injuries of piglets, as most injuries appeared with lucerne pellets and fewest with straw pellets. During fattening, no differences in tail length losses and tail injuries between the different pelletized or chopped plant-based enrichment materials were found.

The higher exploration durations for pelletized materials (i.e. lucerne pellets (LP) and straw pellets (SP)) by rearing pigs are in line with previous findings in fattening pigs. In a short-term choice test, fattening pigs explored lucerne pellets and straw pellets more often, compared to chopped straw, chopped hay and lignocellulose (Kauselmann et al., 2020a). In a long-term study, finishing pigs preferred straw pellets compared to chopped straw, chopped *Miscanthus giganteus* and bark compost (Zwicker et al., 2013). However, in contrast to the study of Zwicker et al. (2013) and Kauselmann et al. (2020a), we found in fattening pigs that they preferred chopped material, i.e. hay (CH) compared to CS and SP while lucerne pellets (LP) were intermediate. Thus, the focus of exploration in plant-based enrichment materials changed from rearing to fattening in our study, without being a result from habituation, as all materials were equally distributed in an alternating order to the animals. Kauselmann et al. (2020a) tested the short-term preference for six different materials with single pigs in a 2.5-minutes test paradigm. Zwicker et al. (2013) offered four different materials that changed every three weeks. In that study, a maximum of four out of six pigs had simultaneous access to the dispenser in which straw pellets were offered. These differences to our study, in which a single material altered biweekly and about eight out of twelve pigs had simultaneous access to the dispenser could have contributed the different results. Changed exploration behaviours of pigs were also shown in previous studies. For example, pre-parturient sows show changed motivations to get access to straw, as 24 h before farrowing, access to straw has a higher importance than 2 days before farrowing (Arey, 1992). Thus, the motivation to interact with enrichment materials can be hormonally induced. In addition, it has been found that the intensity of exploring different enrichment materials can change from sucklers to weaners and growers (Docking et al., 2008). Thus, the motivation to interact with enrichment materials might change with age or time spent with enrichment might be reduced in favour of other behaviours such as play in rearing pigs or both.

While in our study fattening pigs spent most exploration duration with chopped materials, rearing pigs mostly explored pellets, which can be chewed in smaller pieces. Previous studies suggest that chewing seems to be an important part of exploration behaviour in pigs (Fraser et al., 1991; Oostindjer et al., 2011) and chewing also is part of manipulation behaviour such as tail and ear biting (Bolhuis et al., 2005; Fraser et al., 1991; Oostindjer et al., 2011; Peeters et al., 2006). In addition, chewing seems to be an important part of feeding behaviour, as rearing piglets prefer pelletized to mashed diets with the same ingredients (Solà-Oriol et al., 2008). In our study, food structure changed from mashed food during rearing to pelleted food during fattening. Thus, it might be possible that a motivation of pigs to chew cannot sufficiently be satisfied with mashed food during rearing and, thus, piglets may have tried to compensate this with exploring and chewing LP and SP. In contrast, during fattening pelleted food was offered that could be chewed by the pigs. It might also be possible that intrinsic preferences for materials changed from rearing to fattening. This idea might be supported from the finding that fattening pigs explored lucerne and hay to a higher extend compared to straw, irrespective from whether materials were offered in chopped or pelleted form. These comparisons show that the straw-based materials were less attractive for fattening pigs to both lucerne and hay, which might be due to its lower nutritional value or due to differences in flavour. It is well known that pigs choose their food according to its nutrient composition (Kyriazakis and Emmans, 1995; Whittemore et al., 2001) and that pigs show preferences for certain flavours (Hellekant and Danilova, 1999; Kauselmann et al., 2020a; Kauselmann et al. (submitted); Tinti et al., 2000). Thus, nutritional content or flavour of enrichment materials might be an important property to be considered.

Median exploration durations ranged from 63.7 min (CS) to 131.3 min (LP) per week and animal during the rearing period and from 192.7 min (SP) to 270.7 min (CH) per week and animal during the fattening period. Thus, rearing pigs explored LP as the most attractive enrichment material at 1.3% of the 24h-day, while a fattening pig spent 2.7% of the day with the most attractive material (CH). These findings are comparable to other studies, which found pigs to 0.3% to 27.4% of observations exploring enrichment material (Lyons et al., 1995; Scott et al., 2006, 2007; Trickett et al., 2009; Van de Weerd et al., 2006). However, it has to be considered that these studies used time sampling methods and animals were observed during the main hours of activity that started between 8:30 and 9:30 and ended between 17:00 and 20:30. In our study, the duration pigs spent at the material dispenser was continuously recorded (24 h a day) throughout the whole rearing and fattening period. The most activity at the material dispenser was recorded from 9:00 to 19:00, i.e. more or less during the light phase of the day with a peak in the afternoon. During this time each animal spent on average 11.0 min per day at the material dispenser during rearing (1.8% of time) and 32.6 min during fattening (5.4% of time). This proportions were still in the lower range compared to other studies. However, it has to be considered that due to the participation in the German ITW program the pens were equipped with additional enrichment materials for which we did not recorded exploration durations of the pigs.

Exploration behaviour in rearing and fattening shows a single peak in the afternoon, which already has been described for autumn and winter season (Kauselmann et al., 2020b). However, fattening pigs spent almost twice more time at the material dispenser than rearing pigs, although the materials known from rearing were offered again during fattening. As pigs usually habituate to enrichment material, which has been shown by decreasing exploration over time in previous studies (Trickett et al., 2009; Van de Perre et al., 2011), it could have been expected that exploration duration would decrease from rearing to fattening. However, as mentioned above, the time budget for different behaviours can change with age, as growers spent more time inactive compared to sucklers and weaners, but spent most of their active time with object direct behaviour (Docking et al., 2008). It is so far barely investigated for how long a pig can remember enrichment materials. When enrichment material was offered for two days, pigs remembered it up to five days and preferred a novel enrichment material (Gifford et al., 2007). In addition, the weekly rotation of different enrichment materials increased novelty but cannot completely avoid habituation (Trickett et al., 2009). The used material dispenser in our study was well-accepted by the pigs and even increased their interest over time for the material changed every two weeks. However, also age-related changes in activity could have affected an increase of exploration duration from rearing to fattening.

There was an effect of the offered enrichment materials on the daily weight gains of the pigs during rearing but not during fattening. During rearing, highest daily weight gains were found when chopped hay was offered. The offered quantities in means of weight were higher for pelletized than for chopped materials (data shown in the supplementary table 3). However, it has to be considered that pellets have a higher density and, therefore, they have a higher weight compared to chopped straw and hay with the same volume. As considerable proportions of materials have fallen through the slatted floor we are not able to estimate the material that actually was eaten by pigs. Anyway, the high exploration durations for pelletized materials could have led to a reduced food consumption and, therefore, to reduced weight gains. However, even strongly preferred plant-based material did not reduce food intake compared to less preferred materials in the fattening period in which exploration duration at the dispensers were even higher compared to rearing. Similar results were shown in a comparison of different roughages as enrichment material for fattening pigs, where the offered materials affected exploration duration of pigs but not their daily weight gains (Olsen et al., 2000).

In our study, rearing pigs spent the most time at the material dispenser when LP and SP were offered. Interestingly, we found a tendency that the fewest tail length losses appear when using these two materials. The use of enrichment materials reduces manipulation behaviour against penmates (Bolhuis et al., 2005; Fraser et al., 1991; Peeters et al., 2006). It is obvious that the more time piglets spent with plant-based manipulable enrichment material, the less length losses occur.

Beside this effect of type of material, the amount of pigs with tail length losses during rearing increased from section 1 to section 4 (i.e. from the first to seventh week of rearing). Thus, an additional time effect has to be considered. Previous studies found that tail biting is a problem especially during rearing, what can be confirmed by our data. Schrøder-Petersen et al. (2010) investigated tail-in-mouth behaviour in piglets at an age between five and eight weeks. They found that oral manipulation of the penmates' tails increased with age. In Blackshaw (1981), tail biting occurs first between the first and seventh week after weaning. Jans-Wenstrup (2018) observed that the frequency of tail lesions in piglets increased from an age of four weeks to an age of eight weeks but varies between the evaluated groups. In addition, the severity of tail lesions increased over this time. Abriel and Jais (2013) and Veit (2016) found the most tail injuries in piglets from the second to third week after weaning, with a peak at the fifth week after weaning (Veit, 2016). Both, weight and age of pigs, which are directly related to each other, influence tail biting in pigs (Schrøder-Petersen and Simonsen, 2001).

In our study, we had barely changes in tail length losses during the fattening period (section 1 to 4), compared to the rearing period. It might be that the already short tails in the fattening period were not bitten as much as long tails during the rearing period. The shorter tails in fattening may have the same effect as docked tails, which were less affected by tail biting in different management systems compared to undocked tails (Hunter et al., 2001). In addition or alternatively, the higher exploration durations at the dispenser reduced tail biting in the fattening pigs.

During rearing, the most tails without injuries (category 0) were found when SP (straw pellets) was provided, which was one of the preferred materials of the piglets. Surprisingly, we found the same levels of exploration duration for LP, where we had the most tail injuries. During the fattening period we found a similar but less pattern which however, was not significant. Here, CH was explored most and again the highest incidence and severity of tail injuries were found when CH was offered. However, tail length losses were not affected. A possible explanation for increased tail biting while highly preferred materials had been offered is that the popular material triggered competition for access to the material. This might have induced social stress leading to tail biting and, thus, tail injuries. In Van de Perre et al. (2011) very popular toys also increased biting-penmate behaviour in pigs until these toys were removed from the pens, which terminated competition. Also in Kauselmann et al. (2020b) the enrichment materials with the highest exploration duration were related to an increase in tail length losses. Another possibility might be that an increased tail biting activity coincide with a higher use of the offered material, i.e. that an increasing motivation for oral manipulation results in both tail biting and use of material in parallel. Anyway, this would mean that offering enrichment material as in our study might not fully compensate the need for manipulation.

The occurrence of tail injuries changed over time (section 1 to 4) in piglets. Occurrence of injuries at the tails decreased from section 1 to section 2 and continuously increased again from section 2 to section 3 and section 4. Similarly, previous studies found increased tail lesions over time (Hakansson et al., 2020; Veit et al., 2016). In section 1, we recorded the most tail injuries compared to the following sections. However, the fewest Δ-tail lengths occurred in section 1 (and section 4). The injuries at the tails in section 1 could be triggered by stress and social interactions after weaning. When piglets were mixed in new groups, they were brought in a new environment with different penmates. New environments and the need to establish social relationships can lead to stress and frustration, which are risk factors for tail biting in pigs (Schrøder-Petersen and Simonsen, 2001).

As each of the four materials (SP, LP, CH and CS) was offered during each section in one of the four rearing pens, both the temporal changes in tail status and the effect of enrichment material on tail status could be considered. During rearing, tail injuries were affected by material and section and there was a significant interaction between both factors. We think however, that this interaction has to be interpreted carefully as we changed the enrichment material in a biweekly order and there was no material that consistently affected the most tail injuries. Thus, the order of the enrichment materials could have affected tail injuries as possibly a preferred material followed by a less preferred material led to frustration in the pigs. However, the results show that in all four sections low numbers of tail injuries occurred when SP, one of the most explored enrichment materials during rearing, was offered. Furthermore, it must be considered that tail biting has multifactorial causes (Brunberg et al., 2016; Schrøder-Petersen and Simonsen, 2001) and factors not considered in this study may have affected the results regarding tail status of the pigs.

5. Conclusions

Taken together, our study provides new insights in the preferences of commercially housed rearing and fattening pigs for plant-based enrichment materials over long-term and their influences on tail biting and injuries. The offered plant-based enrichment materials were frequently used by the pigs. We found that preferences for certain plant-based materials changed with age. During rearing, piglets preferred pelletized materials (LP and SP) accompanied by fewer tail length losses compared to chopped materials. Fattening pigs explored materials of chopped hay (CH) more compared to straw-based materials (CS and SP), which might have age-specific, nutritional or flavour reasons. The overall exploration durations for the plant-based enrichment materials increased with age, i.e. from rearing to fattening. Plant-based enrichment materials seem to have age-specific positive effects on the behaviour and the tail biting prevalence of pigs. However, the cause of the increased incidence of tail damages combined with high exploration durations should be further investigated. In addition, it is recommended to measure the motivation of pigs to explore enrichment materials depending on their age and to investigate the amount of enrichment material actually eaten by the pigs and the effects on daily weight gains.

Declaration of Competing Interest

The authors declare that there is no conflict of interest.

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References

Abriel, M., Jais, C., 2013. Einfluss der Haltungsbedingungen auf das Auftreten von Kannibalismus bei Aufzuchtferkeln. Landtechnik 68 (6), 389–394.

Adrion, F., Kapun, A., Eckert, F., Holland, E., Staiger, M., Götz, S., Gallmann, E., 2018. Monitoring trough visits of growing-finishing pigs with UHF-RFID. Comput. Electron. Agr. 144, 144–153. https://doi.org/10.1016/j.compag.2017.11.036.

Anonymous, 2008. Council Directive 2008/120/EC of 18 December 2008 Laying Down Minimum Standards for the Protection of Pigs (Codified Version).

Arey, D.S., 1992. Straw and food as reinforcers for prepartal sows. Appl. Anim. Behav. Sci. 33, 217–226.

Averberg, U., Scholz, T., Ziron, M., 2018. Futtervorlage Bei Mastschweinen. DLG Merkblatt 360. Retrieved from. https://www.dlg.org/fileadmin/downloads/landwi rtschaft/themen/publikationen/merkblaetter/dlg-merkblatt_360.pdf.

Bates, D., Maechler, M., Bolker, B., Walker, S., 2015. Fitting linear mixed-effects models using lme4. J. Stat. Softw. 67 (1), 1–48. https://doi.org/10.18637/jss.v067.i01.

Beattie, V.E., Walker, N., Sneddon, I.A., 1995. Effects of environmental enrichment on behaviour and productivity of growing pigs. Anim. Welfare. 4, 207–220.

Blackshaw, J.K., 1981. Some behavioural deviations in weaned domestic pigs. Persistent inguinal nose thrusting, and tail and ear biting. J. Anim. Sci. 33 (3), 325–332. https://doi.org/10.1017/S000335610003172X.

Bolhuis, J.E., Schouten, W.G.P., Schrama, J.W., Wiegant, V.M., 2005. Behavioural development of pigs with different coping characteristics in barren and substrate-enriched housing conditions. Appl. Anim. Behav. Sci. 93 (3-4), 213–228. https://doi. org/10.1016/j.applanim.2005.01.006.

Brunberg, E., Wallenbeck, A., Keeling, L.J., 2011. Tail biting in fattening pigs: associations between frequency of tail biting and other abnormal behaviours. Appl. Anim. Behav. Sci. 133 (1–2), 18–25. https://doi.org/10.1016/j. applanim.2011.04.019.

Brunberg, E.I., Rodenburg, T.B., Rydhmer, L., Kjaer, J.B., Jensen, P., Keeling, L.J., 2016. Omnivores going astray: a review and new synthesis of abnormal behavior in pigs and laying hens. Front. Vet. Sci. 3, 57. https://doi.org/10.3389/fvets.2016.00057.

Docking, C.M., Van de Weerd, H.A., Day, J.E.L., Edwards, S.A., 2008. The influence of age on the use of potential enrichment objects and synchronisation of behaviour of pigs. Appl. Anim. Behav. Sci. 110 (3–4), 244–257. https://doi.org/10.1016/j. applanim.2007.05.004.

EFSA, 2007. Scientific Opinion of the Panel on Animal Health and Welfare on a request from Commission on the risks associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems. Efsa J. 611, 1–13.

EFSA, E.F.S.A., 2014. Scientific opinion concerning a multifactorial approach on the use of animal and non-animal based measures to access the welfare of pigs. Efsa J. 611, 1–13.

Fox, J., Weisberg, S., 2019. An {R} Companion to Applied Regression, third edition. Sage, Thousand Oaks CA.

Fraser, A.F., 1983. The behaviour of maintenance and the intensive husbandry of cattle, sheep and pigs. Agric. Ecosyst. Environ. 9, 1–23.

Fraser, D., Phillips, P.A., Thompson, B.K., Tennessen, T., 1991. Effect of straw on the behaviour of growing pigs. Appl. Anim. Behav. Sci. 30, 307–318.

Gifford, A.K., Cloutier, S., Newberry, R.C., 2007. Objects as enrichment: effects of object exposure time and delay interval on object recognition memory of the domestic pig. Appl. Anim. Behav. Sci. 107 (3–4), 206–217. https://doi.org/10.1016/j. applanim.2006.10.019.

Hakansson, F., Lahrmann, H.P., Forkman, B., 2020. A longitudinal study of pre- and post-weaning tail damage in non-docked pigs. Animal 14 (10), 2159–2166. https://doi. org/10.1017/S1751731120001081.

Hellekant, G., Danilova, V., 1999. Taste in domestic pig, Sus scrofa. J. Anim. Physiol. An. N. 82, 8–24.

Hunter, E.J., Jones, T.A., Guise, H.J., Penny, R.H., Hoste, S., 2001. The relationship between tail biting in pigs, docking procedure and other management practices. Vet. J. 161 (1), 72–79. https://doi.org/10.1053/tvjl.2000.0520.

Jans-Wenstrup, I., 2018. Untersuchungen zur Pr¨avention der Caudophagie bei Absetzferkeln unter besonderer Berücksichtigung einer Pelletzulage. Dissertation. Justus-Liebig-Universität Gießen.

Jensen, M.B., Pedersen, L.J., 2007. The value assigned to six different rooting materials by growing pigs. Appl. Anim. Behav. Sci. 108 (1–2), 31–44. https://doi.org/ 10.1016/j.applanim.2006.10.014.

Kauselmann, K., Krause, E.T., Glitz, B., Gallmann, E., Schrade, H., Schrader, L., 2020a. Short-term choice of fattening pigs for additional plant-based materials. Appl. Anim. Behav. Sci. 226, 104975. https://doi.org/10.1016/j.applanim.2020.104975.

Kauselmann, K., Schrader, L., Glitz, B., Gallmann, E., Schrade, H., Krause, E.T., 2020b. Turning the gaze to maize: the effects of maize kernels in straw as enrichment on exploration and tail status in pigs. Berl. Munch. Tierarztl. Wochenschr. 133 https:// doi.org/10.2376/1439-0299-2020-24.

Kauselmann, K., L. Schrader, B. Glitz, E. Gallmann, H. Schrade and E. T. Krause, submitted. Tasty straw pellets – Exploration of flavoured rooting material by pigs.

Kyriazakis, I., Emmans, G.C., 1995. The voluntary feed intake of pigs given feeds based on wheat bran, dried citrus pulp and grass meal, in relation to measurements of feed bulk. Br. J. Nutr. 73 (2), 191–207. https://doi.org/10.1079/bjn19950023.

Larsen, M.L.V., Andersen, H.M., Pedersen, L.J., 2018. Which is the most preventive measure against tail damage in finisher pigs: tail docking, straw provision or lowered stocking density? Animal 12 (6), 1260–1267. https://doi.org/10.1017/ S175173111700249X.

Li, Y.Z., Zhang, H.F., Johnston, L.J., Martin, W., Peterson, J.D., Coetzee, J.F., 2017. Effects of tail docking and tail biting on performance and welfare of growing-finishing pigs in a confinement housing system. J. Anim. Sci. 95 (11), 4835–4845. https://doi.org/10.2527/jas2017.1571.

Lyons, C.A.P., Bruce, J.M., Fowler, V.R., English, P.R., 1995. A comparison of productivity and welfare of growing pigs in four intensive systems. Livest. Prod. Sci. 43, 265–274.

Marques, B.M.F.P.P., Bernardi, M.L., Coelho, C.F., Almeida, M., Morales, O.E., Mores, T. J., Borowski, S.M., Barcellos, D.E.S.N., 2012. Influence of tail biting on weight gain, lesions and condemnations at slaughter of finishing pigs. Pesqui. Vet. Bras. 32 (10), 967–974.

Maselyne, J., Saeys, W., Briene, P., Mertens, K., Vangeyte, J., De Ketelaere, B., Hessel, E. F., Sonck, B., Van Nuffel, A., 2016. Methods to construct feeding visits from RFID registrations of growing-finishing pigs at the feed trough. Comput. Electron. Agr. 128, 9–19. https://doi.org/10.1016/j.compag.2016.08.010.

Olsen, A.W., Vestergaard, E.M., Dybkjaer, L., 2000. Roughage as additional rooting substrates for pigs. Anim. Sci. 70, 541–456.

Oostindjer, M., van den Brand, H., Kemp, B., Bolhuis, J.E., 2011. Effects of environmental enrichment and loose housing of lactating sows on piglet behaviour before and after weaning. Appl. Anim. Behav. Sci. 134 (1-2), 31–41. https://doi.org/10.1016/j. applanim.2011.06.011.

Peeters, E., Driessen, B., Moons, C.P.H., Ödberg, F.O., Geers, R., 2006. Effect of temporary straw bedding on pigs' behaviour, performance, cortisol and meat quality. Appl. Anim. Behav. Sci. 98 (3–4), 234–248. https://doi.org/10.1016/j. applanim.2005.10.002.

Petersen, V., Simonsen, H.B., Lawson, L.G., 1995. The effect of environmental stimulation on the development of behaviour in pigs. Appl. Anim. Behav. Sci. 45, 215–224.

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., Team, R.C., 2019. Nlme:linear and nonlinear mixed effects models. R package version 3, 1–141.

R Core Team, 2019. R: a Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Schrøder-Petersen, D.L., Simonsen, H.B., 2001. Tail biting in pigs. Vet. J. 162 (3), 196–210. https://doi.org/10.1053/tvjl.2001.0605.

Schrøder-Petersen, D.L., Simonsen, H.B., Lawson, L.G., 2010. Tail-in-mouth behaviour among weaner pigs in relation to age, gender and group composition regarding gender. Anim. Sci. 53 (1), 29–34. https://doi.org/10.1080/09064700310002017.

Scott, K., Taylor, L., Gill, B.P., Edwards, S.A., 2006. Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems, 1. Hanging toy versus rootable substrate. Appl. Anim. Behav. Sci. 99 (3-4), 222–229. https://doi.org/10.1016/j.applanim.2005.10.013.

Scott, K., Taylor, L., Gill, B.P., Edwards, S.A., 2007. Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems, 2. Ratio of pigs to enrichment. Appl. Anim. Behav. Sci. 105 (1–3), 51–58. https://doi.org/10.1016/j.applanim.2006.05.042.

Sinisalo, A., Niemi, J.K., Heinonen, M., Valros, A., 2012. Tail biting and production performance in fattening pigs. Livest. Sci. 143 (2–3), 220–225. https://doi.org/ 10.1016/j.livsci.2011.09.019.

Solà-Oriol, D., Roura, E., Torrallardona, D., 2008. Feed preference in pigs: effect of cereal sources at different inclusion rates. J. Anim. Sci. 87 (2), 562–570. https://doi.org/ 10.2527/jas.2008-0949.

Špinka, M., 2018. Advances in Pig Welfare. Woodhead Publishing. https://doi.org/ 10.1016/C2015-0-05682-9.

Stolba, A., Wood-Gush, D.G.M., 1984. The identification of behavioural key features and their incorporation into a housing design for pigs. Annales de Recherches V´et´erinaires, INRA Editions 15, 287–302.

Stolba, A., Wood-Gush, D.G.M., 1989. The behaviour of pigs in a semi-natural environment. Anim. Sci. 48 (2), 419–425.

Studnitz, M., Jensen, M.B., Pedersen, L.J., 2007. Why do pigs root and in what will they root? Appl. Anim. Behav. Sci. 107 (3–4), 183–197. https://doi.org/10.1016/j. applanim.2006.11.013.

TierSchNutztV, 2017. Tierschutz-Nutztierhaltungsverordnung in the Version Published on 22. August 2006 (BGBl. I S. 2043), Last Amended by Article 3(2) of the Act of 30. June 2017 (BGBl. I p. 2147).

Tinti, J.M., Glaser, D., Wanner, M., Nofre, C., 2000. Comparison of gustatory responses to amino acids in pigs and in humans. Lwt - Food Sci. Technol. 33 (8), 578–583. https://doi.org/10.1006/fstl.2000.0713.

Trickett, S.L., Guy, J.H., Edwards, S.A., 2009. The role of novelty in environmental enrichment for the weaned pig. Appl. Anim. Behav. Sci. 116 (1), 45–51. https://doi. org/10.1016/j.applanim.2008.07.007.

Van de Perre, V., Driessen, B., Van Thielen, J., Verbeke, G., Geers, R., 2011. Comparison of pig behaviour when given a sequence of enrichment objects or a chain continuously. Anim. Welfare 20, 641–649.

Van de Weerd, H., Ison, S., 2019. Providing effective environmental enrichment to pigs: how far have we come? Animals 9 (5). https://doi.org/10.3390/ani9050254.

Van de Weerd, H.A., Docking, C.M., Day, J.E.L., Avery, P.J., Edwards, S.A., 2003. A systematic approach towards developing environmental enrichment for pigs. Appl. Anim. Behav. Sci. 84 (2), 101–118. https://doi.org/10.1016/s0168-1591(03)00150- 3.

Van de Weerd, H.A., Docking, C.M., Day, J.E.L., Breuer, K., Edwards, S.A., 2006. Effects of species-relevant environmental enrichment on the behaviour and productivity of finishing pigs. Appl. Anim. Behav. Sci. 99 (3–4), 230–247. https://doi.org/10.1016/j.applanim.2005.10.014.

Veit, C., 2016. Influence of Raw Material and Weaning Management on the Occurrence of Tail-biting in Undocked Pigs. Dissertation. University of Veterinary Medicine Hannover.

Veit, C., Traulsen, I., Hasler, M., T¨olle, K.-H., Burfeind, O., Beilage, Eg., Krieter, J., 2016. Influence of raw material on the occurrence of tail-biting in undocked pigs. Livest. Sci. 191, 125–131. https://doi.org/10.1016/j.livsci.2016.07.009.

Whittemore, E.C., Emmans, G.C., Tolkamp, B., Kyriazakis, I., 2001. Tests of two theories of food intake using growing pigs - 2. The effect of a period of reduced growth rate on the subsequent intake of foods of different bulk content. Anim. Sci. 72, 361–373.

Wood-Gush, D.G.M., Vestergaard, K., 1989. Exploratory behavior and the welfare of intensively kept animals. J. Agr. Ethics 2, 161–169.

Zonderland, J.J., Bracke, M.B.M., den Hartog, L.A., Kemp, B., Spoolder, H.A.M., 2010. Gender effects on tail damage development in single- or mixed-sex groups of weaned piglets. Livest. Sci. 129 (1–3), 151–158. https://doi.org/10.1016/j. livsci.2010.01.018.

Zonderland, J.J., Schepers, F., Bracke, M.B., den Hartog, L.A., Kemp, B., Spoolder, H.A., 2011. Characteristics of biter and victim piglets apparent before a tail-biting outbreak. Animal 5 (5), 767–775. https://doi.org/10.1017/S1751731110002326.

Zwicker, B., Gygax, L., Wechsler, B., Weber, R., 2013. Short- and long-term effects of eight enrichment materials on the behaviour of finishing pigs fed ad libitum or restrictively. Appl. Anim. Behav. Sci. 144 (1–2), 31–38. https://doi.org/10.1016/j. applanim.2012.11.007.

4. Turning the gaze to maize: The effects of maize kernels in straw as enrichment on exploration in pigs

Mais im Fokus: Auswirkungen von Maiskörnern in Stroh als Beschäftigungsmaterial auf die Exploration bei Schweinen

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Summary

Tail biting is one of the biggest problems in pig production systems that causes animal welfare and economic problems. Therefore, tail docking is a widely used intervention to reduce tail biting. However, appropriate enrichment material that stimulates and increases exploration behaviour of pigs also reduces the prevalence and risk of tail biting. In 288 pigs with undocked tails we investigated whether the attractiveness of chopped straw (CS) as enrichment material can be further increased when maize kernels were added (CS+MK). Further, we examined whether a higher attractiveness is accompanied by reduced tail incidents. We used material dispensers equipped with ultra-high-frequency radio-frequency identification (UHF RFID) systems to record individual exploration times of the pigs to the offered enrichment materials. Furthermore, animals were scored thrice for tail length losses and tail injuries, i.e. after the rearing period, in the middle of the fattening period and at the end of the fattening period. Both rearing and fattening pigs had higher exploration durations when housed with CS+MK compared to CS (LME: rearing, $P<0.001$, fattening, $P<0.05$). Interestingly, enrichment materials not only remained interesting but were used even more from rearing to fattening. However, when CS+MK was offered pigs showed a higher prevalence for tail biting incidents in the rearing, but not in the fattening period, compared to CS (rearing GLMM, $P<0.01$). This may have resulted from competition for the more attractive enrichment material (CS+MK). An edible additive increased the interest for straw in pigs over long term but could not improve tail status.

Keywords: nutritive additive, fattening, rearing, Sus scrofa domesticus, tail biting

Zusammenfassung

Eine der größten Problematiken in der kommerziellen Schweinehaltung ist das Auftreten von Schwanzbeißen, was tierschutzrelevante wie auch wirtschaftliche Probleme verursacht. Daher ist bisher das Schwanzkupieren eine weitverbreitete Maßnahme, um das Schwanzbeißen zu vermeiden. Jedoch können geeignete Beschäftigungsmaterialien, die bei den Tieren zu einem Anstieg der Explorations-und Beschäftigungszeit führen, das Risiko für Schwanzbeißen mindern. An 288 unkupierten Schweinen wurde untersucht, ob gehäckseltes Stroh mit Maiskörnern (CS+MK) im Vergleich zu gehäckseltem Stroh (CS) attraktiver ist und ob eine höhere Attraktivität zu weniger Schwanzverletzungen und Teilverlusten während der Aufzucht und Mast führt. Dafür verwendeten wir Beschäftigungsautomaten, in denen ein ultrahochfrequentes Radiofrequenz-Identifikations-System (UHF RFID) eingebaut wurde, um die individuellen Beschäftigungszeiten der Schweine für das angebotene Beschäftigungsmaterial aufzuzeichnen. Weiterhin wurden die Schwänze der Schweine dreimal bonitiert: nach der Aufzucht, zur Mitte und zum Ende der Mast. In der Aufzucht und Mast war die Beschäftigungszeit der Schweine, die CS+MK erhielten, signifikant höher, verglichen mit Schweinen, die ausschließlich CS erhielten (Aufzucht, LME, P<0,001, Mast, LME, P<0,05). Das Interesse an den eingesetzten Beschäftigungsmaterialien konnte nicht nur aufrechterhalten werden, sondern stieg interessanterweise von der Aufzucht bis zur Mast weiter an. Jedoch zeigten Schweine, die CS+MK erhielten, in der Aufzucht mehr Schwanzlängenverluste als Schweine, die ausschließlich CS erhielten (Aufzucht GLMM, P<0,01). In der Mast gab es keinen Unterschied. Dies könnte möglicherweise daran liegen, dass durch das stark präferierte Beschäftigungsmaterial (CS+MK) in der Aufzucht eine Konkurrenz ausgelöst wurde. Ein fressbarer Zusatz steigerte langfristig das Interesse von Schweinen für Stroh, konnte den Zustand der Schwänze jedoch nicht verbessern.

Schlüsselwörter: fressbare Zusätze, Aufzucht, Mast, Sus scrofa domesticus, Schwanzbeißen

Introduction

Abnormal behaviours appear often in commercially housed pigs and are considered as important indicators for animal welfare problems (Beattie et al. 1995, Schouten 1986). Behavioural disorders of domestic pigs are especially manifested in tail biting (e.g. Beattie et al. 1995, Bolhuis et al. 2005, Fraser et al. 1991, Petersen et al. 1995), which mainly occur during the rearing period (Abriel and Jais 2013, Blackshaw 1981, Jans-Wenstrup 2018, Schrøder-Petersen et al. 2010, Veit et al. 2016). Indications of physiological stress were found in tail biters (Munsterhjelm et al. 2013) and it is assumed that pigs try to compensate for occurring stressors by biting the tails of their penmates (Schrøder-Petersen and Simonsen 2001). The consequences of tail biting for the victim pigs range from skin injuries, to tail losses or even to inflammation and abscesses as a late consequence (Kritas and Morrison 2007, Li et al. 2017, Valros et al. 2007). Beside these severe animal welfare and health issues, these animal-related consequences also can cause economic losses for the farmers (Kritas and Morrison 2007, Li et al. 2017, Valros et al. 2007). To reduce the occurrence of tail biting, tail docking is so far a widely used method that reduces but does not prevent the risk for tail damages (Hunter et al. 2001, Larsen et al. 2018, Li et al. 2017). Tail docking as other interventions (Veit et al. 2017) are in general legally prohibited in the European Union despite specific implemented exceptional permission (Anonymous 2008). These exceptional permissions are widely used with the consequence that 77% of the pigs in the European Union are routinely tail docked (De Briyne et al. 2018). Thus, for animal welfare reasons, which can be optimal realized when also economic considerations are taken into account, methods need to be identified that reduce the prevalence or even avoid tail biting in undocked pigs. To find solutions for preventing tail biting is rather complex as this behavioural disorder is assumed to have multifactorial causes (Brunberg et al. 2016, Schrøder-Petersen and Simonsen 2001). It is influenced by both the animal itself (e.g. genetic and breed, growth, sex, behavioural characteristics, health) and the environment (e.g. feed/feeding, space available and group size, enrichment material, climate and management) (Valros 2018). Many studies found that enrichment materials can help to prevent certain abnormal behaviours in pigs (Beattie et al. 1995, Hunter et al. 2001, Larsen et al. 2018) and can reduce tail biting (Beattie et al. 1995, EFSA 2014). However, materials that are highly preferred by pigs can lead to competition resulting in agonistic interactions and increasing risks for tail biting (Van de Perre et al. 2011). Pigs habituate to durable, non-plant-based materials quickly. Exploration times usually decreases within few days (Van de Perre et al. 2011) or even faster within hours after offering an enrichment object (Apple and Craig 1992). Plant-based materials may also trigger decreasing exploration over time, however, other studies showed that these materials sustain interest and exploration over weeks such as straw offered in different forms (Van de Weerd et al. 2006, Zwicker et al. 2013). Plant-based materials are changeable, manipulable, chewable, edible or odorous. These properties seem to be crucial for suitable enrichment materials for pigs (Fraser et al. 1991, Jensen and Pedersen 2007, Studnitz et al. 2007, Van de Perre et al. 2011, Van de Weerd et al. 2003). When given the choice pigs prefer plant-based materials to non-plant-based materials (Scott et al. 2006, 2009). Among the plant-based materials, straw is so far best investigated and it is highly recommended as enrichment material for pigs (Bolhuis et al. 2005, Fraser et al. 1991, Jensen and Pedersen 2007, Studnitz et al. 2007, Van de Perre et al. 2011, Van de Weerd et al. 2003). Materials including different mixed structures or with edible additives were even better accepted by pigs than straw (Jensen and Pedersen 2007, Zwicker et al. 2013). When pigs get a food reward the attractivity of rootable plant-based enrichment material increases (Holm et al. 2008). A possible reason is that pigs can better perform their innate foraging behaviour if they are able to search, chew and eat edible parts while exploring the enrichment material (Studnitz et al. 2007). However, from a practical point of view plant-based materials are likely to rise problems in the recent conventional pig housing systems as in pens with slatted floors they can clog the slurry pits.

We here aim to identify a practicable way to increase attractiveness of plant-based enrichment material which are feasible also later under practical conditions over the entire production period, i.e. from rearing to fattening, in order to reduce tail damages and thus avoid tail docking in pigs. For this purpose we used material dispensers with an integrated ultra-high-frequency radio-frequency identification (UHF RFID) system and investigated how chopped straw compared to chopped straw with maize kernels provided as enrichment material affect (i) exploration durations (i.e. time spent at the material dispenser), and (ii) tail status (i.e. tail length and injuries) in pigs from rearing to the end of fattening period. We hypothesize that straw enriched with a nutritive additive, i.e. maize, remains more attractive for pigs and results in higher exploration times in rearing and fattening pigs compared to straw without any additives. According to this, we expect less tail biting activities in straw with the maize supplemented groups what will be associated with a better tail status.

Methods

Animals and housing

We used a total of 288 pigs with randomly mixed sexes in three successive replicates (replicate 1: 55 females and 41 castrated males, replicate 2: 47 females and 49 castrated males, replicate 3: 52 females and 44 castrated males). The crossbred pigs (German Piétrain x German Hybrid) with undocked tails were housed in forced ventilated stables at the Bildungs- und Wissenszentrum Boxberg (LSZ), Germany. The study with all three identical replicates was carried out from June 2018 to February 2019 (Tab. 1). At weaning, with an age of about 28 days, the piglets were weighted and individually equipped with common ear tags that were internally equipped with an UHF RFID tag (MS Tag Round UHF, MS Schippers, Netherlands). Each piglet got two tags with the same number (one per ear) for individual identification. At the day of weaning, piglets had an average weight of 7.4 kg (±1.2 kg SD). In each of the three replicates, 96 piglets were transferred to the study stable and divided in four identical rearing pens (24 piglets each), according to their assigned treatment (see below). Each pen had 15 m^2 (5 x 3 m) floor space (Fig. 1a) with 7.5 m^2 slatted plastic floor (38.5% perforation), 3.0 m^2 slatted concrete floor (17.0% perforation), and 4.5 m^2 partly slatted concrete floor (7.0% perforation) under a heated covering. All rearing pens were equipped with a material dispenser, a scrubber bar, a wooden pole attached on a metal chain and sisal ropes. Piglets had ad libitum access to water from two drinking bowls (Suevia 92 R, Suevia Haiges GmbH, Kirchheim, Germany) and two additional nipple drinkers in each pen. Mashed feed was offered ad libitum by an automatic mash feeder (2.4:1, animal:feeding place ratio) in two phases. Feed composition changed after two weeks of rearing (detailed information on feed composition is given in the electronic supplementary material). One week before rearing ended, the piglets were additionally fed with pellet concentrate (approximately 25 kg per pen) from a single feeder to habituate them to the feed change in fattening. During the seven weeks in the rearing pens, we had to remove a total of eleven piglets in all three replicates (4 pigs with locomotion problems, 2 runts, 2 identified tail biters, 2 died without identifiable reason and 1 pig with a swollen cheek), i.e. 3.8%, resulting in 91 pigs in replicate 1 (52 females and 39 castrated males), 93 pigs in replicate 2 (46 females and 47 castrated males), and 93 pigs in replicate 3 (50 females and 43 castrated males) (Tab. 1). The pigs were distributed in eight fattening pens per replicate, respectively. The animals of each rearing pen were randomly split up in two groups for fattening pens (max. 12 pigs per pen). Thus, the pigs of each fattening group were familiar to each other. At the beginning of fattening, pigs had an average weight of 30.6 kg (±4.2 kg SD). Pigs were housed in each fattening pen (Fig. 1b) with 15 m2 (5 x 3 m) floor space and fully slatted concrete floor (17% perforation). All fattening pens were identically equipped with a material dispenser. Pigs had ad libitum access to water from four nipple drinkers in each pen. Feed was offered ad libitum in two phases as pellet concentrate from a single feeder. When pigs reached an average weight of about 80 kg, feed composition changed (detailed information on feed composition is given in the electronic supplementary material, Supplementary Tab. 1). The pigs were housed in the fattening pens for at least eleven weeks. Thereafter the study and, thus, the data collection ended. Pigs were fattened until reaching final mass and were then slaughtered and marketed.

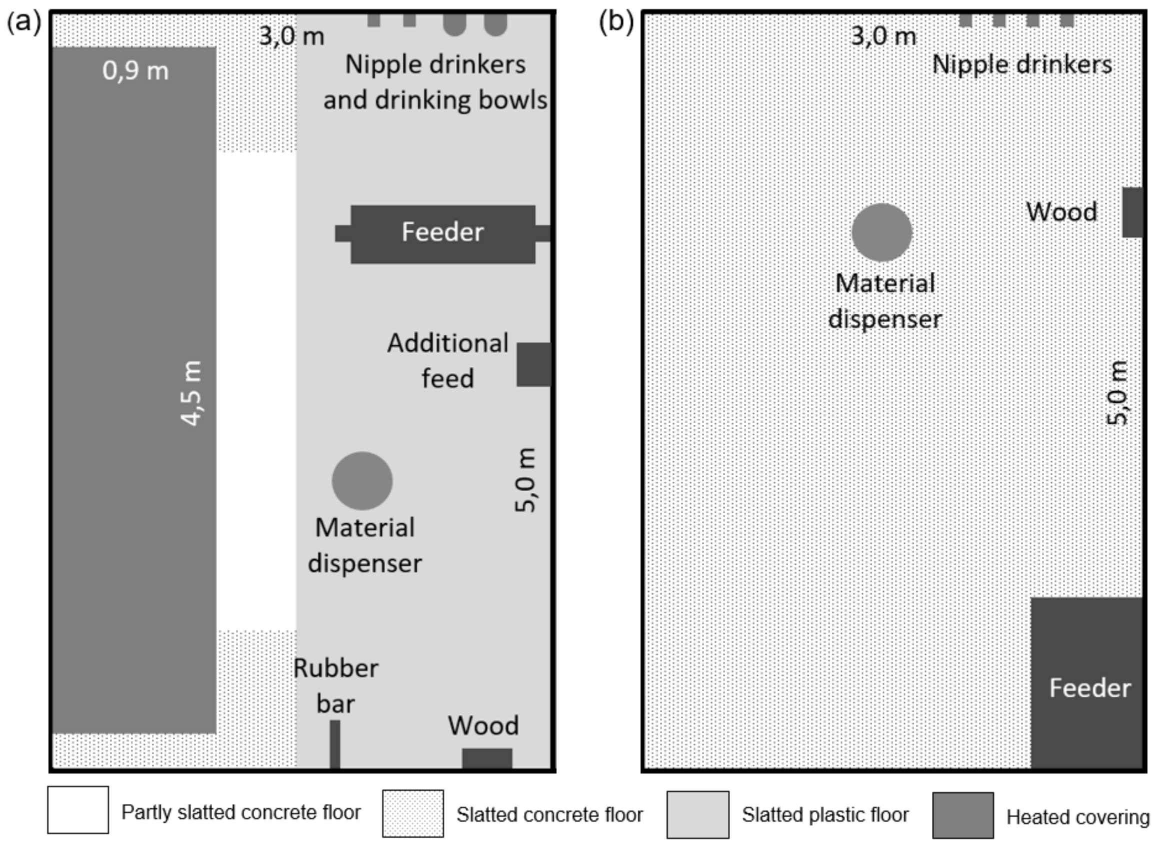

Figure 1. Schematic drawing of a (a) rearing and (b) fattening pen with partly slatted concrete floor with 7% perforation (white), slatted concrete floor with 17% perforation (dotted), slatted plastic floor with 38.5% perforation (lined) and heated covering (grey).

Table 1. Dates of data collection with the corresponding times of sunrise and sunset in Germany.

Period	Replicate		Date	Sunrise	Sunset	Mean sunrise	Mean sunset
rearing	1	Begin	14.06.2018	5:03	21:07	6:44	19:22
		End	01.08.2018	5:40	20:40		
	2	Begin	16.08.2018	6:14	20:42		
		End	02.10.2018	7:27	19:00		
	3	Begin	18.10.2018	7:53	18:25		
		End	05.12.2018	8:11	16:19		
fattening	1	Begin	01.08.2018	5:40	20:40	7:30	18:06
		End	17.10.2018	7:52	18:28		
	2	Begin	02.10.2018	7:27	19:00		
		End	20.12.2018	8:25	16:19		
	3	Begin	05.12.2018	8:11	16:19		
		End	21.02.2019	7:27	17:50		

With regard to the offered enrichment materials, we took up the recommendations of the European Commission (2016) and, in addition to the material dispenser, we continuously offered additional enrichment materials to the pigs during rearing (wood, sisal rope, rubber bar) and fattening (wood, sisal ropes), what exceed the minimum requirements. Furthermore, space allowance in rearing (0.58 m^2/pig) and fattening (1.14 m^2/pig) was higher than minimum requirements by the TierSchNutztV (2017).

All housing and management procedures of the animals were conducted in accordance to German legislation (TierSchNutztV) for farm animals. Animals were visually inspected daily for health issues. In case of tail biting, additional paper bags, mineral feed, squeezed oats and zeolite were offered and the pigs were further closely observed. If biters could be identified, they were removed from the group and kept in a separate pen. Bitten pigs were immediately medicated or also kept in a separate pen if necessary.

Enrichment materials and material dispenser design

At the beginning of each replicate, pens were allocated to one of the two enrichment treatments, which the animals received throughout the entire study, i.e.

rearing and fattening. Pigs in the pens of treatment one (two pens in each rearing period and respectively four pens in each fattening period in each replicate) received chopped barley straw (in the following abbreviated as CS) with a length of approximately 10 to 100 mm as enrichment material. In the respective pens of the second treatment, the chopped barley straw was mixed with whole grain maize kernels from regular forage maize (CS+MK) in a weight proportion of 10% of the straw. The appropriate enrichment material was offered continuously in rearing and fattening through material dispensers to the pigs. The storage tube of the material dispenser was filled by hand daily, except on weekends. For this reason, on Fridays, the storage tube of the material dispensers were filled with a stock for the weekend.

In the middle of each pen a material dispenser was installed (Fig. 1 and Supplementary Fig. 1) and consists of a storage tube containing the enrichment material. Between the storage tube and the floor there was a gap of 2.4 cm where the pigs could root for the enrichment material by moving a 25 cm long, 5 cm wide and 0.8 cm thick plastic bolt with balls (diameter 5.5 cm) at both ends. Around the 100 cm high storage tube with a diameter of 25 cm, a 10 cm high cement ring with an inner diameter of 63 cm was installed to create a rooting area around the storage tube. According to the recommendations to calculate the animal:feeding place ratio (Averberg et al. 2018), a width of 18 cm for rearing pigs and of 33 cm for fattening pigs was used to calculate the animal:dispenser place ratio. The resulting animal:dispenser place ratio was 1.7:1 in the rearing pens and 1.5:1 in the fattening pens. Under the storage tube and the cement ring, we installed a mat that prevents the enrichment material from falling through the slatted floor.

Data collection

Each material dispenser was equipped with a dust- and waterproof UHF RFID antenna (Kathrein MiRa ETSI, KATHREIN Solutions GmbH, Ismaning, Germany) inside the storage tube. The antenna was installed horizontally at a height of 50 cm above the floor. When the pigs stay at the rooting area of the material dispenser, the UHF RFID antenna reads the UHF RFID tags in the ears of the pigs and this was recorded as exploration time. The collected data were transferred through a converter and an UHF RFID reader into a database. We used a software application (Phenobyte GmbH & Co. KG., Ludwigsburg, Germany) to assign the animals to their pens and thus to the corresponding UHF RFID antenna. This enabled us to collect the time at the material dispenser for each animal, in each of the two respective treatments, i.e. straw with or without maize. The antenna settings were taken over as described in (Kauselmann et al. submitted [a]). Accordingly, the radiated output power at the antennas was 22.4 dBm. All pigs were scored according to the “Deutscher Schweine Bonitur Schlüssel” (DSBS 2017) and weighed four times during the test: at the beginning of the rearing period (i.e. at weaning), at the end of the rearing period, after six weeks of the fattening period, and at the end of observations (i.e. after eleven weeks of fattening period). At these occasions tail length was scored in five categories: (0) full/natural length (1) length loss up to one-third, i.e. here we also include individuals with only minimal losses at the tassel (2) distinct damages are documented, i.e. length losses from at least one third up to two-thirds (3) length loss more than two-thirds and (4) total loss with a maximum of 1 cm leftover for piglets in the rearing and 2 cm leftover for pigs in the fattening. We recorded tail skin injuries of the pigs’ in the following four categories: (0) no injuries (1) superficial perforation of the skin, punctually or in the form of a line (2) deeper, planar perforation of the skin, maximum as large as the diameter of the tail at the respective point, and (3) deeper, planar perforation of the skin, larger than the diameter of the tail at the respective point.

Statistical analysis

We calculated the recorded time at the material dispenser per animal and week for the seven weeks of rearing period (in the following referred to as section 1), the first six weeks of fattening (section 2) and the last five weeks of fattening (section 3) for each individual. Thus, the times can be compared between the sections (with different weeks). To get the amounts of newly recorded tail length losses, for each section we calculated the difference of the scored tail length loss to the score of the previous section and used the resulting Δ tail length for further analysis. For example, if a pig had a tail length category of 0 at the beginning of rearing and a tail length category of 1 after rearing, tail length changed by 1 (1-0) category (Δ tail length = 1) during rearing (section 1). If the same pig had a tail length category of 2 after both section 2 and 3 of fattening, tail length changed by 1 (2-1) category (Δ tail length = 1) during section 2 and by 0 (2-2) categories (Δ tail length = 0) during section 3 of fattening.

The time animals spent at the material dispensers per week for each section was analyzed separately for rearing and fattening period. Normal distribution of the residuals was reached by log-transformation [log(x+1)] and was checked by visual inspection of the q-q plot. Linear mixed effect models (LME) with the exploratory variables (i) type of enrichment material provided in the material disperser (2-level factor, CS or CS+MK) (ii) body weight (measured at the end of each section) and (iii) two-way interactions between each exploratory variable were used. For the fattening pens section (2-level factor) was additionally considered as exploratory variable. AnimalID and PenID were considered as nesting random factors. PenID's were assigned across replicates.

To analyze the body weights of the animals at the end of the sections we used similar LMEs separately for rearing and fattening period with the same random factors and nesting random factors as described above. Here, only the type of enrichment material was used as explanatory variable in the models.

Δ tail lengths and skin injuries at the tails were also analyzed separately for rearing and fattening with generalized linear mixed models (GLMMs) with Poisson distribution. For the one section in rearing, we used the type of enrichment material as explanatory variable. As nesting random factor we used AnimalID and PenID. For the two sections in fattening, type of enrichment material, section, and the two-way interactions were used as explanatory variables. Random factors were the same as in the model for rearing. We used R version 3.3.1 (R Core Team 2019) and the packages lme4 (Bates et al. 2015) and nlme (Pinheiro et al. 2019) for the statistical analyses. To calculate the p-values for the GLMMs we used the package car (Fox and Weisberg 2019).

Results

Effects on exploration time of piglets during rearing

During rearing, a mean exploration duration of 160.4 min (±4.8 min SE) was recorded per pig and week. Within days the exploration at the material dispenser peaked about five hours after onset and about three hours before end of the light phase (Fig. 2a). During the dark phase of a 24-hour day, exploration remained at a low level.

Type of enrichment material (CS or CS+MK) had a significant effect on exploration times at the material dispenser throughout the rearing period (LME, factor material, $F_{1, 10} = 22.0$, $P<0.001$, Fig. 3a). Median exploration time was higher for chopped straw with maize kernels (177.8 min per animal and week, CS+MK) compared to chopped straw (120.6 min per animal and week, CS). The weight of the piglets had no effect on the exploration time at the material dispenser during rearing (LME, factor weight, $F_{1, 262} = 1.6$, $P = 0.2$) nor the interaction of both (LME, $F_{1, 262} = 1.6$, $P = 0.2$).

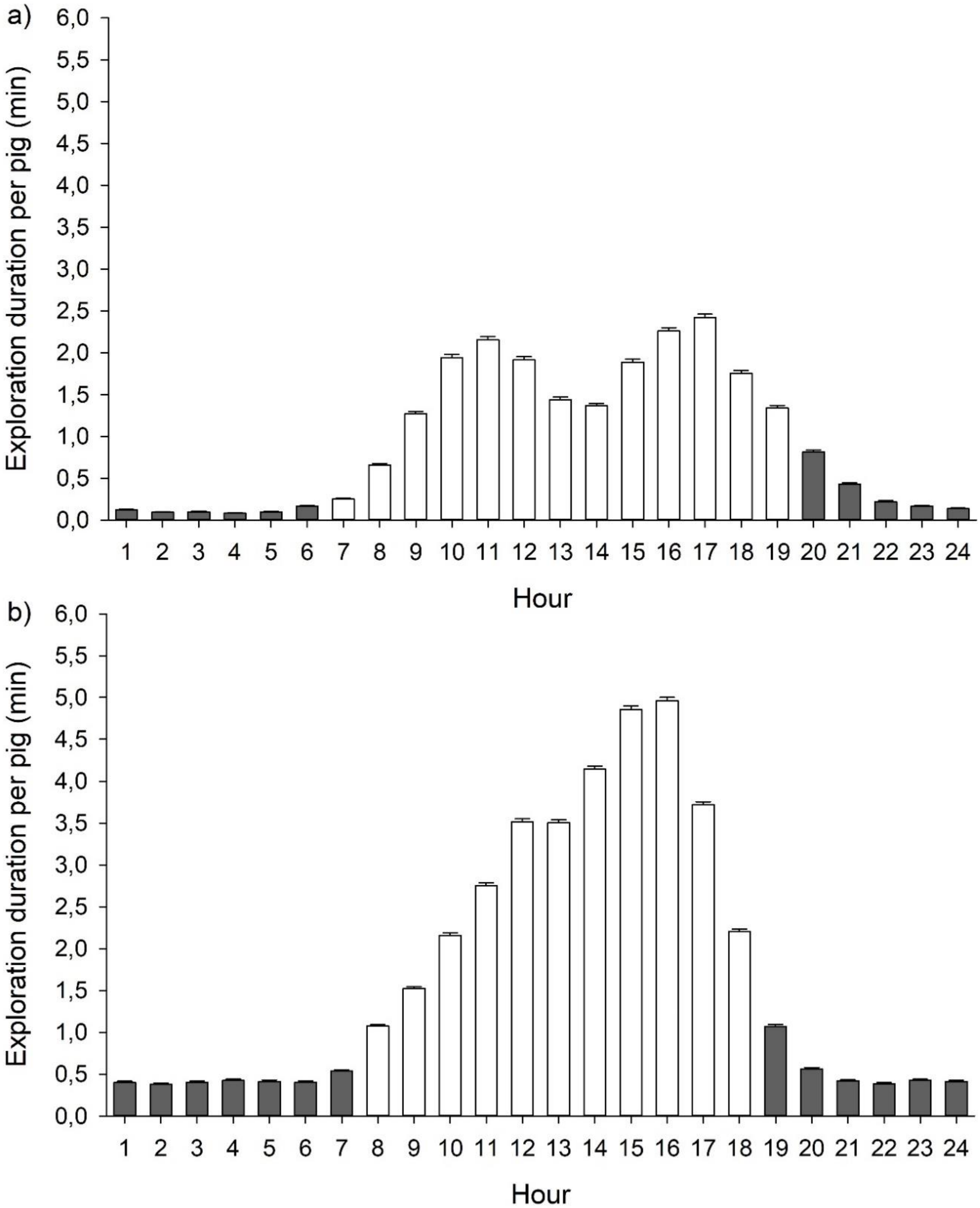

Figure 2. Diurnal rhythm of mean (± SE) exploration duration in minutes per pig at the material dispenser during (a) the rearing and (b) the fattening period. White bars show the calculated mean light phase and gray bars show the mean dark phase of a 24 hour day during data collection (see Table 1).

Effects on tail status during rearing period

Δ tail lengths were influenced by the offered enrichment materials (GLMM, factor material, n = 276, χ^2_1 = 7.9, P<0.01, Fig. 4a and Supplementary Tab. 3). However, category 4 was never recorded in any of the pigs and in category 1 often only losses of a small part of the tail tip were observed. There was no effect of the treatment on injuries at the tails of the piglets (GLMM, factor material, n = 276, χ^2_1 = 0.7, P = 0.4, Fig. 4b and Supplementary Tab. 3).

The different treatments had no effect on the weights of the piglets during the rearing period (LME, factor material, $F_{1, 10}$ = 2.7, P = 0.1). Piglets had a daily weight gain of 476.1 g (±74.1 g SD) during rearing.

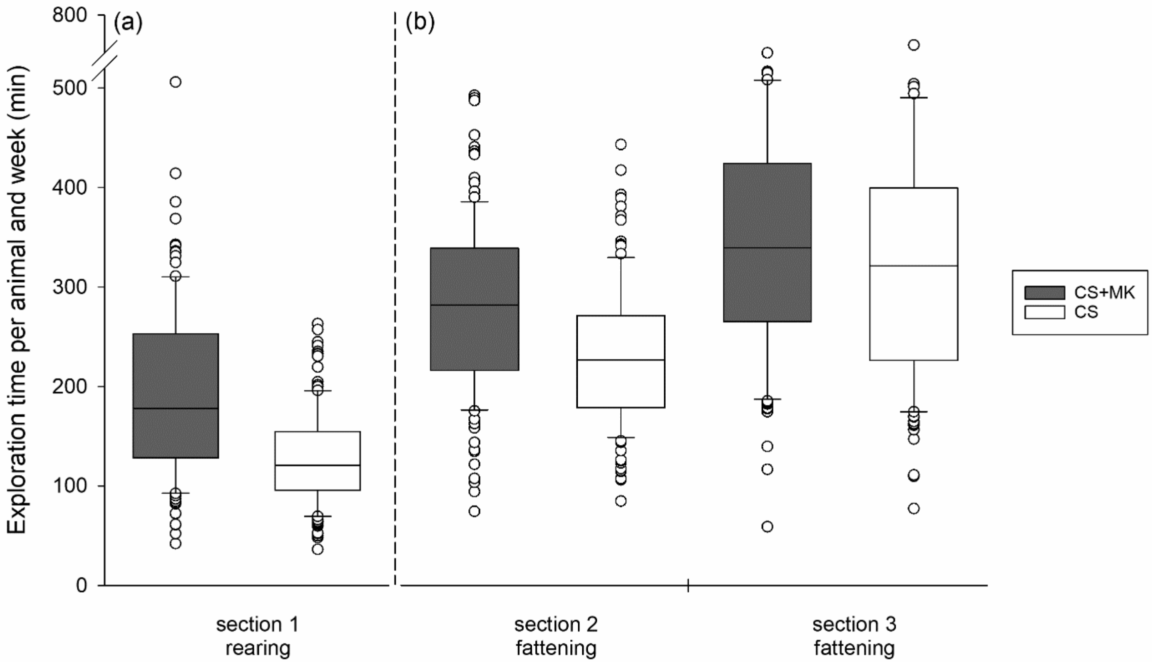

Figure 3. Median and quartiles of the exploration time per animal and week at the material dispenser, filled with chopped straw (CS, white) and chopped straw with maize kernels (CS+MK, dark grey) during (a) the section in the rearing period and (b) the two sections in the fattening period.

Effects on exploration time of pigs during fattening

During fattening, mean exploration duration of 296.6 min (±4.9 min SE) were recorded per pig and week. Within days exploration increased when the light phase began and reached a peak at 16:00 (Fig. 2b). Thereafter exploration duration decreased again. During the dark phase of a 24-hour day, mean exploration duration remained at a low level.

The time fattening pigs spent at the material dispenser was affected by the offered enrichment materials (LME, factor material, $F_{1, 22} = 7.0$, $P<0.05$, Fig. 3b). Animals spent more time at the material dispenser when CS+MK was offered compared to material dispensers filled with CS. Moreover, exploration duration was affected by section (section 2 and section 3) (LME, factor section, $F_{1, 254} = 226.8$, $P<0.0001$, Fig. 3b). In section 3 higher exploration durations were recorded at the material dispenser than in section 2. In addition, weight of the pigs (LME, factor weight, $F_{1, 254} = 70.9$, $P<0.0001$) affected exploration times at the material dispenser. Higher weights were negatively related to exploration. There was a significant interaction between the offered material and the section (section 2 and section 3) (LME, $F_{1, 254} = 10.7$, $P<0.01$).

Effects on tail status during fattening period

Δ tail lengths were not affected by the enrichment material during fattening (section 2 and section 3) (GLMM, factor material, n = 530, $\chi^2_1 = 0.0$, P = 1.0, Supplementary Tab. 3). The sections (section 2 and section 3) had no effect on Δ tail lengths (GLMM, factor section, n = 530, $\chi^2_1 = 2.7$, P = 0.1), whereby, in section 2 more Δ tail lengths occurred (26.9%) compared to section 3 (6.2%). As during rearing, category 4 was never recorded in any of the pigs and in category 1 often only losses of a small part of the tail tip were observed.

Tail injuries were not affected by the enrichment material during fattening (section 2 and section 3) (GLMM, factor material, n = 530, $\chi^2_1 = 2.8$, P = 0.1, Supplementary Tab. 3), however the section had a significant effect on tail injuries (GLMM, factor section, n = 530, $\chi^2_1 = 12.4$, P<0,001). With 92.3% we scored more tails without injuries in section 3 compared to section 2 (86.3%).

The offered enrichment materials (CS+MK and CS) had no effect on the weights of the pigs during fattening (LME, factor material, $F_{1, 22} = 3.6$, $P = 0.1$). Fattening pigs had a daily weight gain of 957.7 g (±111.5 g SD).

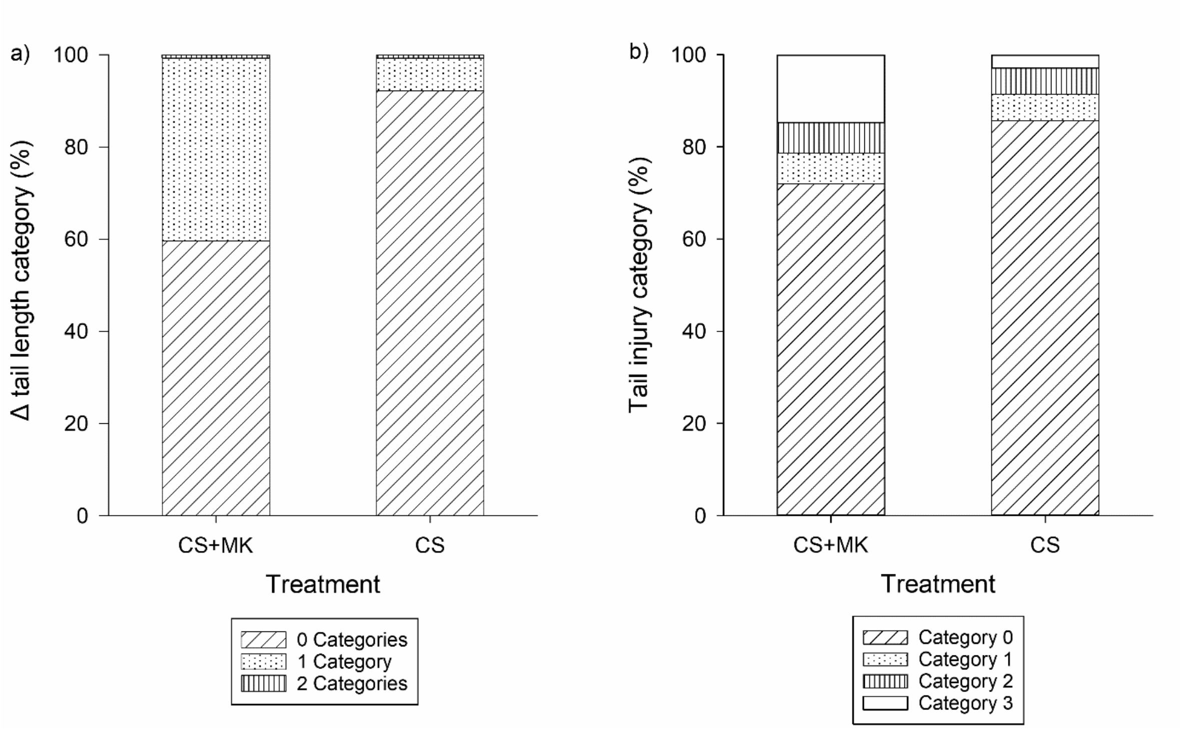

Figure 4. Percentage of (a) Δ tail length during the rearing period to the previous data collection of 0 (diagonal stripes), 1 (dotted) or 2 (vertical stripes) categories and (b) tail injuries during the rearing period ((category 0; diagonal stripes) no injuries, (category 1; dotted) superficial perforation of the skin, punctually or in the form of a line, (category 2; vertical stripes) deeper, planar perforation of the skin, maximum as large as the diameter of the tail at the respective point, (category 3; white) deeper, planar perforation of the skin, larger than the diameter of the tail at the respective point) after chopped straw (CS) and chopped straw with maize kernels (CS+MK) were offered.

Discussion

As hypothesized, during both rearing and fattening period pigs showed higher interactions with chopped straw supplemented with maize kernels (CS+MK) compared to only chopped straw (CS) in a material dispenser. The duration pigs interacted with the offered enrichment materials increased from rearing to fattening and did not show any signs of habituation over time. However, in contrast to our hypothesis, increased exploration durations for CS+MK did not result in less losses of tail length although the prevalence of tail lesions did not indicate increased tail biting. Effects of the treatments on tail length were only found during rearing.

Diurnal exploration durations of rearing pigs correspond to the known diurnal activity of pigs with an activity peak in the morning and a second in the evening (Fraser et al. 1991, Lyons et al. 1995, Olsen et al. 2000, Zwicker et al. 2012). Fattening pigs, however, showed only one diurnal activity peak. Data collection in rearing was from summer to winter (June to December) while data in fattening were recorded from autumn to spring (August to February). Thus, light phase was longer during rearing compared to fattening (Tab. 1). Comparable observations of a shift of feeding activity from two activity peaks during long to one peak during shorter light phases were done in an earlier study on feeding behaviour of fattening pigs (Bünger et al. 2017). Thus, the differences in the diurnal pattern of exploration is likely to result from seasonal differences in day length, i.e. length of light phase.

Pigs in the rearing and fattening period explored the offered chopped straw longer when maize kernels were supplemented. These findings are in line with a short term choice test, where chopped straw with maize kernels were preferred by fattening pigs compared to chopped straw mixed with either grated carrots, squeezed oats, wheat kernels or without edible additive (Kauselmann et al. 2020). Thus, short and long-term preferences of pigs seem to reflect similar patterns of behavioural preferences, which may raise important implication for future choice experiments. Our findings, in general, are in line with several studies found that enrichment materials with edible compounds can increase the attractiveness for pigs (Haskell et al. 1996, Jensen and Pedersen 2007, Olsen et al. 2000, Studnitz et al. 2007, Young et al. 1994, Zwicker et al. 2013). It is assumed that a food reward (Haskell et al. 1996, Studnitz et al. 2007) and compound or heterogeneous materials (Jensen and Pedersen 2007, Ocepek et al. 2020) stimulate exploration behaviour in pigs. Our approach reveals that straw attractiveness can be further increased for pigs by simply adding maize kernels, thus a solution that can be easily transferred into practice. Furthermore, the pigs seem not to habituate to that stimulation.

Surprisingly, the exploration durations of pigs for the offered materials increased from rearing (section 1) to fattening (section 2 and section 3). A similar trend of increasing exploration times with the age of the animals was reported in a comparison of different plant-based enrichment materials in a two-week change (Kauselmann et al. submitted [a]). However, in the current study we continuously offered the materials (either CS+MK or CS) from rearing to fattening to the pigs. In contrast, previous studies found decreasing exploration times of pigs for enrichment materials over time: In Petersen et al. (1995) rooting the enrichment material (straw, logs and branches) decreased in pigs with an age of 18 weeks, while general activity time remained constant over the observation times (at an age of 4, 7 and 18 weeks). Also Jensen et al. (2010) found that manipulation of rooting material (maize silage and straw) decreased from 13 to 20 weeks of age and pens with maize silage had higher exploration times than pens enriched with straw. Pigs may habituate to enrichment material within one week (Trickett et al. 2009, Van de Perre et al. 2011) or even within the hour after offering (Apple and Craig 1992). Regular refreshing of small amounts of deep straw can reduce habituation (Bolhuis et al. 2005). In addition to the added maize, in our study we also refreshed the material as the material dispenser regularly was refilled with fresh material. Furthermore, the absolute number of pigs decreased from 24 in rearing pens to 12 in fattening pens. Thus, although the animal:dispenser place ratio remained similar between rearing (1.7:1) and fattening (1.5:1), at the beginning of fattening, pigs had better access to the material dispenser than at the end of rearing, which could also have increased exploration duration of fattening pigs compared to rearing pigs.

Median exploration duration ranged from 177.8 min (CS+MK) to 120.6 min per animal and week (CS) during rearing and from 339.4 min (CS+MK) to 321.4 min per animal and week (CS) at the end of fattening (section 3). In previous studies between 0.3% and 27.4% of observation time pigs were observed exploring material. In these studies, observations were done in time sampling and observation times were restricted to the main activity phase of pigs and ranged between 8:30 and 20:30 (Lyons et al. 1995, Scott et al. 2006, 2007, Trickett et al. 2009, Van de Weerd et al. 2006). In contrast, in our study we continuously recorded exploration time of pigs for 24 h per day. The main hours of activity in our study were between 8:00 and 18:00. In this time, each pig spent 19.7 min at the material dispenser per day during rearing and 34.4 min during fattening. Thus, they explored 3.0% of the activity phase during rearing and 5.2% during fattening, what is within the lower range found in the previous studies mentioned above. However, in our study pigs had access to additional enrichment material (sisal ropes and wood) and exploration of these materials are not included in our data.

Although the straw supplemented with maize was more attractive, however, in the rearing period more partial losses of tail length were recorded in the treatment with CS+MK compared to the treatment with only CS. This finding was in contrast to our hypothesis, because higher exploration of enrichment material supporting foraging behaviour should lead to a reduction of penmate manipulation (Beattie et al. 1995, Fraser et al. 1991, Petersen et al. 1995) and, thus, should reduce the risk for tail biting. In line with this, we assumed that high exploration times would reduce penmate manipulation more than less explored materials. However, it might be that CS+MK was so highly attractive for the piglets that it triggered competitive social behaviour. Although aggressive interactions due to limited access to resources does not directly lead to tail biting (Prunier et al. 2020), an increased stress level of pigs resulting from the competition for resources increases the risk for tail biting (Munsterhjelm et al. 2013, Schrøder-Petersen and Simonsen 2001). The pigs' preference for CS+MK was noticeable in the quantities consumed (details on consumed enrichment materials were given in the supplementary material, Supplementary Tab. 2). Thus, material dispensers in pens where CS+MK was offered were used up faster compared to CS. However, the material dispensers were not refilled at weekends. Perhaps the pigs developed an expectation to have constant access to the material, which turned into frustration, and thus stress, when the material dispensers remained empty. Thus, it is crucial to better investigate the amount of enrichment material and how many animals should have access to the materials simultaneously.

In the fattening period, there were neither differences in partial losses of tail length between the treatments (CS+MK and CS) nor over time (section 2 and section 3). It is well known that tail biting is influenced by age and weight of the pigs (Schrøder-Petersen and Simonsen 2001) and occurs mainly during rearing. Most tail-in-mouth behaviour (Schrøder-Petersen et al. 2010) and most tail biting behaviour (Jans-Wenstrup 2018) had been observed at an age between 4 and 8 weeks of life. Tail biting seems to start in the first weeks after weaning (Abriel and Jais 2013, Blackshaw 1981, Veit et al. 2016). Due to partial losses of tail length during the rearing period, some tails were already short when pigs were moved to the fattening pens. Short bitten tails can be compared with docked tails that reduce tail biting (Hunter et al. 2001, Larsen et al. 2018, Li et al. 2017). In our study, reduced tail length often just affected the tip of the tail. However, even if only the tail tip is affected, injured nerves can lead to neuropathic pain (Devor and Rappaport 1990). An increased sensitivity to pain is a proposed reason for reduced tail biting of docked tails (Simonsen et al. 1991) and could also be considered in bitten pigs.

Reduced tail biting behaviour also resulted in reduced tail injuries during the fattening period (section 2 and section 3) compared to the rearing period (section 1). Tail injuries decreased over time during fattening, i.e. from section 2 to section 3, what is in line with Larsen et al. (2018), who found that tail damages occur first mainly in the first week and first half of the finishing period. As well as for Δ tail lengths the material had no effect on the tail injuries of the pigs during fattening. Preferences of pigs for enrichment materials change with age (Docking et al. 2008) and from rearing to fattening (Kauselmann et al. submitted [a]), what could lead to a better satisfaction of behavioural preferences and, therefore, to reduced tail biting activities during the fattening period compared to the rearing period. Furthermore, as mentioned above, in our test it has to be considered that the absolute number of animals was halved in fattening pens and the animal:dispenser place ratio was comparable in the rearing and the fattening pens. According to Schmolke et al. (2003) group size has no effect on tail biting. However, due to a reduced group size, pigs in our study had more place at the material dispenser in the beginning of the fattening period compared to the end of the rearing period. As competition for enrichment material can trigger biting penmates (Van de Perre et al. 2011), reduced competition for the enrichment material could have led to reduced tail damages in fattening pigs.

Although straw is recommended as enrichment material for pigs (Bolhuis et al. 2005, Fraser et al. 1991, Jensen and Pedersen 2007, Studnitz et al. 2007, Van de Perre et al. 2011, Van de Weerd et al. 2003) and maize kernels have the additional property of being edible, increased exploration durations when offering CS+MK could not reduce tail biting compared to CS. In a review, Godyń et al. (2019) showed to the contrary that even enrichment materials classified as of marginal interest for pigs (Anonymous 2016) can achieve a welfare benefit. Thus, by using enrichment materials, much more factors affecting the pigs have to be taken into account than recommendations, i.e. the Commission Recommendation (EU) 2016/336. An effect on welfare can be influenced by numerus factors due to the multifactorial problem of tail biting. Enrichment material can improve welfare, however, there are other factors that should be considered in reducing tail biting. Several enrichment materials, i.e. chopped straw on the floor of the pen or ryegrass haylage offered in a wired spherical rack, can be used as an early intervention when the first signs of tail biting were recorded (Lahrmann et al. 2018). Thus, in the present study a greater effect possibly might have been achieved if straw had been permanently offered to the pigs and maize kernels had been used to increase exploration duration at the first signs of tail biting.

The different treatments (CS+MK and CS) had no effect on the weights of the animals. The exploration times and enrichment consumption was higher for CS+MK than for CS. Since parts of the material fell through the slatted floor, we cannot estimate which material was actually eaten by pigs. However, the intake of CS+MK does not seem to have led to an additional weight gain. Either the additional intake of nutrients by the maize (average usage of 5.1 g per pig and day) was rather low or the pigs reduced feed intake, which was not recorded in our study.

Conclusion

Our approach to provide chopped straw enriched with maize kernels as enrichment material in commercial housing systems can be recommended to increase exploration duration and, thus, probably facilitate the natural behaviour of the animals from rearing to fattening. However, probably limited access to the highly preferred enrichment material could have led to competitive behavior and losses of tail length. Future studies are needed to assess what quantities of enrichment material must be offered and how many pigs must have access to the material simultaneously in order to provide highly preferred enrichment materials without triggering competitive behaviour among piglets. As for feeding data, there were seasonal changes in exploration behavior of pigs. These findings should be further investigated to better understand exploration behavior in pigs and to adapt provision of enrichment material.

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Conflicts of Interest

The authors declare no conflict of interest.

Ethical statement

The data acquisition was performed in accordance with the laws of Germany at that time and did not require specific approval. We provided additional enrichment materials to commercially housed pigs. All data were recorded at a licensed farm that produces, rears, fattens and markets pigs (VVVO-Number: 08 128 0140 538). Pigs from the study were marketed at the end of the study. Housing, management and data acquisition was conducted under farm conditions and in accordance to German legislation (TierSchNutztV) for farm animals. Furthermore, space allowance in rearing (0.58 m^2/pig) and fattening (1.14 m^2/pig) exceeded the minimum requirements by the German legislation, i.e. TierSchNutztV (2017).

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Data curation, writing original draft and creating figures: K.K.

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References

Abriel M, Jais C (2013): Einfluss der Haltungsbedingungen auf das Auftreten von Kannibalismus bei Aufzuchtferkeln. Landtechnik 68(6): 389–394.

Anonymous (2008): Council directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs (Codified version).

Anonymous (2016): Commission Recommendation (EU) 2016/336 of 8 March 2016 on the application of Council Directive 2008/120/EC laying down minimum standards for the protection of pigs as regards measures to reduce the need for tail-docking.

Apple JK, Craig JV (1992): The influence on pen size on toy preference of growing pigs. Appl Anim Behav Sci 35: 149–155.

Averberg U, Scholz T, Ziron M (2018): Futtervorlage bei Mastschweinen. DLG Merkblatt 360. Retrieved from https://www.dlg.org/fileadmin/downloads/landwirtschaft/themen/publikationen/merkblaetter/dlg-merkblatt_360.pdf.

Bates D, Maechler M, Bolker B, Walker S (2015): Fitting linear mixed-effects models using lme4. J Stat Softw 67(1): 1–48. doi: 10.18637/jss.v067.i01.

Beattie VE, Walker N, Sneddon IA (1995): Effects of environmental enrichment on behaviour and productivity of growing pigs. Anim Welfare 4: 207–220.

Blackshaw JK (1981): Some behavioural deviations in weaned domestic pigs. Persistent inguinal nose thrusting, and tain and ear biting. J Anim Sci 33(3): 325–332. doi: 10.1017/S000335610003172X.

Bolhuis JE, Schouten WGP, Schrama JW, Wiegant VM (2005): Behavioural development of pigs with different coping characteristics in barren and substrate-enriched housing conditions. Appl Anim Behav Sci 93(3-4): 213–228. doi: 10.1016/j.applanim.2005.01.006.

Brunberg EI, Rodenburg TB, Rydhmer L, Kjaer JB, Jensen P, Keeling LJ (2016): Omnivores going astray: a review and new synthesis of abnormal behavior in pigs and laying hens. Front Vet Sci 3: 57. doi: 10.3389/fvets.2016.00057.

Bünger B, Zacharias B, Schrade H (2017): Wann fressen Mastschweine wenn sie können wie sie wollen? Aktuelle Arbeiten zur artgemäßen Tierhaltung 2017. KTBL-Schrift 513, Darmstadt, 236–246.

De Briyne N, Berg C, Blaha T, Palzer A, Temple D (2018): Phasing out pig tail docking in the EU – present state, challenges and possibilities. Porcine Health Manag 4: 27. doi: 10.1186/s40813-018-0103-8.

Devor M, Rappaport ZH (1990): Pain and the pathophyiology of damaged nerve. In: Fields HL (ed.), Pain Syndromes in Neurology. Butterworths International Medical Reviews, Butterworth-Heinemann, Oxford, 47–83. Retrieved from http://www.sciencedirect.com/science/article/pii/B9780407011243500095.

Docking CM, Van de Weerd HA, Day JEL, Edwards SA (2008): The influence of age on the use of potential enrichment objects and synchronisation of behaviour of pigs. Appl Anim Behav Sci 110(3-4): 244–257. doi: 10.1016/j.applanim.2007.05.004.

DSBS (2017): Deutscher Schweine Bonitur Schlüssel. Retrieved from https://www.fli.de/fileadmin/FLI/ITT/DSBS_EN_Kombi_170530.pdf.

EFSA (2014): Scientific opinion concerning a multifactorial approach on the use of animal and non-animal based measures to access the welfare of pigs. EFSA J 611: 1–13.

European Commission (2016): Commission Staff Working Document on Best Practices with a View to the prevention of Routine Tail-Docking and the Provision of Enrichment Materials to Pigs. European Commission, Brussels, Belgium.

Fox J, Weisberg S (2019): An {R} companion to applied regression. 3rd ed. Sage, Thousand Oaks, CA.

Fraser D, Phillips PA, Thompson BK, Tennessen T (1991): Effect of straw on the behaviour of growing pigs. Appl Anim Behav Sci 30: 307–318.

Godyń D, Nowicki J, Herbut P (2019): Effects of Environmental Enrichment on Pig Welfare – A Review. Animals (Basel) 9(6): 383. doi: 10.3390/ani9060383.

Haskell MJ, Terlouw EMC, Lawrance AB, Erhard HW (1996): The relationship between food consumption and persistence of post-feeding foraging behaviour in sows. Appl Anim Behav Sci 48: 249–262.

Holm L, Jensen MB, Pedersen LJ, Ladewig J (2008): The importance of a food feedback in rooting materials for pigs measured by double demand curves with and without a common scaling factor. Appl Anim Behav Sci 111(1-2): 68–84. doi: 10.1016/j.applanim.2007.05.013.

Hunter EJ, Jones TA, Guise HJ, Penny RH, Hoste S (2001): The relationship between tail biting in pigs, docking procedure and other management practices. Vet J 161(1): 72–79. doi: 10.1053/tvjl.2000.0520.

Jans-Wenstrup I (2018): Untersuchungen zur Prävention der Caudophagie bei Absetzferkeln unter besonderer Berücksichtigung einer Pelletzulage. Justus-Liebig-Universität, Gießen, Diss.

Jensen MB, Pedersen LJ (2007): The value assigned to six different rooting materials by growing pigs. Appl Anim Behav Sci 108(1-2): 31–44. doi: 10.1016/j.applanim.2006.10.014.

Jensen MB, Studnitz M, Pedersen LJ (2010): The effect of type of rooting material and space allowance on exploration and abnormal behaviour in growing pigs. Appl Anim Behav Sci 123(3-4): 87–92. doi: 10.1016/j.applanim.2010.01.002.

Kauselmann K, Krause ET, Glitz B, Gallmann E, Schrade H, Schrader L (2020): Short-term choice of fattening pigs for additional plant-based materials. Appl Anim Behav Sci 226: 104975. doi: 10.1016/j.applanim.2020.104975.

Kauselmann K, Krause ET, Glitz B, Gallmann E, Schrade H, Schrader L (submitted [a]): Effect of plant-based enrichment materials on exploration in rearing and fattening pigs (Sus scrofa domesticus).

Kritas SK, Morrison RB (2007): Relationship between tail biting in pigs and disease lesions and condemnations at slaughter. Vet Rec 160: 149–152.

Lahrmann HP, Hansen CF, D´Eath RB, Busch ME, Nielsen JP, Forkman B (2018): Early intervention with enrichment can prevent tail biting outbreaks in weaner pigs. Livest Sci 214: 272–277. doi: 10.1016/j.livsci.2018.06.010.

Larsen MLV, Andersen HM, Pedersen LJ (2018): Which is the most preventive measure against tail damage in finisher pigs: tail docking, straw provision or lowered stocking density? Animal 12(6): 1260–1267. doi: 10.1017/S175173111700249X.

Li YZ, Zhang HF, Johnston LJ, Martin W, Peterson JD, Coetzee JF (2017): Effects of tail docking and tail biting on performance and welfare of growing-finishing pigs in a confinement housing system. J Anim Sci 95(11): 4835–4845. doi: 10.2527/jas2017.1571.

Lyons CAP, Bruce JM, Fowler VR, English PR (1995): A comparison of productivity and welfare of growing pigs in four intensive systems. Livest Prod Sci 43: 265–274.

Munsterhjelm C, Brunberg E, Heinonen M, Keeling L, Valros A (2013): Stress measures in tail biters and bitten pigs in a matched case-control study. Anim Welfare 22(3): 331–338. doi: 10.7120/09627286.22.3.331.

Ocepek M, Goold CM, Busančić M, Aarnink AJA (2020): Maize silage as enrichment material improves the welfare of growing-finishing pigs in environmentally-friendly pens. Appl Anim Behav Sci 230. doi: 10.1016/j.applanim.2020.105043.

Olsen AW, Vestergaard EM, Dybkjaer L (2000): Roughage as additional rooting substrates for pigs. Anim Sci 70: 541–456.

Petersen V, Simonsen HB, Lawson LG (1995): The effect of environmental stimulation on the development of behaviour in pigs. Appl Anim Behav Sci 45: 215–224.

Pinheiro J, Bates D, DebRoy S, Sarkar D, Team RC (2019): nlme:Linear and nonlinear mixed effects models. R package version 3.1-141.

Prunier A, Averos X, Dimitrov I, Edwards SA, Hillmann E, Holinger M, Ilieski V, Leming R, Tallet C, Turner SP, Zupan M, Camerlink I (2020): Review: Early life predisposing factors for biting in pigs. Animal 14(3): 570–587. doi: 10.1017/S1751731119001940.

R Core Team (2019): R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Schmolke SA, Li YZ, Gonyou HW (2003): Effect of group size on performance of growing-finishing pigs. J Anim Sci 81: 874–878.

Schouten WGP (1986): Rearing conditions and behaviour in pigs. Ph.D. thesis, Agricultural University Wangeningen, Netherlands.

Schrøder-Petersen DL, Simonsen HB (2001): Tail biting in pigs. Vet J 162(3): 196–210. doi: 10.1053/tvjl.2001.0605.

Schrøder-Petersen DL, Simonsen HB, Lawson LG (2010): Tail-in-mouth behaviour among weaner pigs in relation to age, gender and group composition regarding gender. Anim Sci 53(1): 29–34. doi: 10.1080/09064700310002017.

Scott K, Taylor L, Gill BP, Edwards SA (2006): Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems. 1. Hanging toy versus rootable substrate. Appl Anim Behav Sci 99(3-4): 222–229. doi: 10.1016/j.applanim.2005.10.013.

Scott K, Taylor L, Gill BP, Edwards SA (2007): Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems. 2. Ratio of pigs to enrichment. Appl Anim Behav Sci 105(1-3): 51–58. doi: 10.1016/j.applanim.2006.05.042.

Scott K, Taylor L, Gill BP, Edwards SA (2009): Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems. 3. Hanging toy versus rootable toy of the same material. Appl Anim Behav Sci 116(2-4): 186–190. doi: 10.1016/j.applanim.2008.07.002.

Simonsen HB, Klinken L, Bindseil E (1991): Histopathology of intact and docked pigtails. Br Vet J 147: 407–412.

Studnitz M, Jensen MB, Pedersen LJ (2007): Why do pigs root and in what will they root? Appl Anim Behav Sci 107(3-4): 183–197. doi: 10.1016/j.applanim.2006.11.013.

TierSchNutztV (2017): Tierschutz-Nutztierhaltungsverordnung in the version published on 22. August 2006 (BGBl. I S. 2043), last amended by Article 3(2) of the Act of 30. June 2017 (BGBl. I S. 2147).

Trickett SL, Guy JH, Edwards SA (2009): The role of novelty in environmental enrichment for the weaned pig. Appl Anim Behav Sci 116(1): 45–51. doi: 10.1016/j.applanim.2008.07.007.

Valros A (2018): Tail biting. In: Špinka M, Camerlink I (eds.), Advances in Pig Welfare. Woodhead Publishing, Cambridge, 137–166. https://doi.org/10.1016/C2015-0-05682-9.

Valros A, Ahlström S, Rintala H, Häkkinen T, Saloniemi H (2007): The prevalence of tail damage in slaughter pigs in Finland and associations to carcass condemnations. Acta Agric Scand Section A – Anim Sci 54(4): 213–219. doi: 10.1080/09064700510009234.

Van de Perre V, Driessen B, Van Thielen J, Verbeke G, Geers R (2011): Comparison of pig behaviour when given a sequence of enrichment objects or a chain continuously. Anim Welfare 20: 641–649.

Van de Weerd HA, Docking CM, Day JEL, Avery PJ, Edwards SA (2003): A systematic approach towards developing environmental enrichment for pigs. Appl Anim Behav Sci 84(2): 101–118. doi: 10.1016/s0168-1591(03)00150-3.

Van de Weerd HA, Docking CM, Day JEL, Breuer K, Edwards SA (2006): Effects of species-relevant environmental enrichment on the behaviour and productivity of finishing pigs. Appl Anim Behav Sci 99(3-4): 230–247. doi: 10.1016/j.applanim.2005.10.014.

Veit C, Traulsen I, Hasler M, Tölle K-H, Burfeind O, Beilage Eg, Krieter J (2016): Influence of raw material on the occurrence of tail-biting in undocked pigs. Livest Sci 191: 125–131. doi: 10.1016/j.livsci.2016.07.009.

Veit C, Marahrens M, Schwarzlose I, Krause ET, Schrader L (2017): Alternativen zur betäubungslosen Ferkelkastration in Deutschland: Überblick zum aktuellen Stand der Forschung. Berl Munch Tierarztl Wochenschr 131. doi: 10.2376/0005-9366-17062.

Young RJ, Carruthers J, Lawrence AB (1994): The effect of a foraging device (the Edinburgh football) on the behaviour of pigs. Appl Anim Behav Sci 39: 237–247.

Zwicker B, Gygax L, Wechsler B, Weber R (2012): Influence of the accessibility of straw in racks on exploratory behaviour in finishing pigs. Livest Sci 148(1-2): 67–73. doi: 10.1016/j.livsci.2012.05.008.

Zwicker B, Gygax L, Wechsler B, Weber R (2013): Short- and long-term effects of eight enrichment materials on the behaviour of finishing pigs fed ad libitum or restrictively. Appl Anim Behav Sci 144(1-2): 31–38. doi: 10.1016/j.applanim.2012.11.007.

5. Tasty straw pellets – Exploration of flavoured rooting material by pigs

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Abstract

Tail biting is a common problem in pigs kept in conventional fully slatted pens. Suitable enrichment materials can help to prevent the occurrence of this behavioural disorder by encouraging pigs to increase exploration behaviour. We investigated whether additional flavours can increase exploration behaviour in undocked pigs. Therefore, we offered straw pellets flavoured with either fried onion (FO), strawberry (SB), ginger (GI), almond (AL), vanilla (VA) or without flavour (control) during rearing (eight groups in total) and fattening (16 groups in total). Flavoured pellets were offered in an altering order during intervals of one week in material dispensers. Exploration duration at the material dispensers was continuously recorded via an ultra-high-frequency radio-frequency identification (UHF-RFID) system. Pigs were weighed weekly and their tail lengths and tail injuries were scored in four categories. For analysis, changes in tail length score compared to the previous week were calculated as Δ-tail length. The different flavours affected pigs' exploration durations in both rearing (factor flavour, $P<0.0001$) and fattening (factor flavour, $P<0.0001$). Highest exploration durations during rearing were recorded when straw pellets were flavoured with FO and AL compared to all others. During fattening exploration duration was highest towards controls without significant difference to SB. Exploration durations additionally were affected by temporal effects, i.e. week and day during rearing (both factors: $P<0.0001$) and fattening (both factors: $P<0.0001$). During rearing highest exploration durations were recorded in the first week and on the first day within week after changing the flavour of the straw pellets. During fattening period exploration durations varied between weeks and within weeks. The highest durations were recorded at the end of weeks, i.e. on the fifth and seventh day after material change. During rearing, tail injuries were affected by week ($P<0.0001$). From the fourth week of rearing, the prevalence of tail injuries significantly increased. During the fattening period, tail injuries were affected by flavour ($P<0.05$). Fattening pigs had fewest tail injuries after straw pellets flavoured with AL were offered. Altogether, based on the exploration durations, rearing pigs showed different preferences for the flavoured straw pellets but highly explored flavours differed between rearing and fattening pigs. Despite a weekly change of the flavour of straw pellets, exploration durations decreased during rearing but increased again in the transition between rearing and fattening. Thus, straw pellets with alternating flavours are a suitable possibility to provide environmental enrichment to pigs but will not prevent tail biting.

Keywords: aromatized enrichment, fattening, rearing, *Sus scrofa* domesticus, tail biting

Implications

We added different flavours to straw pellets in weekly intervals in order to provide attractive rooting material. Flavours increased exploration duration in rearing pigs and thus represent a suitable enrichment. Exploration durations for flavours/control differed between rearing and fattening pigs. Attractiveness in means of exploration time of the enrichment material could be maintained at a constant level throughout rearing and fattening period. Our results indicate that the change of added flavours may be more important than offering certain flavours. Offering changing flavours on straw pellets may increase novelty and is a suitable way to maintain exploration in conventionally housed pigs.

Introduction

Commercial housing systems of farm animals are often criticized by the public with regard to animal welfare. Accordingly, 82 % of European citizens are the opinion that the protection of animal welfare should be improved (European European Commission, 2016). One of the most severe animal welfare issues in commercial pig production systems is tail biting (Fraser, 1983) that is tremendously prevalent in undocked pigs (Veit et al., 2016), but even could occur in tail docked pigs (Hunter et al., 2001; Larsen et al., 2018). Many factors can contribute to tail biting (Brunberg et al., 2016). However, exploration and foraging are highly motivated behaviours in pigs and the provision of suitable enrichment material is a possibility to reduce the occurrence of tail biting (Fraser et al., 1991; Larsen et al., 2018). Enrichment materials which are changeable, chewable, edible, manipulable or odorous are recommended most for pigs (Fraser et al., 1991; Jensen and Pedersen, 2007; Studnitz et al., 2007; Van de Weerd et al., 2003). Plant-based enrichment materials meet these requirements and are also preferred by pigs in comparison to non-plant-based materials (Scott et al., 2006). Straw is considered to be very suitable as enrichment material for pigs (e.g. Fraser et al., 1991; Hunter et al., 2001). Especially long-stalk straw is recommended over chopped straw due to the quality of straw-directed behaviours of pigs and regarding tail biting (Day et al., 2008). Nevertheless, long-stalk straw is seldom offered in commercial pens with fully slatted floors for practicable reasons as it can plug the slurry system. While pigs show no preference for either chopped or long-stalk straw (Lahrmann et al., 2015), they prefer pelletized materials over chopped materials (Kauselmann et al., 2020a). Beside being favoured by pigs, pellets have the practicable advantage that they dissolve in the manure and, thus, cause almost no problems in the slurry system when falling through the slatted floor.

Pigs are macrosmatic animals having better olfactory than visual capacities (Croney et al., 2003). Pigs gustatory preferences are apparent for sweet tastes (Hellekant and Danilova, 1999; Tinti et al., 2000) and umami (Hellekant and Danilova, 1999), while they reject bitter flavours (Nelson and Sanregret, 1997; Tinti et al., 2000). When given a choice, pigs explore containers including natural flavours (e.g. grass, dried mushrooms or moist soil) or synthetic strawberry aroma more than other synthetic aromas (Nowicki et al., 2015). Furthermore, an aromatic additive can increase exploration of plant-based enrichment material (Blackie and de Sousa, 2019). These effects of flavours on the behavior of pigs may offer an opportunity to make enrichment materials more attractive for commercially housed pigs, i.e. to increase and sustainably maintain exploration duration and, thus, may represent a potential tool to reduce manipulative behaviours against penmates.

In this study we offered commercially housed rearing and fattening pigs straw pellets of different flavours to test the effect of flavours on their exploration duration. We used an ultra-high-frequency radio-frequency identification (UHF RFID) system to continuously measure the pigs' exploration behaviour. Furthermore, tail damages were analyzed in relation to the respective flavours. We hypothesized that pigs show different exploration durations indicating different preferences for certain flavours applied to straw pellets. We expect that these additional flavours increase exploration durations and may also reduce tail damages.

Material and Methods

Animals and housing

In this study, 192 crossbred pigs (German Piétrain x German Hybrid) with intact tails were housed in buildings with forced ventilation and daylight windows at the Bildungs- und Wissenszentrum - Schweinehaltung, Schweinezucht - Boxberg (LSZ), Germany. The pigs were tested in two successive replicates with randomly mixed sexes (replicate 1: 96 animals: 44 females and 52 castrated males; replicate 2: 96 animals: 51 females and 45 castrated males) from January 2018 to August 2018 (Table 1). In each replicate, pigs were housed in four pens during rearing (24 piglets per pen) and eight pens during fattening (12 pigs per pen).

At weaning at four weeks of age, piglets were individually weighted and equipped with UHF RFID tags (MS Tag Round UHF, MS Schippers, Netherlands) for individual identification. Weaned piglets weighting on average 7.7 kg (± 1.1 kg SD) were randomly divided in one of four identical rearing pens (24 piglets per pen) with 15 m^2 (5 m x 3 m) floor space (Fig. 1a), respectively. Accordingly, space allowance during rearing was 0.6 m^2/pig. The rearing pens were continuously numbered across the two replicates (8 PenIDs in total). The floor consists of perforated plastic floor (7.5 m^2, with 38.5 % perforation), slatted concrete floor (3.0 m^2, with 17.0 % perforation) and partly slatted concrete floor (4.5 m^2, with 7.0 % perforation) under heated covering. The piglets had free access to water from two drinking bowls (“Suevia 92R”, Suevia Haiges GmbH, Kirchheim/Neckar, Germany) and two additional nipple drinkers and were fed *ad libitum* with mashed feed in two phases. After two weeks of rearing feed composition changed (see electronic supplementary material Table S1 for detailed information). Animal:feeding place ratio at the feeder was 2.4:1.

At an age of eleven weeks, pigs weighted on average 29.1 kg (± 3.9 kg SD) and were split up in eight fattening pens (twelve pigs per pen, Fig. 1b). The Fattening pens were continuously numbered across the two replicates (16 PenIDs in total). Pigs of the same rearing pens were randomly assigned to two fattening pens, thus, the pigs remained in groups with familiar conspecifics and received the same treatment prior to fattening. Fattening pens had 15 m^2 floor space (Fig. 1b) resulting in a space allowance of 1.1 m^2/pig. The floor consists of fully slatted concrete floor (with 17 % perforation). During the whole fattening period, pigs had free access to water from four nipple drinkers and were fed *ad libitum* from a single feeder with pelleted concentrate. When the pigs reached an average weight of about 80 kg, feed composition changed (see electronic supplementary material Table S1). At this time, pigs had an age of about 18 weeks. After eleven weeks of fattening, data collection stopped, i.e. when first animals reached slaughter weight and were taken out from the groups. At this age of 22 weeks, fattening pigs had an average live weight of 102.2 kg (± 9.2 kg SD). All pens during rearing and fattening were identically equipped with two sisal ropes and a piece of wood hanging on metal chains. Rearing pens were additionally equipped with a rubber bar.

Table 1. Dates of data collection, i.e. exploration duration of pigs for respective flavoured rooting materials, in rearing and fattening pens with the corresponding times of sunrise and sunset in Germany.

Period	Date	sunrise	sunset	mean sunrise[1]	mean sunset[1]
Rearing				6:28	19:19
Replicate 1					
Begin	31.01.2018	7:37	17:00		
End	21.03.2018	6:46	19:33		
Replicate 2					
Begin	12.04.2018	6:22	19:50		
End	30.05.2018	5:09	20:56		
Fattening				5:44	20:27
Replicate 1					
Begin	21.03.2018	6:46	19:33		
End	06.06.2018	5:05	21:02		
Replicate 2					
Begin	30.05.2018	5:09	20:56		
End	15.08.2018	5:59	20:19		

[1] mean values were calculated separately for rearing and fattening, using the times of sunrise and sunset of the two replicates respectively.

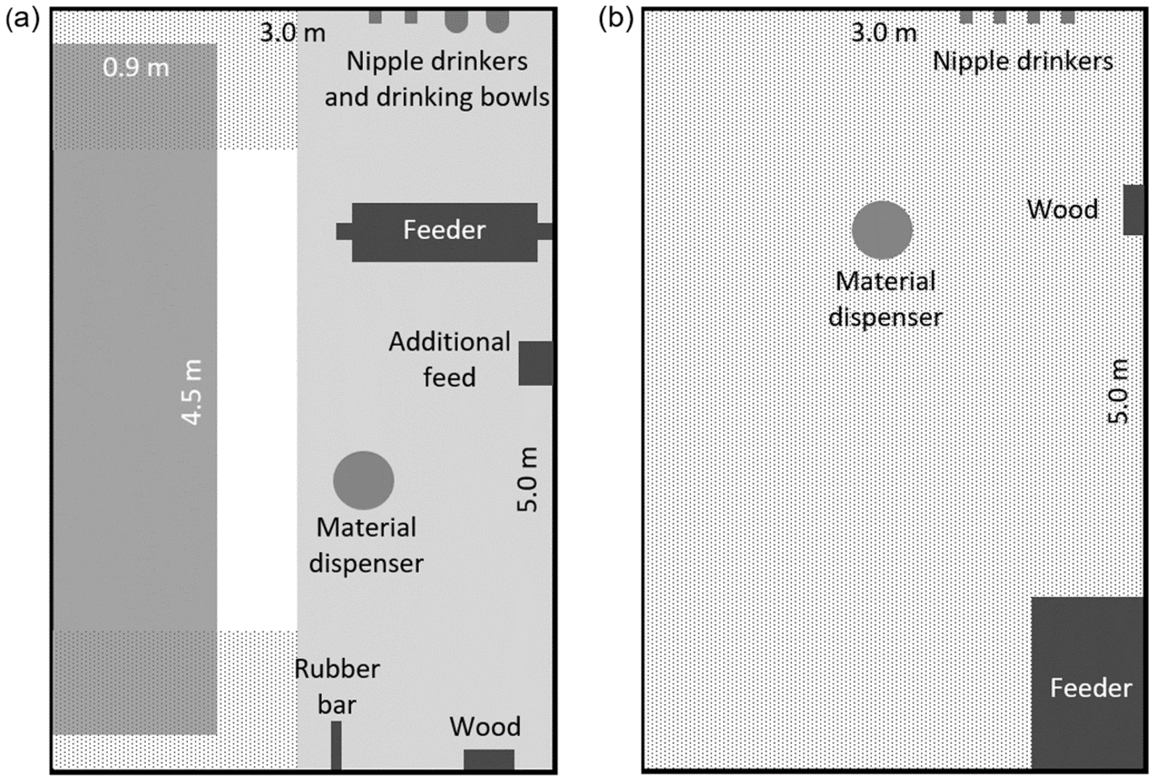

Fig. 1. Schematic drawing of the (a) rearing and (b) fattening pens of the pigs with partly slatted concrete floor of 7% (white) and 17% perforation (dotted). A lying area was equipped with a heated cover (transparent dark grey) and a slatted plastic floor with 38.5% perforation (light grey).

Enrichment material and data collection

We tested straw pellets which were aromatized with one of five different flavours and as control we used straw pellets wetted with only water and thus without additional flavour (control). To aromatize the straw pellets, we used synthetic nature-identical food flavourings (aroma-shopping GmbH, Rödinghausen, Germany), i.e. fried onion (FO; “Bratzwiebel”, order number: AS10360), strawberry (SB; “Erdbeere”, order number: AS10100), vanilla (VA; “Vanille”, order number: AS10248), almond (AL; “Mandel”, order number: AS10309) and ginger (GI; “Ingwer”, order number: AS10367). We mixed the food flavourings with water to get a flavour content of one percent in the flavoured water (detailed information about flavour ingredients is given in the electronic supplementary material Table S2). The straw pellets were aromatized with the flavoured water at a ratio of 1:50 (flavoured water:straw pellets) under constant turning by using a pressure sprayer. Thereafter, the flavoured pellets were sealed hermetically and immediately before offering to the pigs, they were mixed with unflavoured straw pellets at a ratio of 1:1. Straw pellets were offered to the pigs continuously from rearing to fattening, while the flavours were alternatingly changed weekly in different order in each pen according to an experimental plan (see electronic supplement Table S3). Initially, the flavors were assigned to the pens in a random order. Afterwards flavours were assigned in a systematic order considering that across both replicates each flavour occurs at least in one pen at a given time. The resulting sequence of flavours differed between the replications and was repeated in each pen after six weeks, i.e. after all flavours were already available once. On days of material change, all remains of flavoured straw pellets were removed from the rooting area and the storage tube to refill it with fresh straw pellets of a different flavour. The same method was used during fattening (Table S3), with the exception that always two of the eight pens received the same flavour applied on the straw pellets. The flavour of the straw pellets usually was changed every Thursday, which was the first day of a one-week interval. Since the material dispensers were not refilled at the weekends, a stock of flavoured straw pellets was filled into the storage tube on Fridays to ensure the supply during the weekend.

In the center of each rearing and fattening pen, identical material dispensers were installed (Fig. 1, for photos see electronic supplementary material Fig. S1), which consisted of a 100 cm high PVC storage tube with a diameter of 25 cm that was manually filled with flavoured straw pellets, as described above, so that pigs continuously had pellets to their disposal. The material dispensers were constructed as described in Kauselmann et al. (2021). Briefly, a 10 cm high cement ring with an inner diameter of 63 cm was installed around the storage tube on the floor with a plastic mat underneath to prevent the straw pellets from falling through the slatted floor. Thus, a circular rooting area was created and pigs could root the offered pellets from the storage tube through a 1.5 cm wide gap on the ground of the dispenser. Based on recommendations for feeding places (Averberg et al., 2018) a trough length of 18 cm per pig in the rearing and 33 cm in the fattening period was used to calculate the animal:dispenser place ratio (1.7:1 in the rearing pens and 1.5:1 in the fattening pens).

In the storage tube of the material dispenser, a dust- and waterproofed UHF RFID antenna (Kathrein MiRa ETSI, Kathrein Solutions GmbH, Ismaning, Germany) was installed at a height of 50 cm above the floor to read the tags attached to both ears of the pigs when they stayed at the material dispenser. Based on the start and end time of stays at the dispenser the duration of each individual at the material dispenser was calculated. When a stay at the material dispenser of an animal ended and re-started within 30 seconds, these two events were merged into one duration. The antenna transferred the collected data to a converter and an UHF RFID reader and via a software application (Phenobyte GmbH & Co KG., Ludwigsburg, Germany) data were stored in a database (see electronic supplementary material S1 for detailed information on the UHF RFID system). The optimal technical parameters for the UHF RFID antennae were validated in advance (Kauselmann et al., 2021). Accordingly, best sensitivity (70.7 % in rearing and 79.3 % in fattening) and specifity (99.4 % in rearing and 99.5 % in fattening) were achieved by using an output power of 22.4 decibel milliwatt (dBm) at the antennae.

During the 18 weeks of continuous RFID data collection, the pigs were weekly individually weighted and tail status was scored according to the Deutscher Schweine Bonitur Schlüssel (DSBS, 2017), always on days when the flavoured pellets were changed. Tail length was evaluated following the DSBS using five categories: (0) full/natural length, (1) length loss up to one-third, i.e. also minimal losses at the tassel were included, (2) length loss up to two-thirds, (3) length loss more than two-thirds and (4) total loss with a maximum of 1 cm leftover for piglets in the rearing and 2 cm leftover for pigs in the fattening. However, it should be noted that in category 1 often only losses of a small part of the tail tip were observed and category 4 was never recorded. Tail injuries were also recorded according to the DSBS in four categories: (0) no injuries, (1) superficial perforation of the skin, punctually or in the form of a line, (2) deeper perforation of the skin, the size of the injury does not exceed the diameter of the tail at the respective location, and (3) deeper perforation of the skin, the size of the injury exceeds the diameter of the tail at the respective location.

The daily weight gains of the pigs were calculated for the period of data collection, separately for the rearing and fattening period.

Housing and management of the animals was conducted in accordance to German legislation for farm animals (TierSchNutztV, 2017). Space allowance (0.6 m^2/pig in rearing pens and 1.1 m^2/pig in fattening pens) and additional offered enrichment materials (sisal ropes, wood and rubber bar in rearing pens and sisal ropes and wood in fattening pens) exceeded the minimal legal requirements. Animals were daily visually inspected for health issues. In case of tail biting, additional materials such as paper bags, mineral feed, squeezed oats and zeolite were offered. In case biters could be identified (3 piglets each during rearing and fattening), they were removed from groups and kept in a separate pen. Pigs with severely bitten tails were also removed from groups and medicated in a separate pen.

Statistical analysis

The time each pig was recorded at the material dispenser was summed up to a daily (24 hour) value (exploration duration). Thus, for the statistical analysis we used the exploration duration in a period of seven days after changing the flavour of the straw pellets for each pig and each day, separately in rearing and fattening. To analyze the effect of each flavour on tail length we calculated the difference of recorded tail length categories to the previous one-week interval and used the resulting Δ-tail length per week. For example, if a pig had a tail length of category 1 after week 2 and of category 2 after week 3, a change of tail length, i.e. Δ-tail length, of 1 (2 – 1) was related to week 3. Calculation of Δ-tail length should avoid misinterpretation of the tail length data as tails that once showed a loss in length will remain short. For scored tail injuries we did not calculate differences to the previous week as injuries may heal over time.

The data of daily exploration durations in the rearing and fattening period were log-transformed (log(x+1)) to reach normal distribution of residuals, checked by visual inspection of the qq-plots. However, the qq-plot for exploration duration in fattening showed a minor deviation from normal distribution. However, such minor deviations have been shown to not crucially affect linear mixed effects models (LME) (Schielzeth et al., 2020). All data were analyzed separately for rearing and fattening. The detailed hierarchical model structure is exemplarily shown for rearing in the electronic supplement (electronic supplementary Fig S2). The used LMEs included the exploratory variables (i) flavour of the straw pellets in the material dispenser (6-level factor; FO, SB, GI, AL, VA and control), (ii) week (week in which a flavour was offered), (iii) days of week (continuously numbered days of provided flavour within week) and (iv) two-way interactions between the explanatory variables. Since pigs within pens were not independent of each other, (i) animal (AnimalID), (ii) pen (PenID) and (iii) week were considered as nesting random factors. In case of significant differences, post hoc pairwise comparisons were calculated using pairwise t-tests. The results are given as median exploration duration.

Due to a high number of zero values, Δ-tail lengths of rearing and fattening pigs and tail injuries of rearing pigs were transformed ((Δ-tail length + 1) and (tail injuries + 1)) to avoid errors in the statistical calculation. The weights of the animals after each week were log transformed (log(x+1)).

To analyze Δ-tail lengths and tail injuries generalized linear mixed models (GLMMs) with Poisson distribution were used separately for the rearing and fattening period. The explanatory variables (i) flavour of the straw pellets in the material dispenser (6-level factor; FO, SB, GI, AL, VA and control), (ii) week (week in which a flavour was offered) and (iii) two-way interaction were used in the models. Weight of the animals after each week after flavours were changed was also considered as exploratory variable without calculating interactions in the model to analyze Δ-tail length of rearing pigs. Animal and pen were considered as nesting random factors. As many zero values in the fattening model for tail injuries caused a low variance between the weeks, convergence problems in the model appeared. Therefore, we had to combine the injury scores 1, 2 and 3 to only 1 (i.e. injury apparent) and considered a binomial distributed model here (0 = no injuries, 1 = injuries) with flavour as explanatory variable.

For all statistical analyses R version 3.3.1 (R Core Team, 2019) and the packages nlme (Pinheiro et al., 2019) and lme4 (Bates et al., 2015) were used. The package car (Fox and Weisberg, 2019) was used to calculate the p-values for the GLMMs.

Results

Effects on exploration duration of piglets during rearing

The flavour of the offered straw pellets significantly affected the exploration duration piglets spent at the material dispenser (LME, factor flavour, $F_{5, 1095} = 9.6$, $P < 0.0001$, Fig. 2). Post-hoc pairwise comparisons showed highest exploration duration per pig and day for straw pellets flavoured with fried onion (18.0 minutes/day) and almond (17.4 minutes/day). Lowest exploration durations per pig were recorded when straw pellets were flavoured with vanilla (13.1 minutes/day) or when the control, i.e. straw pellets without aroma (13.9 minutes/day), was offered. Exploration durations of piglets differed between the seven weeks (LME, factor week, $F_{6, 1095} = 51.7$, $P < 0.0001$, Fig. 3). Piglets spent most time at the material dispenser during the first week (26.7 minutes median exploration duration per pig and day, see electronic supplementary material Table S4) compared to the following six weeks. The days within the week affected the time piglets were recorded at the material dispenser (LME, factor day, $F_{6, 7770} = 64.7$, $P < 0.0001$, Fig. 4). The highest median exploration durations per pig and day were found during the first day after change of flavour (18.4 minutes), thereafter exploration durations decreased until day 4 (12.5 minutes) and increased again to day 6 (17.5 minutes).

There were interactions between flavour and week (LME, $F_{30, 1095} = 14.7$, $P < 0.001$). Highest exploration durations were recorded for straw pellets flavoured with fried onion in week 1, strawberry in week 2, vanilla in week 3 and ginger in week 4. In week 5 and 6 the differences of exploration durations between the flavours were lowest, however, pigs showed highest exploration durations when the straw pellets were flavoured with strawberry and almond in week 5 and fried onion in week 6. In week 7, the straw pellets without added flavour were explored most.

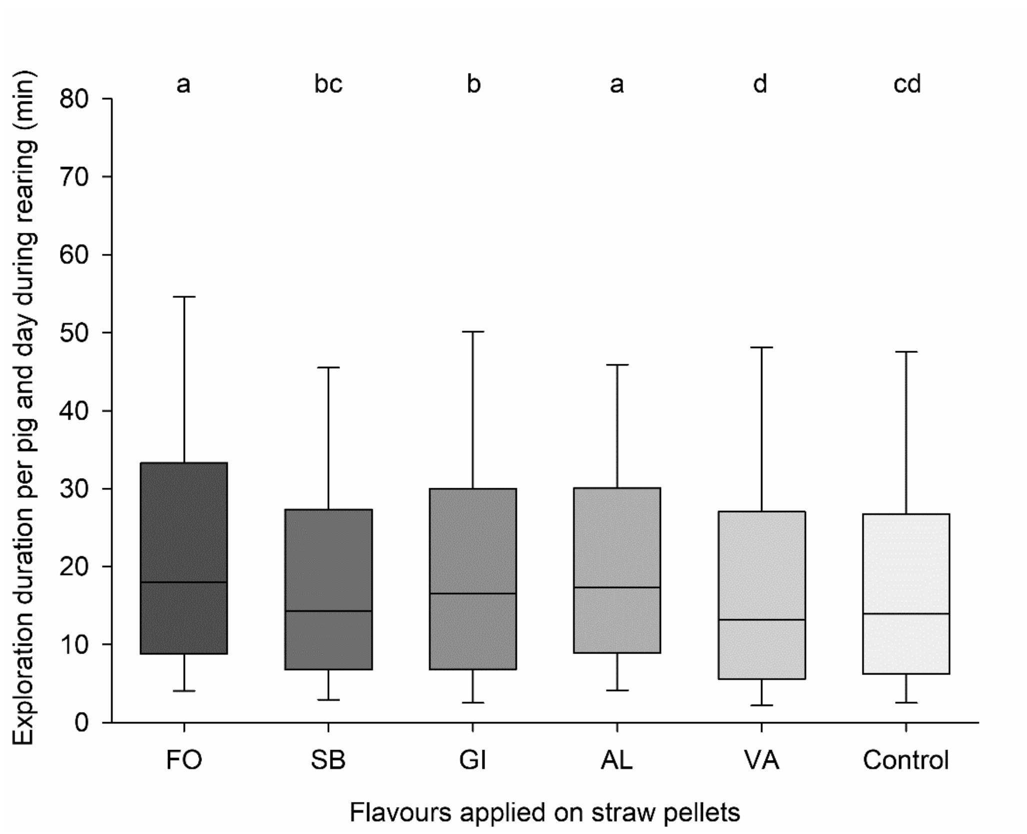

Fig. 2. Exploration duration (median per pig and day) rearing pigs spend at the material dispenser filled with straw pellets flavoured with fried onion (FO), strawberry (SB), ginger (GI), almond (AL), vanilla (VA) and control, i.e. straw pellets without flavour. The horizontal line in the box represents the median, while the boxes and the whiskers represent the quartiles. Outliers, i.e. data points that lie outside the 10^{th} and 90^{th} percentiles are not shown. Different letters indicate significant differences between the flavours applied on straw pellets (pairwise t-test; $P<0.05$).

There are also significant interactions between flavour and day within week (LME, $F_{30, 7770} = 7.7$, $P < 0.001$). On all days, except for day 3, FO was the most explored flavour. In addition to FO, high exploration durations were recorded for GI and straw pellets without additional flavour (control) on day 2, for AL on day 6 and for GI on day 7. On day 3, pigs showed highest exploration durations for the straw pellets without additional flavour (control).

In addition, there were significant interactions between week and day within week (LME, $F_{36, 7770} = 21.2$, $P < 0.001$). During week 5, highest exploration duration was recorded on day 2. In the remaining weeks, highest exploration durations were recorded on days 1, 6 or 7.

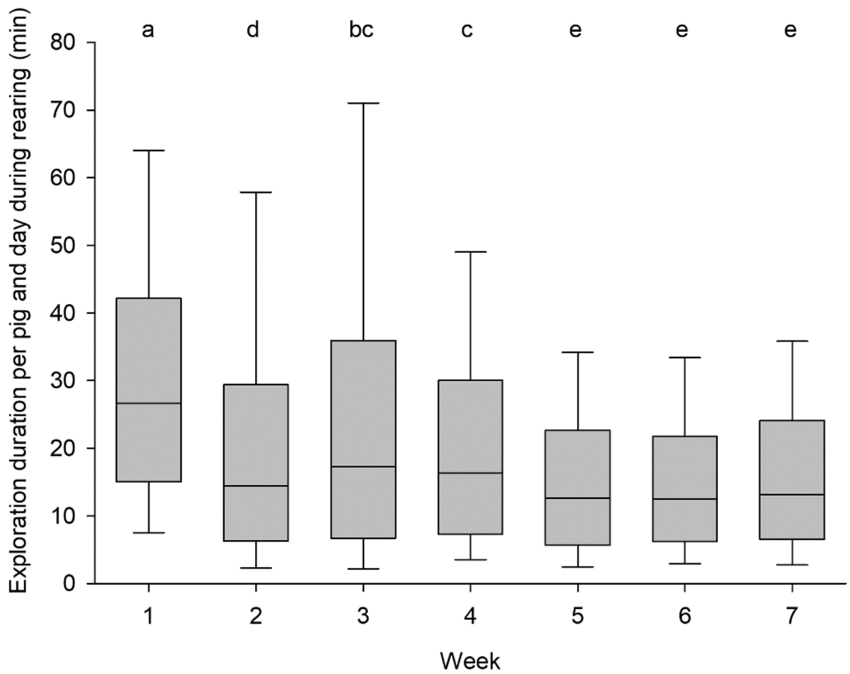

Fig. 3. Exploration duration (median per pig and day) rearing pigs spend at the material dispenser throughout seven weeks of rearing period. The horizontal line in the box represents the median, while the boxes and the whiskers represent the quartiles. Outliers, i.e. data points that lie outside the 10th and 90th percentiles are not shown. Different letters indicate significant differences between the weeks (pairwise t-test; P<0.05).

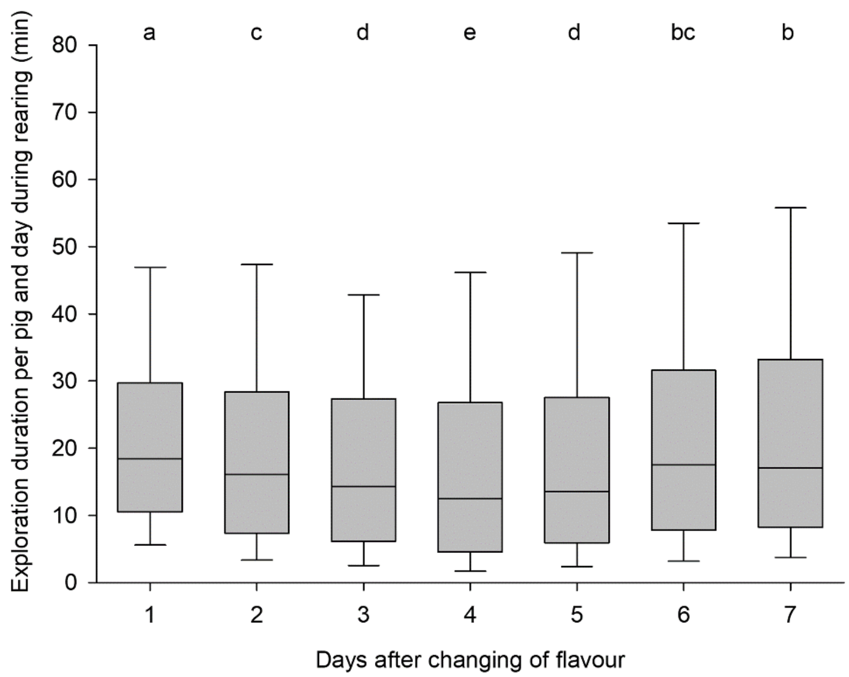

Fig. 4. Exploration duration (median per pig and day) rearing pigs spend at the material dispenser during the days of a week. Flavoured straw pellets were changed at day 1 and offered for 7 days.

The horizontal line in the box represents the median, while the boxes and the whiskers represent the quartiles. Outliers, i.e. data points that lie outside the 10^{th} and 90^{th} percentiles are not shown. Different letters indicate significant differences between the days within week (pairwise t-test; $P<0.05$).

Effects on tail status during rearing period

Δ-tail length of rearing piglets was neither affected by flavour (GLMM, factor flavour, $\chi^2_5 = 0.03$, $P = 1.0$), week (GLMM, factor week, $\chi^2_6 = 1.0$, $P = 1.0$) nor weight of the animals (GLMM, factor weight, $\chi^2_1 = 0.07$, $P = 0.8$). During the rearing period, piglets reached daily weight gains of an average of 442.1 g (± 70.4 g SD). After rearing, 57.9 % of pigs had tails with natural length (category 0) and 37.7 % had a partial loss up to one third (category 1). Flavour had no effect on tail injuries (GLMM, factor flavour, $\chi^2_5 = 4.0$, $P = 0.6$; electronic supplementary Fig. S3). Tail injuries during rearing were affected by week (GLMM, factor week, $\chi^2_6 = 59.8$, $P < 0.0001$; electronic supplementary Fig. S4). Tail injuries (categories 1 and 2) occurred from the first week of rearing (6.8 %), increased at week four of rearing (23.8 %) and reached a peak at the fifth week of rearing (33.3 %). We also found a significant interaction between week and flavour (GLMM, $\chi^2_{30} = 122.6$, $P < 0.0001$). In week 1, 2, 3 and 6, most rearing piglets had no injuries at the tails (category 0). Category 3 was most often scored when piglets received straw pellets with VA in week 4 (79.2 % of the piglets) and when pigs received straw pellets with FO (52.2 % of the piglets) in week 5. When straw pellets were flavoured with VA in week 7, category 2 was scored most often (33.3 %).

Effects on exploration duration of pigs during fattening

During fattening, exploration durations of pigs were affected by flavour of the provided straw pellets (LME, factor flavour, $F_{5, 1662} = 9.1$, $P < 0.0001$, Fig. 5). Post-hoc pairwise comparisons showed that exploration durations of fattening pigs were highest when straw pellets without flavour were offered (20.8 minutes median exploration duration per pig and day), while there was no significant difference to straw pellets flavoured with strawberry (19.9 minutes median exploration duration per pig and day). Lowest median exploration durations were recorded for straw pellets flavoured with almond (17.5 minutes per pig and day).

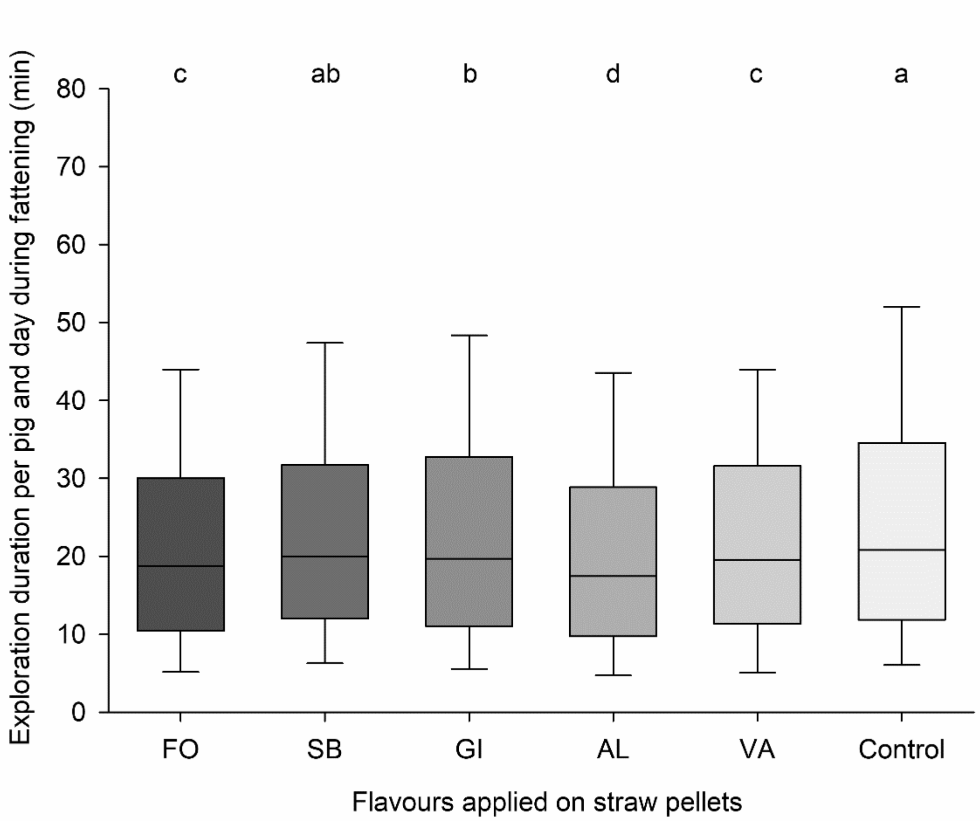

Fig. 5. Exploration duration (median per pig and day) fattening pigs spend at the material dispenser filled with straw pellets flavoured with fried onion (FO), strawberry (SB), ginger (GI), almond (AL), vanilla (VA) and control, i.e. straw pellets without flavour. The horizontal line in the box represents the median, while the boxes and the whiskers represent the quartiles. Outliers, i.e. data points that lie outside the 10^{th} and 90^{th} percentiles are not shown. Different letters indicate significant differences between the flavours applied on straw pellets (pairwise t-test; $P<0.05$).

The week affected the exploration duration of pigs during fattening (LME, factor week, $F_{10, 1662} = 56.6$, $P < 0.0001$). The lowest exploration durations were recorded in the first week of fattening (week 1), where the median exploration duration per pig and day was 13.7 minutes (electronic supplementary Table S4). Thereafter, exploration durations varied, reached a peak from week 4 to week 6 and decreased again. Exploration duration was affected by the day within the week (LME, factor day, $F_{6, 11064} = 11.4$, $P < 0.0001$). On the fifth day after a flavour of the straw pellets was changed, the highest median exploration duration per pig and day was recorded (20.6 minutes/day), without significant differences to the seventh day (20.3 minutes/day).

There were interactions between flavour and week (LME, $F_{50,\ 1662}$ = 16.6, P < 0.0001). Highest exploration durations for straw pellets without flavour were recorded in week 6 and 11. In week 1 and 10 pigs showed the highest exploration durations when straw pellets with strawberry flavour were offered. Highest exploration durations in week 3 were recorded when straw pellets were flavoured with almond. In week 5 and 7 highest exploration durations were recorded for straw pellets flavoured with vanilla and in week 2 and 9 straw pellets with ginger reached highest exploration durations. In week 4 pigs explored straw pellets with ginger flavour or without flavour most and in week 8 straw pellets without flavour or vanilla.

There were also significant interactions between flavour and day within week (LME, $F_{30,\ 11064}$ = 4.0, P < 0.001). During day 1, all flavours and straw pellets without flavor were explored at the same level. During day 2 to day 5, pigs reached highest exploration durations for straw pellets without added flavour. Highest exploration durations were recorded when straw pellets with strawberry or ginger were offered during day 6. During day 7 highest exploration durations were recorded when straw pellets flavoured with strawberry, ginger or vanilla were offered.

There were significant interactions between week and day within week (LME, $F_{60,\ 11064}$ = 27.2, P < 0.0001). In all weeks the exploration durations of the pigs varied within a small range. Highest exploration durations were recorded during day 5 and 7 in week 1, during day 1 in week 2, 3, 7 and 9, during day 3 in week 4, during day 6 in week 5, during day 7 in week 6, during day 5 in week 8, during day 1 and 7 in week 10 and during day 3, 5 and 7 in week 11.

Effects on tail status during fattening period

Δ-tail length was neither affected by flavour of straw pellets (GLMM, factor flavour, χ^2_5 = 1.0, P = 1.0), week (GLMM, factor week, χ^2_{10} = 0.8, P = 1.0), nor weight of the animals (GLMM, factor weight, χ^2_1 = 0.0, P = 1.0). The pigs reached daily weight gains of an average of 949.5 g (± 100.1 g SD) during fattening. At the end of fattening, 22.6 % of the pigs had tails with natural length (category 0) and 66.7 % had a partial loss up to one third (category 1). Tail injuries during fattening were influenced by flavour of straw pellets (GLMM, factor flavour, χ^2_5 = 12.1, P < 0.05;

electronic supplementary Fig. S5)). Most tails without injuries (category 0) were scored when AL was offered.

Exploration within days in rearing and fattening pigs

Mean exploration duration at the material dispenser during rearing was 23.2 minutes (± 0.3 minutes SE) per pig and day. Within days, exploration showed peaks about six hours after sunrise (1.3 minutes/hour (± 0.03 minutes SE) exploration per pig; Fig. 6a) and three hours before sunset (2.3 minutes/hour (± 0.04 minutes SE) exploration per pig). Calculated time for sunrise and sunset for the period of data collection are provided in Table 1.

Mean exploration duration at the material dispenser during fattening was 23.7 minutes (± 0.2 minutes SE) per pig and day. Within days, mean exploration duration showed peaks about four hours after sunrise (1.2 minutes/hour (± 0.02 minutes SE) exploration per pig; Fig. 6b) and about three hours before sunset (2.8 minutes/hour (± 0.03 minutes SE) exploration per pig).

Most exploration duration was recorded between 0900 h and 2100 h in rearing and between 0800 h and 2000 h in fattening. During these hours, pigs spent on average 17.3 minutes at the material dispenser during rearing and 18.9 minutes during fattening, representing 2.4% of the active hours during rearing and 2.6% of the active hours during fattening.

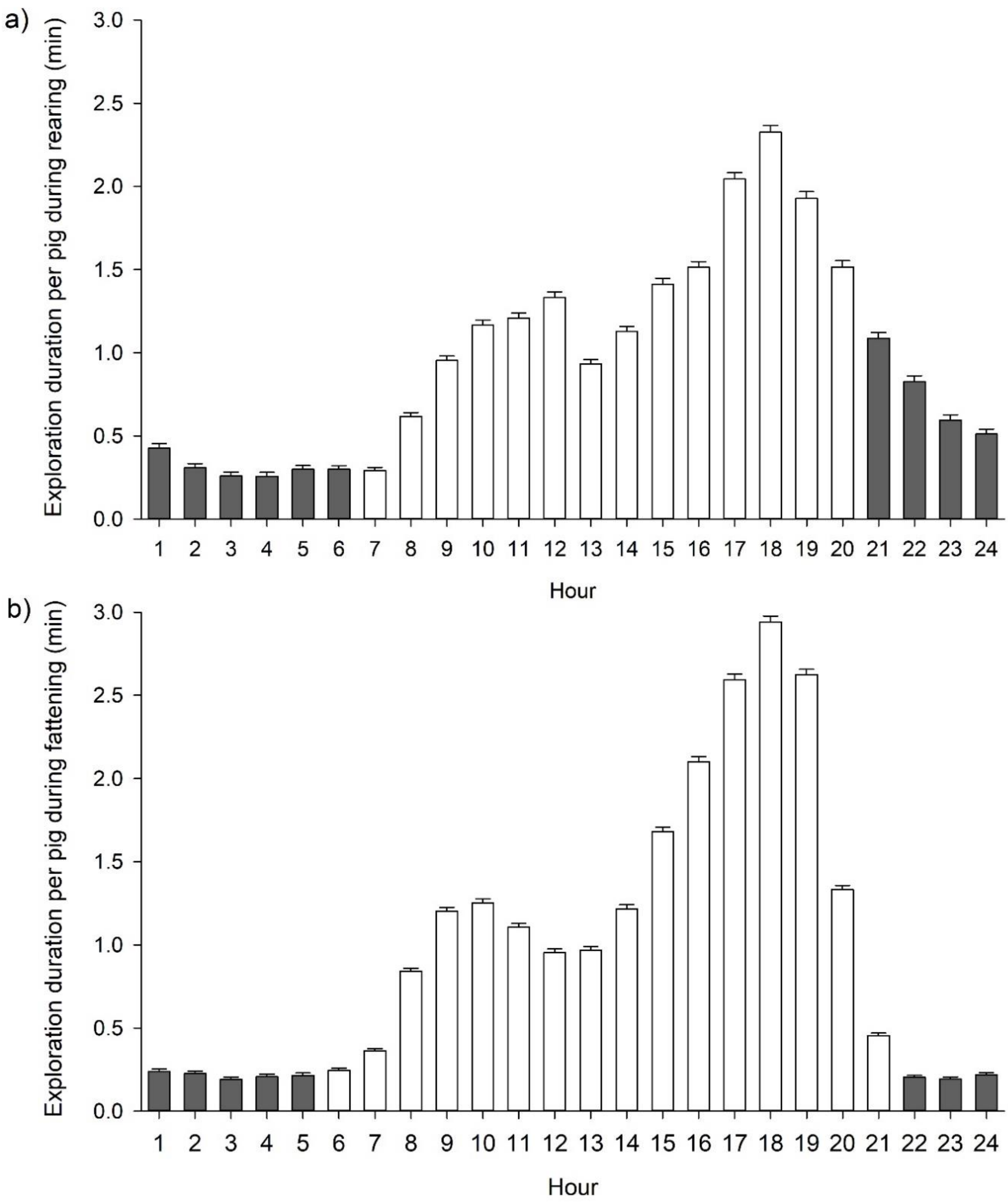

Fig. 6. Diurnal rhythm of mean (±SE) exploration duration in minutes per pig at the material dispenser during (a) the rearing and (b) the fattening period. Light bars show the calculated mean light phase and dark bars show the mean dark phase of a 24-hour day during data collection.

Discussion

The duration pigs spent at the material dispenser differed between the flavours applied on the straw pellets as enrichment and between ages of pigs. Rearing pigs explored most the flavours fried onion (FO) and almond (AL), while fattening pigs spent most time exploring with pellets with strawberry flavour (SB) and with control pellets, i.e. straw pellets without flavour. Exploration duration during rearing decreased over time but increased again after pigs were moved from rearing to fattening pens. The prevalence of tail injuries of piglets increased until the fifth week of rearing and fattening pigs showed least tail injuries during weeks in which straw pellets with almond flavour were offered.

Pigs seem to explore some flavours more than others. During the rearing period, pigs showed longest stays at the dispenser when straw pellets flavoured with fried onion (FO) or almond (AL) were offered. The flavour of fried onion can be attributed to umami which is known to be preferred by pigs (Hellekant and Danilova, 1999). Furthermore, onion and garlic are botanically closely related and also preferences of pigs for garlic ropes had been shown (Blackie and de Sousa, 2019). Pigs adapt feed intake to their nutritional needs (e.g. Kyriazakis et al., 1991). Almond flavour (AL), which was also highly explored during rearing, has a nutty taste which might be associated with a high fat content and a high nutritional value of nuts. Fattening pigs showed highest exploration durations for straw pellets flavoured with strawberry and the control, i.e. straw pellets without additional flavour. Like other fruits, strawberries contain sugar and sweet taste also known to be highly preferred by pigs (Hellekant and Danilova, 1999; Tinti et al., 2000). However, fattening pigs in our study also showed high exploration durations for straw pellets without additional flavour. The latter result contrasts the results of Blackie and de Sousa (2019) and Nowicki et al. (2015) who found a general higher preference in means of higher exploration durations for flavoured enrichment materials compared to unflavoured ones. However, the control pellets were made of straw which has its own natural flavour and natural odours seem to be attractive per se. Nowicki et al. (2015) offered weaned piglets natural materials (grass, dried mushrooms and damp soil) and synthetic aromas (mint, orange, strawberry and vanilla). In line with our results in fattening pigs, in that study piglets also preferred the natural aromas, while strawberry was the most explored synthetic aroma.

Our findings that pigs' preference, as indicated by exploration durations, changed from rearing to fattening was also found in a study in which we offered enrichment materials differing in structure to rearing and fattening pigs (Kauselmann et al., 2021). In that study rearing pigs preferred pelletized compared to chopped materials, while fattening pigs preferred pelletized and chopped material, suggesting that pellets better allow chewing which may have a higher behavioural priority in young pigs. However, in the present study we offered all flavours on the same material, and, thus, different exploration durations of rearing and fattening pigs for structure cannot explain our results on differences in their exploration of flavours.

Rearing pigs showed the highest exploration durations in the first week of rearing period. Thereafter, the exploration durations remained at a comparable level despite significant differences between certain weeks. Previous studies also found highest exploration durations in pigs immediately after offering enrichment materials (Trickett et al., 2009; Van de Perre et al., 2011) or showed decreased exploration durations over time (Apple and Craig, 1992; Van de Perre et al., 2011). As novelty is an important property of enrichment materials to attract pigs' interest (Docking et al., 2008; Trickett et al., 2009), the high exploration duration in the first week of our study is likely to be caused by the pigs having their first contact with the offered enrichment materials during this time. A weekly change of two enrichment materials (rope and wood) (Trickett et al., 2009) or seven objects with different colors (yellow ribbon, orange rope, yellow garden hose, purple ribbon, rubber bar, gray garden hose, rubber ball) (Van de Perre et al., 2011) could reduce, however, not completely avoid habituation. It seems that weekly rotation of six different flavours on the same material, as we did in our study, is more suitable to avoid habituation in pigs than the weekly change of two or seven different objects. As we offered six different flavours (including control) in a weekly change, the flavour offered during in the first week was also offered in the seventh week. Repeated offering of enrichment material can lead to decreased exploration durations in pigs (Jensen and Pedersen, 2007), but the five weeks between repetitions as in our study seemed to be sufficient to prevent habituation.

In our study, the overall exploration durations remained at a constant level from rearing until the end of fattening. In addition, although significantly different, the absolute differences of exploration durations between flavours were small both in rearing and fattening period. It seems likely that the weekly change of flavours had been more important for maintaining the exploration durations on a high level than offering certain flavours. Thus, a regular change of flavours seems to be a possibility to maintain the novelty of an otherwise unchanged enrichment material.

Interestingly, mean exploration duration during the fattening period did not differ to the rearing period. Although fattening pigs knew the flavours they did not show signs of habituation, possibly due to the long interval of five weeks between re-application of flavours. Thus, by using and changing flavours to enhance enrichment material, exploration duration of pigs could be maintained. In recent studies we likewise found increased exploration durations from rearing to fattening when enrichment materials (i.e. lucerne pellets, straw pellets, chopped straw or chopped hay) were changed in two-week intervals (Kauselmann et al., 2021) but also if chopped straw or chopped straw with maize kernels was continuously offered (Kauselmann et al., 2020b). In these studies, we used the same material dispenser (one per pen) and the same group sizes as in the present study. When pigs were moved from rearing to fattening pens group size decreased from 24 to 12. Thus, at beginning of fattening the number of pigs per material dispenser decreased. Although animal:dispenser place ratio did not differ very much between rearing (1.7:1) and fattening (1.5:1) on a calculative basis taking account the larger size of fattening compared to rearing pigs, the access to the material dispenser was easier at the beginning of fattening compared to the end of rearing period. This also may have contributed to similar exploration durations from rearing to fattening. In contrast to the rearing period, in the fattening period exploration durations were lowest in the first week. In the first week of fattening the new environment and group constellation could have led to a reduced exploration of the material as exploration was guided more towards the novel housing conditions than towards the already known enrichment material.

Rearing pigs showed a decrease in exploration durations from day 1 to day 4, i.e. a decrease throughout the first days after changing of flavours. On the following days exploration durations again increased to a higher level. Day 2 of observations usually was a Friday. On this day the storage tube of the material dispensers was filled with a stock for the whole weekend and straw pellets were not refilled during weekends. Thus, the flavours of the straw pellets could evaporate during the weekends and refilling with fresh flavoured straw pellets on Mondays (usually day 5) could have led to increased exploration durations. Also fattening pigs showed highest exploration durations at day 5, while they reached a comparable level of exploration at day 7. Similar effects of increased exploration durations were found after cotton ropes were re-aromatized with garlic flavour after eight days of usage (Blackie and de Sousa, 2019). Thus, regular re-aromatized enrichment materials can increase exploration durations of pigs.

By using the used UHF RFID system, it was possible to record and analyze the exploration durations of the pigs continuously for 24 hours each day and for 18 weeks from the beginning of rearing to the end of fattening (i.e. beginning of slaughtering). For the different flavoured straw pellets in this study median exploration durations differed between 13.1 minutes (VA) and 18.0 minutes (FO) per pig and day during rearing and between 17.5 minutes (AL) and 20.8 minutes (control) during fattening. Kapun et al. (2016) used an UHF RFID system to record visits of healthy and sick pigs at the feeder, drinker, playing material and the door to the outside area. They found that fattening pigs spent an average of 8.2 minutes per pig and day at the playing material (piece of wood and plastic tube at a metal chain). However, it must be noted that also sick pigs with reduced exploration durations were considered there. Other studies used time sampling methods and found pigs exploring 0.5 % to 16.4 % of active hours, ranging from 0900 h to 1700 h (Scott et al., 2006; Trickett et al., 2009). In our study, most activity at the material dispenser was recorded between 0900 h and 2100 h during rearing and between 0800 h and 2000 h during fattening. Pigs in the current study explored about 2.5 % of the active hours, what is rather in the lower range of the above mentioned studies. However, in our study further enrichment materials were continuously offered in the rearing and fattening pens for which we did not record exploration durations, since we focused on the exploration of the pigs toward different flavoured straw pellets and only can capture these with the UHF RFID antenna system. Thus, it can be expected that the overall exploration to all materials in the pen is somehow underestimated as pigs also used the other offered enrichment materials, apart from the flavoured straw pellets. However, exploration durations of the present study are comparable to recent studies in which we also used RFID to record the time pigs spend with different structured plant-based enrichment materials (Kauselmann et al., 2021) or straw either with or without additional maize kernels (Kauselmann et al., 2020b). In these studies, median exploration durations per pig and day ranged between 9.1 minutes per day and 25.4 minutes per day during rearing and between 27.5 minutes per day and 43.9 minutes per day during fattening.

Due to continuous data collection, diurnal exploration activity could be evaluated and showed a similar temporal pattern in rearing and fattening with a peak in the morning and in the afternoon. Exploration was also recorded during the dark phase of the day, but with lower durations compared to the light phase. However, the activity peaks were more clearly defined in fattening pigs. The temporal pattern of exploration duration in our study corresponds to the known activity (e.g. Fraser et al., 1991) and feeding behaviour (Bünger et al., 2017) of pigs. Based on similar temporal patterns, pigs may also have used the offered straw pellets as food. In this study, it was not possible to record the amount of straw pellets eaten by the pigs or fallen through the slatted floor. However, since exploration behaviour can be closely related to foraging behaviour (Wood-Gush and Vestergaard, 1989), similar activity patterns are to be expected.

Furthermore, data collection of exploration duration in rearing pigs was from winter to spring (January to May) and data of fattening pigs were recorded during summer (March to August). Thus, during fattening light phase was longer compared to rearing (Table 1). As known from further studies, feeding and exploration activities of pigs showed two peaks during long light phases and one peak during short light phases (Bünger et al., 2017; Kauselmann et al., 2020b). Thus, pigs probably adapt their diurnal exploration activity to the seasonal length of the light phase.

Tail injuries first occurred in the first week of rearing, while the most tail injuries were scored in the fifth week, when piglets reached an age of about nine weeks. The same trend was seen for Δ-tail lengths during the rearing period, but this trend did not reach significance. Tail biting has been reported most often to firstly occur after weaning at an age of about five weeks (Schrøder-Petersen et al., 2010; Veit et al., 2016), what is consistent with our findings. However, our results on Δ-tail lengths should be interpreted very cautiously. We weekly changed the flavours because our main focus was to test the effects of flavours on exploration durations. With respect to tail lesions and partial losses of tails it is very likely that effects of age have masked possible effects of flavour and that irrespective from a certain flavour carry over effects occur between successive weeks when tail biting has started.

During the fattening period, the fewest tail injuries were observed after the weeks during which almond (AL) flavoured straw pellets were offered. Interestingly, pellets with almond flavor (AL) were also least explored by the piglets. Thus, the less explored flavour was associated with the fewest tail injuries. This was not expected, as previous studies showed reduced penmate manipulation when exploration duration increased (Fraser et al., 1991; Nowicki et al., 2015). Our results regarding tail injuries in fattening, however, have to be interpreted carefully, as we had to use a reduced statistical model.

Conclusions and Perspectives

This study provides novel insights on possibilities to increase the attractiveness of exploration material by flavours in rearing and fattening pigs. A weekly change of flavours resulted in a high and sustainable attractiveness of the flavoured straw pellets for exploration throughout rearing and fattening period. A substantial decrease in exploration durations were only observed from the first to the second week of rearing period, but thereafter the time spend with exploration remained constant. Interestingly, attractiveness of flavours seem to become different from rearing to fattening. Thus, rather than the kind of flavour the change of flavours applied on enrichment material may be important to maintain exploration in pigs. The use of straw pellets with changing flavours can be suggested as a suitable way to offer attractive exploration material if pigs are kept in fully slatted pens hampering the use of long fibre organic materials such as straw. It may also be possible to add flavour to pellets in systems by which pellets are automatically delivered to the pigs, e.g. by pipes.

Ethics approval

Not applicaple. All animals were housed and managed in accordance to German legislation (TierSchNutztV) for farm animals.

Data and model availability statement

None of the data were deposited in an official repository. Data and model were available to reviewers upon request.

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Declaration of interest

None.

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References

Adrion, F., Hammer, N., Eckert, F., Götz, S. and Gallmann, E., 2015. Adjustment of a UHF-RFID system for hotspot monitoring of fattening pigs. Proceedings of the 7th European Conference on Precision Livestock Farming, 15-18 September 2015, Milan, Italy, pp. 573-582.

Apple, J. K. and Craig, J. V., 1992. The influence on pen size on toy preference of growing pigs. Applied Animal Behaviour Science 35, 149–155.

Averberg, U., Scholz, T. and Ziron, M., 2018. Futtervorlage bei Mastschweinen. DLG Merkblatt 360. Retrieved on 27 April 2020 from https://www.dlg.org/fileadmin/downloads/landwirtschaft/themen/publikationen/merkblaetter/dlg-merkblatt_360.pdf.

Bates, D., Maechler, M., Bolker, B. and Walker, S., 2015. Fitting linear mixed-effects models using lme4. Journal of Statistical Software 67, 1–48. doi:10.18637/jss.v067.i01.

Blackie, N. and de Sousa, M., 2019. The Use of Garlic Oil for Olfactory Enrichment Increases the Use of Ropes in Weaned Pigs. Animals (Basel) 9. doi:10.3390/ani9040148.

Brunberg, E. I., Rodenburg, T. B., Rydhmer, L., Kjaer, J. B., Jensen, P. and Keeling, L. J., 2016. Omnivores going astray: a review and new synthesis of abnormal behavior in pigs and laying hens. Frontiers in Veterinary Science 3, 57. doi:10.3389/fvets.2016.00057.

Bünger, B., Zacharias, B. and Schrade, H., 2017. When do growing pigs feed, if they can, whenever they want? In Aktuelle Arbeiten zur artgemäßen Tierhaltung 2017, KTBL-Schrift 513. Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL), Darmstadt, Germany, pp. 236–246.

Croney, C. C., Adams, K. M., Washington, C. G. and Stricklin, W. R., 2003. A note on visual, olfactory and spatial cue use in foraging behavior of pigs: indirectly assessing cognitive abilities. Applied Animal Behaviour Science 83, 303-308. doi:10.1016/s0168-1591(03)00128-x.

Day, J. E. L., Van de Weerd, H. A. and Edwards, S. A., 2008. The effect of varying lengths of straw bedding on the behaviour of growing pigs. Applied Animal Behaviour Science 109, 249-260. doi:10.1016/j.applanim.2007.02.006.

Docking, C. M., Van de Weerd, H. A., Day, J. E. L. and Edwards, S. A., 2008. The influence of age on the use of potential enrichment objects and synchronisation of behaviour of pigs. Applied Animal Behaviour Science 110, 244–257. doi:10.1016/j.applanim.2007.05.004.

DSBS, 2017. Deutscher Schweine Bonitur Schlüssel. Retrieved on 05 December 2019 from https://www.fli.de/fileadmin/FLI/ITT/DSBS_EN_Kombi_170530.pdf.

European Commission, 2016. Attitudes of Europeans towards animal welfare. Special Eurobarometer 442. Retrieved on 17 July 2020 from http://ec.europa.eu/COMMFrontOffice/PublicOpinion.

Fox, J. and Weisberg, S., 2019. An {R} companion to applied regression, 3rd edition. Thousand Oaks, SAGE Publications Inc., Thousand Oaks, CA, USA.

Fraser, A. F., 1983. The behaviour of maintenance and the intensive husbandry of cattle, sheep and pigs. Agriculture, Ecosystems and Environment 9, 1-23.

Fraser, D., Phillips, P. A., Thompson, B. K. and Tennessen, T., 1991. Effect of straw on the behaviour of growing pigs. Applied Animal Behaviour Science 30, 307–318.

Hellekant, G. and Danilova, V., 1999. Taste in domestic pig, Sus scrofa. Journal of Animal Physiology and Animal Nutrition 82, 8-24.

Hunter, E. J., Jones, T. A., Guise, H. J., Penny, R. H. and Hoste, S., 2001. The relationship between tail biting in pigs, docking procedure and other management practices. The Veterinary Journal 161, 72–79. doi:10.1053/tvjl.2000.0520.

Jensen, M. B. and Pedersen, L. J., 2007. The value assigned to six different rooting materials by growing pigs. Applied Animal Behaviour Science 108, 31–44. doi:10.1016/j.applanim.2006.10.014.

Kapun, A., Adrion, F., Schmid, L. A., Staiger, M., Holland, E., Gallmann, E. and Jungbluth, T., 2016. Test of a UHF-RFID system for health monitoring of finishing pigs. Proceedings of the International Conference on Agricultural Engineering, 26-28 June 2016, Aarhus, Denmark.

Kauselmann, K., Krause, E. T., Glitz, B., Gallmann, E., Schrade, H. and Schrader, L., 2020a. Short-term choice of fattening pigs for additional plant-based materials. Applied Animal Behaviour Science 226, 104975.

Kauselmann, K., Schrader, L., Glitz, B., Gallmann, E., Schrade, H. and Krause, E. T., 2020b. Turning the gaze to maize: The effects of maize kernels in straw as enrichment on exploration and tail status in pigs. Berliner und Münchener Teriärztliche Wochenschrift 133. doi:10.2376/1439-0299-2020-24.

Kauselmann, K., Krause, E. T., Glitz, B., Gallmann, E., Schrade, H. and Schrader, L., 2021. Effect of plant-based enrichment materials on exploration in rearing and fattening pigs (Sus scrofa domesticus). Applied Animal Behaviour Science 236. doi:10.1016/j.applanim.2021.105261.

Kyriazakis, I., Emmans, G. C. and Whittemore, C. T., 1991. The Ability of Pigs to Contorl Their Protein Intake When Fed in Three Different Ways. Physiology and Behaviour 50, 1197-1203.

Lahrmann, H. P., Oxholm, L. C., Steinmetz, H., Nielsen, M. B. and D'Eath, R. B., 2015. The effect of long or chopped straw on pig behaviour. Animal 9, 862-870. doi:10.1017/S1751731114003024.

Larsen, M. L. V., Andersen, H. M. and Pedersen, L. J., 2018. Which is the most preventive measure against tail damage in finisher pigs: tail docking, straw provision or lowered stocking density? Animal 12, 1260–1267. doi:10.1017/S175173111700249X.

Nelson, S. L. and Sanregret, J. D., 1997. Response of Pigs to Bitter-tasting Compounds. Chemical Senses 22, 129-132.

Nowicki, J., Swierkosz, S., Tuz, R. and Schwarz, T., 2015. The influence of aromatized environmental enrichment objects with changeable aromas on the behaviour of weaned piglets. Veterinarski Arhiv 85, 425-435.

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D. and R Core Team, 2019. nlme:Linear and nonlinear mixed effects models. R package version 3.1-141. Retrieved on 19 November 2019 from https://CRAN.R-project.org/package=nlme.

R Core Team, 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria.

Schielzeth, H., Dingemanse, N. J., Nakagawa, S., Westneat, D. F., Allegue, H., Teplitsky, C., Réale, D., Dochtermann, N. A., Garamszegi, L. Z., Araya-Ajoy, Y. G. and Sutherland, C., 2020. Robustness of linear mixed-effects models to violations of distributional assumptions. Methods in Ecology and Evolution 11, 1141-1152. doi:10.1111/2041-210x.13434.

Schrøder-Petersen, D. L., Simonsen, H. B. and Lawson, L. G., 2010. Tail-in-mouth behaviour among weaner pigs in relation to age, gender and group composition regarding gender. Animal Science 53, 29–34. doi:10.1080/09064700310002017.

Scott, K., Taylor, L., Gill, B. P. and Edwards, S. A., 2006. Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems, 1. Hanging toy versus rootable substrate. Applied Animal Behaviour Science 99, 222–229. doi:10.1016/j.applanim.2005.10.013.

Studnitz, M., Jensen, M. B. and Pedersen, L. J., 2007. Why do pigs root and in what will they root? Applied Animal Behaviour Science 107, 183–197. doi:10.1016/j.applanim.2006.11.013.

TierSchNutztV, 2017. Tierschutz-Nutztierhaltungsverordnung in the version published on 22. August 2006 (BGBl. I S. 2043), last amended by Article 3(2) of the Act of 30. June 2017 (BGBl. I p. 2147). Retrieved on 30 January 2020 from https://www.gesetze-im-internet.de/tierschnutztv/.

Tinti, J. M., Glaser, D., Wanner, M. and Nofre, C., 2000. Comparison of Gustatory Responses to Amino Acids in Pigs and in Humans. LWT - Food Science and Technology 33, 578-583. doi:10.1006/fstl.2000.0713.

Trickett, S. L., Guy, J. H. and Edwards, S. A., 2009. The role of novelty in environmental enrichment for the weaned pig. Applied Animal Behaviour Science 116, 45–51. doi:10.1016/j.applanim.2008.07.007.

Van de Perre, V., Driessen, B., Van Thielen, J., Verbeke, G. and Geers, R., 2011. Comparison of pig behaviour when given a sequence of enrichment objects or a chain continuously. Animal Welfare 20, 641–649.

Van de Weerd, H. A., Docking, C. M., Day, J. E. L., Avery, P. J. and Edwards, S. A., 2003. A systematic approach towards developing environmental enrichment for pigs. Applied Animal Behaviour Science 84, 101–118. doi:10.1016/s0168-1591(03)00150-3.

Veit, C., Traulsen, I., Hasler, M., Tölle, K.-H., Burfeind, O., Beilage, E. g. and Krieter, J., 2016. Influence of raw material on the occurrence of tail-biting in undocked pigs. Livestock Science 191, 125–131. doi:10.1016/j.livsci.2016.07.009.

Wood-Gush, D. G. M. and Vestergaard, K., 1989. Exploratory behavior and the welfare of intensively kept animals. Journal of Agricultural Ethics 2, 161-169.

6. Allgemeine Diskussion

In der vorliegenden Arbeit wurden organische Beschäftigungsmaterialien für Schweine getestet, die güllekompatibel sind und somit in Ställen mit Spaltenböden eingesetzt werden können. Dabei wurde eine vielseitige Auswahl an Beschäftigungsmaterialien untersucht, mit denen unterschiedliche Sinnesreize von Schweinen angesprochen werden sollten. Verschieden strukturierte Materialien boten den Schweinen dabei die Option für die taktile Wahrnehmung von Strukturen mit der Rüsselscheibe. Fressbare Zusätze setzten einen Anlass zur Exploration in Assoziation mit der Futtersuche und aromatisierte Materialien sollten die olfaktorischen Fähigkeiten von Schweinen ansprechen. Dabei wurde das Angebot der Materialien systematisch variiert, wodurch eine zeitgleiche, systematisch alternierende oder kontinuierliche Gabe von Beschäftigungsmaterialien untersucht wurde. Die angewandten Wechselintervalle versprachen einen reduzierenden Effekt auf die Habituation von Schweinen an die angebotenen Beschäftigungsmaterialien zu erzielen. Dabei ließ die Dauer der Versuchsdurchführung von Beginn der Aufzucht bis zum Ende der Mast vielversprechende Ergebnisse hinsichtlich der Langzeitwirkung von Beschäftigungsmaterialien für Schweine erwarten. Die Grundlage zur Erfassung von Auswirkungen der angebotenen Beschäftigungsmaterialien auf auftretende Schwanzschäden bildete der Deutsche Schweine-Boniturschlüssel (DSBS). Darüber hinaus bot die Verwendung eines UHF-RFID-Systems eine neuartige technische Methode zur automatischen und kontinuierlichen Erfassung der Aufenthaltszeiten von Einzeltieren an den angebotenen Beschäftigungsmaterialien. Anhand der erhobenen Daten konnte in der vorliegenden Arbeit der Zusammenhang zwischen der Beschäftigungsdauer mit den eingesetzten Materialien und auftretenden Schwanzschäden bei Schweinen in den beiden Produktionsabschnitten Aufzucht und Mast untersucht werden. Es ergaben sich dabei deutliche Präferenzen von Schweinen für bestimmte Beschäftigungsmaterialien, die sich in Abhängigkeit des Produktionsabschnitts (Aufzucht und Mast) unterschieden. Gleichzeitig beeinflussten die eingesetzten Beschäftigungsmaterialien das Vorkommen von Schwanzschäden in der Aufzucht. Ein allgemeiner Überblick über die eingesetzten Materialien und die Wechselintervalle ist in Tabelle 6.1 dargestellt.

6.1 Eignung der Methode zur Präferenzermittlung

Die untersuchten Beschäftigungsmaterialien wurden den Schweinen in den vorliegenden Versuchen gleichzeitig (Kapitel 2; (Kauselmann et al., 2020a)), systematisch alternierend (Kapitel 3 (Kauselmann et al. 2021) und 4 (Kauselmann et al., 2020b)) oder kontinuierlich (Kapitel 5) angeboten. Somit wurden die Präferenzen der Schweine in den verschiedenen Untersuchungen (Kapitel 2-5) auf unterschiedliche Art und Weise gemessen. Zum einen wurde den Schweinen die Wahlentscheidung über verschiedene Stimuli simultan gegeben (Kapitel 2), das heißt die Schweine hatten individuell die Wahl zwischen unterschiedlichen, zeitgleich angebotenen Materialien. Zwischen den verschiedenen Individuen wurde der Platz der angebotenen Materialien alterniert, um z.B. Seitenpräferenzen auszuschließen (Naguib und Krause, 2020). Zum anderen wurde ein sequenzieller wöchentlicher (Kapitel 3) oder zweiwöchiger (Kapitel 4) Wechsel der untersuchten Beschäftigungsmaterialien durchgeführt, um die Präferenz der Tiere zu ermitteln. Daraus ergaben sich Zeitintervalle, zu denen nacheinander jeweils ein Material pro Bucht in alternierender Reihenfolge getestet wurde. Dabei wurde in jeder der vier Versuchsbuchten in der Aufzucht jeweils zeitgleich ein unterschiedliches Material angeboten. Während der Mast erfolgte das Angebot der Materialien nach demselben Schema wie in der Aufzucht. Jedoch wurde in jedem Zeitintervall jeweils in zwei der acht Versuchsbuchten das gleiche Material zur Verfügung gestellt. Damit sollten zeitliche und zufällige Effekte kontrolliert werden. Aufgrund dessen konnte die erfasste Beschäftigungsdauer für einen Vergleich der Materialien herangezogen werden (Kapitel 3 – 4). In einer weiteren Untersuchung erfolgte das Angebot der untersuchten Beschäftigungsmaterialien kontinuierlich (Kapitel 5), indem jeweils die Hälfte der Aufzucht- bzw. Mastbuchten über den gesamten Versuchszeitraum eines von zwei Materialien erhielten. Beschäftigungsmaterialien, die sich im Vergleich durch eine hohe Beschäftigungsdauer von anderen Materialien abhoben, können daher als von den Schweinen präferierte Materialien angesehen werden. Durch ein simultanes Angebot aller Beschäftigungsmaterialien in jeder Bucht hätten in Kapitel 3 – 5 ebenfalls Präferenzen anhand entsprechender Wahlentscheidungen der Schweine ermittelt werden können, jedoch hätte über den Effekt eines einzelnen Materials auf potenzielle Schwanzschäden keine Aussage getroffen werden können. Der

Effekt des Beschäftigungsmaterials auf Schwanzschäden war jedoch ein weiterer Aspekt der vorliegenden Arbeit, der in Kapitel 6.5 diskutiert wird.

6.2 Präferenzen für Beschäftigungsmaterialien in der Aufzucht und Mast

Beim Angebot unterschiedlich strukturierter Beschäftigungsmaterialien oder wechselnder Aromen, die auf Strohpellets appliziert wurden, zeigten Aufzucht- und Mastschweine anhand der Explorationsdauer klare Präferenzen für bestimmte Materialien. Während Aufzuchtschweine die höchste Beschäftigungsdauer für Strohpellets mit Bratzwiebel- oder Mandel-Aroma zeigten, bevorzugten Mastschweine die Kontrolle (Strohpellets ohne zusätzliches Aroma) oder Strohpellets mit Erdbeer-Aroma (Tabelle 6.1). Diese Aromapräferenzen zeigen wechselnde Geschmackspräferenzen mit dem Alter der Tiere. Auch die untersuchten strukturierten Beschäftigungsmaterialien unterschieden sich in ihrem natürlichen Geschmack und zeigten ebenfalls unterschiedliche Präferenzen zwischen Aufzucht- und Mastschweinen. Während sich Aufzuchtschweine am längsten mit Luzerne- (LP) und Strohpellets (SP) beschäftigten, favorisierten Mastschweine gehäckseltes Heu (CH) und LP. Jedoch steht auch das Kauen in engem Zusammenhang mit der Exploration von Schweinen und scheint die Präferenz von Aufzuchtschweinen für die Darreichungsform von Futtermitteln zu beeinflussen, was die Präferenz von Aufzuchtschweinen für pelletiertes Futter gegenüber Breifutter mit der gleichen Zusammensetzung der Inhaltsstoffe verdeutlicht (Solà-Oriol et al., 2008). Aufzuchtschweine könnten pelletierte Materialien aufgrund eines stark vorhandenen Kaubedürfnisses präferieren, dem sie durch die Fütterung mit Breifutter, verglichen mit den Mastschweinen, die pelletiertes Futter erhielten, nicht adäquat nachgehen konnten. Des Weiteren zeigten bereits vorausgehende Untersuchungen Präferenzen von Schweinen für Materialien, die eine ähnliche Struktur wie Erde besitzen (Jensen et al., 2008). Erdige Materialien wurden in der vorliegenden Arbeit nicht untersucht, jedoch nahmen Luzerne- und Strohpellets eine ähnliche Struktur wie Erde an, wenn diese von den Schweinen angefeuchtet, zerkaut und durchwühlt wurden. Diese Ergebnisse deuten darauf hin, dass sowohl der Geschmack als auch die Struktur die Präferenz von Aufzucht und Mastschweinen für Beschäftigungsmaterialien beeinflusst.

Durch das alternierende Angebot verschiedener Strukturen oder Aromen fand womöglich eine Anpassung an sich ändernde Bedürfnisse zur Exploration der Schweine statt, was die Erfassung unterschiedlicher Präferenzen zwischen Aufzucht- und Mastschweinen ermöglichte. Ein unterschiedlich großes Interesse für organische und nicht-organische Beschäftigungsmaterialien zwischen Saugferkeln, Aufzuchtferkeln und Mastschweinen stellten auch Docking et al. (2008) in einem direkten Vergleich von Beschäftigungsmaterialien (Ball, Schuh, Bürste, Teppich, Kette, Kompost, Eisblock, gehäckseltes Stroh, Seil, Metallblock) fest. Jedoch war Kompost nach fünf Tagen der Beobachtung das von allen drei Altersgruppen am meisten explorierte Material. Die Unterschiede für bevorzugte Beschäftigungsmaterialien zwischen Aufzucht- und Mastschweinen sollten bei der Auswahl geeigneter Beschäftigungsmaterialien für Schweine berücksichtigt werden.

Wurde den Schweinen kontinuierlich gehäckseltes Stroh (CS) oder gehäckseltes Stroh mit Maiskörnern (CS+MK) angeboten, zeigte sich über den gesamten Versuch hinweg, d.h. sowohl in der Aufzucht als auch in der Mast, eine höhere Beschäftigungsdauer bei CS+MK. Der in dieser Arbeit beschriebene simultan Wahlversuch (Kapitel 2), aber auch vorausgehende Studien (z.B. Studnitz et al., 2007; Young und Lawrance, 1994; Zwicker et al., 2013) zeigten, dass die Exploration bei Schweinen eng mit der Futtersuche zusammenhängt und eine klare Präferenz von Schweinen für Beschäftigungsmaterial mit fressbaren Bestandteilen vorliegt. Diese Kenntnis kann genutzt werden, um das arttypische Explorationsverhalten von Aufzucht- und Mastschweinen zu steigern.

Tabelle 6.1 Übersicht aller untersuchten Beschäftigungsmaterialien (Kapitel 3-5), deren Wechselintervalle und Auswirkungen auf die Beschäftigungsdauer sowie Schwanzschäden in der Aufzucht und Mast.

Beschäftigungs-materialien	Eigenschaft	Wechsel-intervall	Präferenz Aufzucht	Mittlere Beschäftigungs-dauer Aufzucht (min/Tier und Tag)	Präferenz Mast	Mittlere Beschäftigungs-dauer Mast (min/Tier und Tag)	Wahl-versuch (Kapitel 2) bestätigt?	Veränderung der Beschäftigungs-dauer zwischen Aufzucht und Mast	Material geringste Längen-verluste[1]
Luzernepellets (LP) Strohpellets (SP) Gehäckseltes Heu (CH) Gehäckseltes Stroh (CS)	Struktur	zwei-wöchig	LP SP	15,4	CH LP	40,0	Aufzucht: ja Mast: nein	Anstieg	SP LP
Bratzwiebel (FO) Erdbeere (SB) Ingwer (GI) Mandel (AL) Vanille (VA) Kontrolle	Aroma	wöchent-lich	FO AL	23,1	Kontrolle SB	23,6		Einheitliches Niveau	n.s.
Gehäckseltes Stroh (CS) Gehäckseltes Stroh mit Maiskörnern (CS+MK)	Fressbarer Zusatz	Ohne Wechsel	CS+MK	22,9	CS+MK	42,4	Aufzucht: ja Mast: ja	Anstieg	CS

[1] in der Aufzucht (keine signifikanten Unterschiede in der Mast), Längenverluste beziehen sich auf neu erfasste Teilverluste während der Zeit, in der das entsprechende Material zur Verfügung stand.

6.3 Zeitlicher Verlauf der Beschäftigungsdauer in den Langzeituntersuchungen

Die Vorlage der untersuchten Beschäftigungsmaterialien variierte in den vorliegenden Langzeituntersuchen zwischen kontinuierlich, wöchentlich alternierend und zweiwöchig alternierend (Kapitel 3 – 5). Dabei ergaben sich unterschiedliche Effekte auf die Beschäftigungsdauer innerhalb der Aufzucht, innerhalb der Mast und über die Aufzucht und Mast hinweg. Diese Ergebnisse stellen bezüglich des Einsatzes von Beschäftigungsmaterialien bei Schweinen eine wichtige Erkenntnis gegenüber bisherigen Studien dar und werden im Folgenden genauer beleuchtet.

Das Angebot unterschiedlich strukturierter Materialien (LP, SP, CH und CS; Kapitel 3) im zweiwöchigen Wechsel führte zu einem Anstieg der Beschäftigungsdauer innerhalb der Aufzucht und innerhalb der Mast. Auch bei dem kontinuierlichen Angebot von CS+MK oder CS (Kapitel 4) konnte ein Anstieg der Beschäftigungsdauer innerhalb der Mast festgestellt werden. Häufig wird von einem schnellen Rückgang des Interesses an aufgehängten Beschäftigungsmaterialien innerhalb weniger Tage berichtet (Trickett et al., 2009; Van de Perre et al., 2011). Die Ergebnisse aus der vorliegenden Arbeit zeigen jedoch, dass eine Habituation an wühlbare Beschäftigungsmaterialien mit unterschiedlichen Strukturen und fressbaren Zusätzen ausblieb, unabhängig davon ob ein Wechsel der Materialien stattfand oder nicht. Wurden die auf Strohpellets applizierten Aromen wöchentlich alterniert, zeigten Aufzucht- und Mastschweine hingegen schwankende Beschäftigungsdauern zwischen den Wochen. Während bei Aufzuchtschweinen in der ersten Woche der Datenerfassung die höchste Beschäftigung am Beschäftigungsturm ermittelt wurde, zeigten Mastschweine in der vierten bis sechsten Mastwoche die höchste Beschäftigung. In einer vorausgehenden Studie wurde Schweinen Stroh, aromatisiertes Futter im wöchentlichen Wechsel oder aromatisiertes Wasser im wöchentlichen Wechsel über verschiedene Substratspender angeboten und deren Nutzungsintensität erfasst (Van de Weerd et al., 2006). Als Vergleich wurde eine Bucht mit Stroheinstreu herangezogen und ein herkömmliches Beschäftigungsobjekt („Bite Rite“) angeboten. Die Autoren stellten fest, dass die

Schweine das aromatisierte Futter und Wasser verglichen mit dem eingestreuten Stroh oder dem Stroh aus dem Substratspender in geringerem Maße nutzten. Möglicherweise hat die Verwendung von Aromen einen weniger großen Effekt auf die Beschäftigungsdauer von Schweinen als zunächst anhand der hohen olfaktorischen Sinnesleistung angenommen.

Die durchschnittliche Beschäftigungsdauer am Beschäftigungsturm pro Tier und Tag unterschied sich in den vorliegenden Versuchen (Kapitel 3 – 5) zwischen der Aufzucht und Mast. Wurde den Schweinen unterschiedlich strukturiertes Beschäftigungsmaterial im zweiwöchigen Wechsel angeboten, stieg die mittlere Beschäftigungsdauer von 15,4 min pro Tier und Tag in der Aufzucht auf 40,0 min pro Tier und Tag in der Mast (Tabelle 6.3). Bei einem wöchentlichen Wechsel des Aromas auf Strohpellets konnte eine mittlere Beschäftigungsdauer von 23,1 min pro Tier und Tag in der Aufzucht erzielt werden, jedoch wurde im Vergleich zur Mast keine Zunahme der Beschäftigungsdauer erreicht (23,6 min pro Tier und Tag; Kapitel 5). Mit einer kontinuierlichen Gabe von CS oder CS+MK wurde bei Aufzuchtschweinen eine mittlere Beschäftigungsdauer von 22,9 min pro Tier und Tag erreicht (Kapitel 4), die mit der mittleren Beschäftigungsdauer von Aufzuchtschweinen vergleichbar ist, die unterschiedlich aromatisierte Strohpellets erhalten haben (Kapitel 5). In der Mast stieg die mittlere Beschäftigungsdauer von Schweinen, die CS oder CS+MK erhalten haben auf 42,4 min pro Tier und Tag an (Kapitel 4), womit das Niveau der Mastschweine erreicht wurde, die unterschiedlich strukturierte Materialien erhalten haben (Kapitel 3). Diese Ergebnisse zeigen Unterschiede in der Beschäftigungsdauer zwischen den Untersuchungen (Kapitel 3 – 5) sowie zwischen der Aufzucht und Mast. Es stellte sich jedoch heraus, dass die Beschäftigungsdauer in allen vorliegenden Untersuchungen von der Aufzucht über die Mast hinweg aufrechterhalten oder sogar gesteigert wurde. Die Beschäftigungsdauer von Schweinen konnte auch bereits in vorausgehenden Studien durch die regelmäßige Vorlage von Stroh aufrechterhalten (Bolhuis et al., 2005) und durch das Austauschen, bzw. erneute Aromatisieren von Beschäftigungsmaterial erneut erhöht werden (Nowicki et al., 2015; Van de Perre et al., 2011). Die bei den Schweinen ausgebliebene Habituation an das angebotene Beschäftigungsmaterial stellt einen Erfolg der vorliegenden Arbeit dar, die auf die regelmäßige Befüllung der Beschäftigungstürme mit frischem Material oder auf den alternierenden Wechsel von Materialien zurückzuführen sein könnte.

Für Schweine gelten Beschäftigungsmaterialien insbesondere dann als interessant, wenn sie eine Neuheit darstellen (Docking et al., 2008). Das Auffinden einzelner Maiskörner beim Wühlen in CS+MK könnte den Effekt der Neuheit ausgelöst haben, obwohl das Beschäftigungsmaterial kontinuierlich angeboten wurde und kein Wechsel von Materialien stattfand. Ein Anstieg der Beschäftigungsdauer von der Aufzucht zur Mast wurde jedoch auch für CS erzielt, was durch das ausbleibende Finden von fressbarem Mais zunächst nicht erklärbar zu sein scheint. Jedoch besitzen Schweine eine große Motivation ihr Verhalten zu synchronisieren (Hsia und Wood-Gush, 1983; Zwicker et al., 2015). Die Schweine der CS und der CS+MK Behandlung wurden in der vorliegenden Arbeit zu je zwei Buchten im selben Abteil gehalten (vier Buchten pro Abteil). Bereits Lautäußerungen der CS+MK Schweine könnten die CS Schweine dazu animiert haben, sich ebenfalls zu beschäftigen, was womöglich zu einem gleichzeitigen Anstieg der Beschäftigungsdauer zwischen CS und CS+MK führte. Das Niveau der Beschäftigungsdauer von Schweinen der CS+MK Behandlung wurde von den CS Schweinen nicht erreicht, näherte sich jedoch im letzten Abschnitt der Mast (80 kg Wiegung bis Schlachtbeginn) der Beschäftigungsdauer der CS+MK Schweine an. Mit dem Alter von Schweinen steigt die objektbezogene Synchronisation (Docking et al., 2008), was ein Grund für die Zunahme der Beschäftigungsdauer in der Mast sein könnte, aber auch die Annäherung der Beschäftigungsdauer im letzten Abschnitt der Mast erklären könnte.

Aufzuchtschweine zeigten die geringste durchschnittliche Beschäftigungsdauer, wenn ihnen unterschiedlich strukturierte Materialein im wöchentlichen Wechsel zur Verfügung standen. Ein zweiwöchiger Wechsel der Materialien in der siebenwöchigen Aufzuchtphase stellt einen langen Zeitraum dar. Zudem zeigten Aufzuchtschweine eine klare Präferenz für pelletierte Materialien, was bedeutet, dass zwei von vier untersuchten Beschäftigungsmaterialien eine geringe Beschäftigung auslösten. Im Vergleich zur Aufzucht zeigten Mastschweine eine höhere durchschnittliche Beschäftigungsdauer am Beschäftigungsautomaten. Durch die Präferenz von Mastschweinen für pelletierte und gehäckselte Materialien (LP und CH), konnten diese sich womöglich besser an weniger beliebte

Materialien anpassen als Aufzuchtschweine. Somit empfiehlt sich zur Steigerung der Beschäftigungsdauer von Aufzuchtschweinen ein wöchentlich alternierendes Angebot der präferierten Materialien, was möglicherweise auch bei Mastschweinen die Beschäftigungsdauer weiter steigern könnte.

Das alternierende Angebot unterschiedlich aromatisierter Strohpellets konnte die Beschäftigungsdauer von der Aufzucht über die Mast hinweg auf einem gleichbleibenden Niveau aufrechterhalten. In der Mast wurde jedoch nicht das Niveau der Beschäftigungsdauer im Vergleich zu unterschiedlich strukturierten Materialien oder verglichen mit der Gabe fressbarer Zusätze in gehäckseltem Stroh erreicht. Zudem präferierten Mastschweine in der vorliegenden Arbeit neben Strohpellets mit Erdbeer-Aroma auch Strohpellets ohne zusätzlich appliziertes Aroma (Kontrolle). Diese Ergebnisse legen nahe, dass die Struktur von Beschäftigungsmaterialien und die Gabe eines fressbaren Zusatzes im Beschäftigungsmaterial einen größeren Einfluss auf die Steigerung der Beschäftigungsdauer von Mastschweinen nimmt als zusätzlich applizierte Aromen.

6.4 Eignung der UHF-RFID zur Verhaltenserfassung

Anhand des eingesetzten UHF-RFID-Systems wurde der Aufenthalt der Schweine in der Nähe des Beschäftigungsturms erfasst. Hierfür wurde das UHF-RFID-System mittels Videoaufnahmen validiert, um die bestmöglichen technischen Einstellungen zu analysieren (Kapitel 3). Dazu wurde der Wühlbereich innerhalb des Betonrings als Beschäftigungsbereich definiert. Dies bedeutet, dass ein Schwein per Definition erst dann vom UHF-RFID-System erfasst werden sollte, wenn der Rüssel über den inneren Ring des Betonringes ragte, um so die Wahrscheinlichkeit zu erhöhen, dass sich ein erfasstes Schwein auch tatsächlich mit dem angebotenen Beschäftigungsmaterial beschäftigt. Anhand der Validierung wurden die technischen Parameter übernommen, mit denen eine möglichst hohe Sensitivität und Spezifität des Systems unter den definierten Bedingungen erreicht wurde. Dabei wurde mit einer Antennenleistung von 22,4 dBm die höchste Sensitivität (70,7 % in der Aufzucht, 79,3 % in der Mast) und Spezifität (99,4 % in der Aufzucht, 99,5 % in der Mast) erreicht. Das in dieser Arbeit eingesetzte UHF-RFID-System erzielte somit eine Sensitivität, die mit ähnlichen

Versuchsanstellungen vergleichbar ist (Adrion et al., 2018; Kapun et al., 2016). Fehlerhafte Lesungen können in der vorliegenden Arbeit aufgrund der berechneten Sensitivität und Spezifität nicht vollständig ausgeschlossen werden, sind jedoch auf dem kleinstmöglichen Niveau zu erwarten. Dabei ist bei den erfassten Daten weniger von einer Überschätzung der Explorationszeit als vielmehr von einer Unterschätzung auszugehen. Das Ziel in den vorliegenden Versuchen (Kapitel 3 – 5) war es, die Beschäftigungsdauer der Schweine in Abhängigkeit des zur Verfügung gestellten Materials kontinuierlich über den gesamten Zeitraum der Aufzucht und Mast zu erfassen. Durch den Einsatz identischer Beschäftigungstürme in baugleichen Buchten, kann davon ausgegangen werden, dass im Falle eines vorhandenen Messfehlerbereichs alle Beschäftigungstürme gleichermaßen betroffen waren, was einen Vergleich der Beschäftigungsdauern zwischen den Buchten ermöglicht.

Der Einsatz der UHF-RFID bietet klare Vorteile gegenüber der oft verwendeten Video- oder Direktbeobachtung bezüglich der örtlichen und zeitlichen Erfassung von Nutztieren. Durch die Erfassung individueller Aufenthaltszeiten mit direkter Übertragung von Einzelwerten können zeitintensivere Methoden abgelöst werden. Da die UHF-RFID eine Empfindlichkeit gegenüber Wasser und metallischen Gegenständen aufweist, muss gerade bei einem Einsatz in der Schweinehaltung das Vorkommen von Fehllesungen berücksichtigt werden (Adrion et al., 2018). Der womöglich größte Vorteil der UHF-RFID liegt in der gleichzeitigen und tierindividuellen Erfassung von der Aufenthaltszeit mehrerer Individuen an einem bestimmten Ort (z.B. Beschäftigungsturm, Tränke oder Futtertrog). Da Schweine eine große Motivation besitzen, ihr Verhalten zu synchronisieren (Hsia und Wood-Gush, 1983; Zwicker et al., 2015), ist die Möglichkeit der zeitgleichen Erfassung mehrerer Tiere in der Schweinehaltung von großer Bedeutung, wofür sich der Einsatz der UHF-RFID besonders gut eignet.

Durch das eingesetzte UHF-RFID-System konnten in der vorliegenden Arbeit neue Erkenntnisse über den Tagesrhythmus der Beschäftigung von Schweinen, durchgängig von der Aufzucht bis zur Mast, gewonnen werden. Ebenso wie das Futterverhalten von Schweinen (Bünger et al., 2017), steht auch das Beschäftigungsverhalten unter einem diurnalen und saisonalen Einfluss. Eine starke Korrelation der Aktivitätszeit mit dem Sonnenuntergang und

Sonnenaufgang wurde auch bereits für Wildschweine festgestellt (Lemel et al., 2003). Wintermonate zeichnen sich in Europa aufgrund der geographischen Lage durch eine kürzere Hellphase im Vergleich zu Sommermonaten aus. So konzentrierte sich die Hauptbeschäftigungszeit von Schweinen in den Wintermonaten auf einen zeitlich kürzeren Abschnitt der Hellphase als in den Sommermonaten (Kapitel 4 und 5). Der Verlauf der Beschäftigungszeit in den Wintermonaten zeichnete sich durch einen Anstieg nach Sonnenaufgang, einen Peak zur Mittagszeit und einen anschließenden Rückgang bis zum Eintreten der Dunkelheit aus. In den Sommermonaten passten Schweine ihren Rhythmus der Beschäftigung an die längere Hellphase an, wobei während der Mittagszeit ein vorübergehender Rückgang der Aktivität zu verzeichnen war. Diese saisonalen Einflüsse auf den Tagesrhythmus der Beschäftigung wurde in der vorliegenden Arbeit sowohl für Aufzucht- als auch für Mastschweine festgestellt. Lahrmann et al. (2015) interpretierten Unterschiede im Tagesrhythmus von Mastschweinen, die sich mit Lang- und Kurzstroh beschäftigten, mit veränderten Aktivitätsmustern von Mastschweinen unterschiedlichen Alters (40 kg und 80 kg). Jedoch fand die Datenerfassung der 40 kg Tiere im Sommer (Juni) und Winter (Januar) statt und die Datenerfassung der 80 kg Tiere im Frühling (März) und Sommer (August). Bei den 40 kg Tieren wurde ein Verlauf der Aktivität des Wühl- und Explorationsverhaltens und des Stroh-/Boden-gerichteten Verhaltens mit einem Peak zur Mittagszeit beobachtet, während die 80 kg Schweine zwei Peaks im Tagesverlauf zeigten. Die Messzeitpunkte lassen sich nicht eindeutig in Winter- und Sommermonate abgrenzen. Jedoch könnte auch hier ein Einfluss der Jahreszeit auf den veränderten Beschäftigungsrhythmus in Betracht gezogen werden.

Schwanzlängenverluste wurden in der vorliegenden Arbeit hauptsächlich bei Aufzuchtschweinen und weniger bei Mastschweinen beobachtet. Zwischen Aufzucht- und Mastschweinen konnten jedoch keine Unterschiede im Tagesrhythmus der Beschäftigung erkannt werden. Somit scheint sich ein erhöhtes Aufkommen von Schwanzlängenverlusten auf Gruppenebene nicht auf das saisonale und diurnale Aktivitätsmuster von Schweinen auszuwirken. Durch die detaillierte Echtzeiterfassung könnten sich mit Hilfe eines UHF-RFID-System jedoch Abweichungen im Verhaltensmuster von Einzeltieren (z.B. Täter und Opfer im Schwanzbeißgeschehen) erkennen lassen. Gerade im Bereich der Schweinehaltung wäre die Verwendung der RFID-Technik denkbar, um ein Frühwarnsystem für Schwanzbeißen zu etablieren. Bereits mehrere Tage vor dem Ausbruch von Schwanzbeißen und dem Auftreten von Schwanzschäden geht die Futteraufnahme (Munsterhjelm et al., 2015; Wallenbeck und Keeling, 2013), sowie das objektbezogene manipulative Verhalten (Larsen et al., 2019) von Schweinen zurück. Eine Identifikation von Täter- und Opfer-Tieren im Schwanzbeißgeschehen wäre notwendig, um anhand eines Beschäftigungsprofils Rückschlüsse auf Abweichungen vom Normalverhalten ziehen zu können. Hierzu wären weiterführende Untersuchungen und die Evaluierung von einzeltierbezogenen Täter- und Opfer-Profilen im Schwanzbeißgeschehen erforderlich. RFID-Daten erlauben ein sehr differenziertes Bild über die Bewegungsaktivität (Kjaer, 2017) und der örtlichen Erfassung von Tieren, jedoch erlauben sie keine weitere Differenzierung der Verhaltensweisen, die ausgeführt werden, während sich das Tier im Lesefeld der Antennen befindet. Diese Grenzen von RFID-Systemen müssen, wie in der vorliegenden Arbeit, bei der Versuchsplanung berücksichtigt werden. Bedarf es anhand der Fragestellung einer weiteren Differenzierung der Verhaltensweisen, müssen weitere Methoden zur Datenerhebung kombiniert werden, wie z.B. Videoaufnahmen oder Accelerometer (Naguib und Krause, 2020).

6.5 Einfluss des Beschäftigungsmaterials auf Schwanz- und Ohrschäden

In der vorliegenden Arbeit hatten die eingesetzten Beschäftigungsmaterialien in der Aufzucht einen Einfluss auf das Vorkommen von Schwanzschäden. Allerdings konnten Schwanzschäden durch eine Steigerung der Beschäftigungszeit am Beschäftigungsturm nicht in zufriedenstellendem Maß reduziert werden. Ohrschäden wurden hingegen nur bei 1,2 % aller untersuchten Schweine beobachtet und stellten somit eine Ausnahme dar. Daher richtet sich der Fokus in diesem Abschnitt auf den Einfluss von Beschäftigungsmaterial auf die Prävalenz von Schwanzschäden.

Schwanzschäden wurden in der vorliegenden Arbeit anhand des Deutschen Schweine-Boniturschlüssels (DSBS) erfasst (DSBS, 2017). Der Anteil der

Schweine mit natürlicher Schwanzlänge, d.h. ohne Schwanzlängenverlust (Kategorie 0) am Ende der Aufzucht und Mast ist in Tabelle 6.2 dargestellt. Dabei fällt auf, dass die meisten Schwanzlängenverluste während der Aufzucht erfasst wurden, sofern unterschiedlich strukturierte Materialien im zweiwöchigen Wechsel angeboten wurden. Vorausgehende Studien zeigten, dass ein wöchentlicher Wechsel von Beschäftigungsmaterialien im Vergleich zu kontinuierlich angebotenen Materialien bei Aufzuchtschweinen (Trickett et al., 2009) einen reduzierenden Effekt auf das Auftreten von Schwanzschäden hat. Wie bereits erwähnt, stellen zwei Wochen in der siebenwöchigen Aufzucht der vorliegenden Arbeit einen relativ langen Zeitraum dar. Eventuell wäre durch einen wöchentlichen Wechsel des Materials, wie er bei der Untersuchung verschiedener Aromen durchgeführt wurde, ein größerer Effekt auf die Reduzierung von Schwanzschäden erreicht worden. Es ist außerdem vorstellbar, dass in der vorliegenden Arbeit vor einem Auftreten von Schwanzbeißen in einer Bucht über zwei Wochen hinweg nicht das von den Schweinen bevorzugte Material zur Verfügung stand, mit dem die Beschäftigungsdauer hätte erhöht und Schwanzschäden hätten vermeiden werden können. Das bereitgestellte Beschäftigungsmaterial kann den Verlauf eines Schwanzbeiß-Geschehens beeinflussen (Lahrmann et al., 2018). Lahrmann et al. (2018) setzten bei ersten Anzeichen von Schwanzverletzungen in einer Bucht unterschiedliche Beschäftigungsmaterialien ein und stellten fest, dass der Einsatz von Heulage oder Stroh im Vergleich zu Buchten, in denen keine Intervention stattfand, den Ausbruch von Schwanzbeißen verhindern konnte, nicht aber ein Seil mit einem süßen Leckstein. Gerade vor einem Ausbruch von Schwanzbeißen scheint somit die Art des zur Verfügung gestellten Beschäftigungsmaterials besonders wichtig zu sein.

Weiter fällt auf, dass die wenigsten Schwanzlängenverluste bei Aufzucht- und Mastschweinen auftraten, wenn CS oder CS+MK kontinuierlich angeboten wurde. Über alle vorliegenden Versuche hinweg (Kapitel 3 – 5) wurden bei den Schweinen, die kontinuierlich CS erhalten haben, nach der Aufzucht (92,1 %) und nach der Mast (53,1 %) die meisten Schweine ohne Schwanzlängenverlust (Kategorie 0) erfasst. Somit traten in dieser Untersuchung (Kapitel 4) mehr Schwanzlängenverluste in der Mast als in der Aufzucht auf. Gerade in der Mast scheint das Angebot von CS daher nicht zur Reduktion von Schwanzschäden geeignet zu sein, was die Ergebnisse aus Kapitel 3 hinsichtlich der Beschäftigungsdauer beim Einsatz von CS bestätigen. Die geringen Teilverluste an den Schwänzen von Aufzuchtschweinen würden jedoch für ein kontinuierliches Angebot desselben Beschäftigungsmaterials ohne fressbaren Zusatz für Aufzuchtschweine sprechen, widerspricht jedoch den Ergebnissen aus bisherigen Untersuchungen. So wurde gezeigt, dass im Vergleich zu einem kontinuierlich angebotenen Seil ein wöchentlicher Wechsel aus sieben verschiedenen Materialien das Vorkommen von Schwanzschäden reduziert (Van de Perre et al., 2011). Die geringeren Teilverluste bei der kontinuierlichen Gabe von CS stellen gleichzeitig einen Wiederspruch zu den in der vorliegenden Arbeit erfassten Schwanzlängenverlusten bei der Untersuchung unterschiedlich strukturierter Materialien dar (Kapitel 3). Hier wurde neben LP, SP und CH auch CS im Wechsel angeboten. Es stellte sich heraus, dass die meisten neu erfassten Schwanzlängenverluste (47,4 %) während der Zeit auftraten, zu der den Aufzuchtschweinen CS zur Verfügung stand. Durch den Wechsel war den Tieren Beschäftigungsmaterial bekannt, die im Vergleich zu CS präferiert wurden. Womöglich wurde durch die Gabe von CS Frustration aufgrund von nicht bereitgestellten Vorlieben ausgelöst. Die wenigsten neu erfassten Schwanzlängenverluste wurden für LP (19,1 %) und SP (8,5 %) erfasst. Bei der Gabe von LP und SP wurde zudem die höchste Beschäftigungsdauer bei Aufzuchtschweinen erzielt.

Tabelle 6.2 Prozentualer Anteil von Schweinen ohne Längenverlust (Kategorie 0) nach der Aufzucht und Mast.

Beschäftigungsmaterialien	Aufzucht		Mast	
	Anteil (%)[1]	Anzahl Tiere gesamt (n)	Anteil (%)[1]	Anzahl Tiere gesamt (n)
Strukturierte Materialien (Kapitel 3)	16,0 %	94	15,7 %	172
Aromatisierte Strohpellets (Kapitel 4)	57,9 %	183	22,6 %	168
Nutritiver Zusatz (Kapitel 5)	76,1 %	276	44,0 %	259

[1]Bezugsgröße ist jeweils die Anzahl der insgesamt bonitierten Schweine (n) am Ende der Aufzucht bzw. Mast.

In der vorliegenden Arbeit stellte sich heraus, dass eine hohe Beschäftigungsdauer nicht immer mit einem geringen Anteil von Schwanzschäden bei Schweinen korreliert. Dies ist eine wesentliche neue Erkenntnis, denn oft wird angenommen (Telkänranta et al., 2014; Van de Weerd et al., 2006), dass das Angebot von Beschäftigungsmaterialien und eine hohe Explorationszeit von Tieren ausreicht, um in der konventionellen Haltung einen ersten Schritt gegen das Auftreten von Schwanzbeißen zu machen. Die Ausganslage scheint jedoch komplexer zu sein, denn mehrfach traten die meisten Schwanzlängenverluste über einen Zeitraum auf, zu dem den Schweinen ein Beschäftigungsmaterial zur Verfügung stand, das eine hohe Beschäftigungsdauer erzielte. Besonders deutlich wurde dies bei der Gabe von CS+MK. In der vorliegenden Arbeit trat Schwanzbeißen meist sehr plötzlich auf und verbreitete sich schnell in der gesamten Bucht. Die beobachtete Form von Schwanzbeißen deckt sich in weiten Teilen mit der Definition des „sudden forceful" Schwanzbeißens von Taylor et al. (2010). Als Ursache beschreiben die Autoren einen nicht verfügbareren Zugang zu einer vom Schwein gewünschten Ressource. Es ist daher nicht auszuschließen, dass Schweine in der vorliegenden Arbeit nicht ausreichend Zugang zu dem angebotenen Beschäftigungsmaterial hatten oder der Vorrat von sehr beliebten Beschäftigungsmaterialien schnell aufgebraucht wurde und den Schweinen an vereinzelten Wochenenden nicht zur Verfügung stand. Für limitierte Ressourcen zeigen Schweine eine höhere Synchronisation des Verhaltens als für *ad libitum* verfügbare Ressourcen (Docking et al., 2008), was verdeutlicht, dass Schweine eine entstehende Ressourcenknappheit erlernen können und ihr Verhalten daran anpassen. Diese erhöhte Konkurrenz um das Beschäftigungsmaterial könnte zu Stress bei den Schweinen geführt haben, was wiederum Schwanzbeißen begünstigt (Schrøder-Petersen und Simonsen, 2001). Aus diesem Grund stellt der ständige Zugang zu Beschäftigungsmaterial in ausreichender Menge für Schweine eine wichtige Voraussetzung dar, um artgerechtes Verhalten zu ermöglichen und um Schwanzbeißen zu reduzieren. Es ist daher naheliegend, dass das Auftreten von Schwanzbeißen durch eine Erhöhung der Tierplätze am Beschäftigungsturm oder einen größeren Vorrat des Beschäftigungsmaterials reduziert werden kann.

Weissenbacher-Lang et al. (2012) untersuchten, ob Mykotoxine im Futter das Vorkommen von Ohrnekrosen beim Schwein beeinflussen. Sie konnten einen Zusammenhang aber weder bestätigen noch ausschließen und vermuteten ein Zusammenwirken mehrerer Faktoren, die Ohrnekrosen auslösen. Nekrosen am

Schwanz von Schweinen können ebenfalls zu Teilverlusten führen. Mykotoxine im Beschäftigungsmaterial können in der vorliegenden Arbeit beim Einsatz von CS oder CS+MK jedoch als Ursache für Schwanzlängenverluste ausgeschlossen werden. Aufgrund des hohen Anteils an Schwanzlängenverlusten von Schweinen, die CS+MK erhielten, wurden Stichproben der verwendeten Beschäftigungsmaterialien (Stroh und Mais) auf ihren Mykotoxingehalt untersucht. Dabei lagen Deoxynivalenol (DON), Zearalenon (ZEA) und Fumonisine unterhalb der Nachweisgrenze oder im unbedenklichen Bereich (DON < 0,2 mg/kg, ZEA < 0,03 mg/kg, Fumonisine < 0,25 mg/kg).

Wie bereits vorausgehend erwähnt, wurde für Aufzuchtschweine, die unterschiedlich strukturierte Materialien erhalten haben und für Mastschweine, die unterschiedlich aromatisierte Strohpellets erhalten haben eine vergleichsweise geringe Beschäftigungsdauer am Beschäftigungsturm erfasst. Wie aus Tabelle 6.2 hervorgeht, wurden in diesen beiden Abschnitten der Versuche (Kapitel 3 und 4) die meisten Schwanzlängenverluste beobachtet. Da die Beschäftigungsdauer von Schweinen bereits vor dem Auftreten von Schwanzbeißen zurückgeht (Larsen et al., 2019), könnten die niedrigen Beschäftigungsdauern auch lediglich ein Anzeichen für stattgefundenes Schwanzbeißen gewesen sein und weniger ein Effekt des untersuchten Materials.

6.6 Gesamtheitliche Betrachtung von Risikofaktoren für Schwanzbeißen

Aufgrund der Tatsache, dass in allen Versuchsdurchgängen zwischen 84,3 und 56,0 % der Schweine einen Schwanzlängenverlust erlitten, wurde die in Kapitel 1.2.2.3 vorgestellte Tabelle 1.2 über Risikofaktoren der Haltungsumwelt auf Schwanzbeißen mit Daten aus der vorliegenden Arbeit erweitert (Tabelle 6.3), um eine Risikoanalyse ableiten zu können.

Der Einsatz einer Breifütterung, zu der mehrere Schweine gleichzeitig Zugang hatten, müsste gemäß Hunter et al. (2001) und Smulders et al. (2008) das Risiko für Schwanzbeißen in der vorliegenden Arbeit reduziert haben. Jedoch wurden die Schweine in der Aufzucht, mit Ausnahme der teilperforierten Liegefläche, auf Vollspaltenboden gehalten, während den Mastschweinen ausschließlich Vollspalten als Bodenbelag zur Verfügung standen. Da die Prävalenz für Schwanzbeißen mit zunehmendem Anteil an Spaltenboden steigt (Smulders 2008), stellte die Bodenbeschaffenheit in der vorliegenden Arbeit ein Risikofaktor für Schwanzbeißen dar. Um die Beschäftigungsdauer zwischen möglichst homogenen Gruppen vergleichen zu können, wurden die Schweine in den vorliegenden Versuchen zufällig auf die Buchten in der Aufzucht und Mast verteilt. Dies brachte eine Heterogenität der Gewichte innerhalb der Buchten mit sich, wodurch das Risiko für Schwanzbeißen ggf. erhöht wurde (Scollo et al., 2016). Der Zugang zu Beschäftigungsmaterial wirkt sich reduzierend auf das Vorkommen von Schwanzbeißen aus (Beattie et al., 1995; Fraser et al., 1991; Hunter et al., 2001) und wurde den Schweinen in der vorliegenden Arbeit in großem Umfang und in einer hohen Vielfalt ermöglicht. Die Gruppengröße in der Schweinehaltung hat vermutlich keinen Einfluss auf die Prävalenz von Schwanzbeißen (Schmolke et al., 2003), dennoch wären anhand der Beobachtungen in der vorliegenden Arbeit für Aufzuchtschweine kleine Gruppen empfehlenswert. Dadurch könnte bei einem Schwanzbeißereignis die Ausbreitung auf eine hohe Tierzahl vermieden werden. Ganzheitlich betrachtet, wurden in der Haltungsumwelt der untersuchten Schweine Risikofaktoren identifiziert, die zusätzlich zu den erfassten und ausgewerteten Daten die Prävalenz für Schwanzbeißen beeinflusst haben könnten.

Wie sich aus Tabelle 6.3 ableiten lässt, sind Wildschweine den jahreszeitlich wechselnden klimatischen Bedingungen sowie dem damit verbundenen wechselnden Nahrungsangebot ausgesetzt. Sie können jedoch innerhalb ihres vielseitigen Lebensraums auftretenden Stressoren ausweichen und sind durch ihre hohe Sinnesleistung bestens an sich ändernde Bedingungen angepasst (omnivore Ernährung, Lebensraum im Wald und auf angrenzenden Flächen, großes Revier; Vgl. Tabelle 6.3). Hausschweine werden hingegen nach guter fachlicher Praxis in einer vom Menschen vorgegebenen Haltungsumwelt untergebracht. Dabei wird den Tieren Schutz vor der Witterung und die Verfügbarkeit von Nahrung geboten. Jedoch wirken dadurch gleichzeitig Umwelteinflüsse, wie eine einseitige Ernährung, hohe Ammoniakkonzentrationen, hohe/niedrige Temperaturen, Futterkonkurrenten oder das Absetzen von der Sau auf das Hausschwein ein (Vgl. Tabelle 6.3), dem es durch die räumliche Begrenzung des Stalles nicht ausweichen kann. Das Hausschwein hat gegen diese auf das Tier einwirkende Umwelteinflüsse Bewältigungsstrategien entwickelt, die je nach Art und Zusammenspiel der Umwelteinflüsse sowie der Möglichkeit zur Stressbewältigung stärker oder schwächer auftreten. Da auf Schweine in der Obhut des Menschen, unabhängig vom Haltungssystem, immer unumgängliche Umwelteinflüsse einwirken werden, scheint es aus aktueller Sicht unmöglich zu sein, das Schwanzbeißen in der Schweinehaltung komplett zu verhindern. Jedoch könnte den Tieren beispielsweise durch das Angebot von ausreichenden Mengen an Beschäftigungsmaterial und durch die Schaffung von Klima- oder Funktionsbereichen die Möglichkeit geboten werden, mit der Haltungsumwelt zu interagieren. Dies würde den Schweinen ermöglichen, ihre stark ausgeprägten Sinne einzusetzen, arttypisches Verhalten wie die Exploration auszuüben und auftretenden Stressoren auszuweichen.

Tabelle 6.3 Der Haltungsumwelt von Hausschweinen zugeordnete Parameter, die einen Risikofaktor für Schwanzbeißen darstellen und Kennwerte der Haltungsumwelt von Haus- und Wildschweinen in einer Gegenüberstellung mit der vorliegenden Studie.

Parameter	Wildschwein		Hausschwein			
	Kennwert	**Literatur**	**Kennwert**	**Risikofaktor**	**Literatur**	**vorliegende Studie**
Klima	Abhängig von der Saison			NH_3 > 10 ppm NH_3 > 2,7 ppm	Scollo et al. (2016) Scollo et al. (2017)	Keine Datenerfassung
				Hohe Temperaturen (Aufzucht)	Smulders et al. (2008)	Keine Datenerfassung
Fütterung	Omnivore Ernährung	Rodríguez-Estévez et al. (2009)	Alleinfutter (Phasenfütterung)			
				Trockenfütterung > Nassfütterung	Smulders et al. (2008)	Aufzucht: Breifutter Mast: Trockenfütterung
				Einzeltierfütterung, Bodenfütterung > zwei oder mehr Futterplätze	Hunter et al. (2001)	Aufzucht: Tier:Fressplatz Verhältnis 2,4:1 Mast: Einzeltierfütterung
	Futteraufnahme: 11,9 %, Futtersuche: 11,3 % der Beobachtungszeit (Scan sampling über ein Jahr)	Blasetti et al. (1988)	Fressdauer: 67,0 min/Tier und Tag		Hyun et al. (1997)	
			68,8 min/Tier und Tag		Brown-Brandl et al. (2013)	
Management und Haltung	Wald sowie daran angrenzende Felder und Wiesen	Dardaillon (1986) Massei und Genov (2004)	Voll- oder Teilspalten bei 91,8 % der Haltungsplätze		BMEL (2010)	
				Hoher Anteil an Spaltenboden	Smulders et al. (2008)	Aufzucht: Teilspalten Mast: Vollspalten
	Säugezeit: 9-14 Wochen	Newberry und Wood-Gush (1985)	Absetzen i.d.R. 4 Wochen nach der Geburt			
				Frühes Absetzen (12 Tage nach der Geburt)	Gonyou et al. (1998)	Absetzen: 4 Wochen nach der Geburt
				Heterogene Gewichte	Scollo et al. (2016)	Heterogene Gewichte (zufällige Verteilung auf die Versuchsgruppen)
	Revier: 104,4 ha	Lemel et al. (2003)	0,4 m^2 (bei 30-50 kg), 0,65 m^2 (bei 95-110 kg)		Richtlinie 2008/120/EG (2008)	

				Hohe Besatzdichte	Scollo et al. (2016)	Aufzucht: 0,58 m²/Tier Mast: 1,14 m²/Tier
	Gruppen bis zu 23 Tiere	Fernández-Llario et al. (1996)		Kein Einfluss der Gruppengröße	Schmolke et al. (2003)	Aufzucht: 24 Tiere/Bucht Mast: 12 Tiere/Bucht
Zugang zu Beschäftigungs-material	Exploration (Futtersuche und Erkundung des Lebensraums)	Day et al. (1995)	Kein Beschäftigungs-material		Beattie et al. (1995) Fraser et al. (1991) Hunter et al. (2001)	Beschäftigungsturm Hanfseile Kauhölzer
			Beschäftigungsmaterial als limitierte Ressource		Van de Perre et al. (2011)	Leere Türme, Tier:Beschäftigungsplatz-Verhältnis: Aufzucht 1,7:1, Mast 1,5:1

7. Ausblick

In der Vergangenheit wurden bereits zahlreiche Beschäftigungsmaterialien für Schweine hinsichtlich ihres Einflusses auf die Beschäftigungszeit und Schwanzschäden untersucht. Dabei lag das Augenmerk in der vorliegenden Arbeit auf der Untersuchung von Beschäftigungsmaterialien, die unterschiedliche Sinnesreize bei Schweinen ansprechen. So wurden Beschäftigungsmaterialien mit verschiedenen Strukturen, applizierten Aromen oder fressbaren Zusätzen eingesetzt. Zwar zeigten Schweine anhand ihrer Beschäftigungszeit klare Präferenzen für bestimmte Materialien, dennoch traten häufig Schwanzschäden in Form von Teilverlusten oder Hautdurchbrechungen auf. Für zukünftige Untersuchungen hinsichtlich der Eignung von Beschäftigungsmaterialien für Schweine wäre eine Kombination der in der vorliegenden Arbeit untersuchten Materialien denkbar. Durch ein alternierendes Angebot unterschiedlicher Materialeigenschaften (Strukturen, Aromen und fressbare Zusätze) könnte der Effekt der Neuartigkeit gesteigert werden. Auch wäre ein Kombinieren der Materialeigenschaften denkbar, wie das Mischen aromatisierter Pellets mit gehäckseltem Material oder das Beifügen unterschiedlicher fressbarer Zusätze in pelletierte Materialien. Diese weiterführenden Untersuchungen könnten die Sinnesleistung von Schweinen in einem noch größeren Maße fordern und arttypisches Verhalten fördern.

Darüber hinaus werden von Schweinen Materialien bevorzugt, die eine ähnliche Struktur wie Erde besitzen (Jensen et al., 2008). Wühlerde wurde als Beschäftigungsmaterial in der vorliegenden Arbeit nicht untersucht, um aus funktionalen und hygienischen Gründen stark anhaftende Verschmutzungen am Beschäftigungsturm zu vermeiden. Weiterführende Untersuchungen mit erdigen Materialien könnten jedoch einen vielversprechenden Ansatz zur Steigerung der Beschäftigungsdauer von Schweinen darstellen.

Der in der vorliegenden Arbeit genutzte Beschäftigungsturm mit Wühlbereich ermöglichte den Schweinen das Ausüben von Explorationsverhalten in Form von Wühlen. Er stellt daher eine praxistaugliche Möglichkeit zur Vorlage von Beschäftigungsmaterialien für Schweine dar. Obwohl die Beschäftigungsdauer am Beschäftigungsturm über die Aufzucht und Mast hinweg aufrechterhalten werden konnte, traten Schwanzschäden auf. In diesem Zusammenhang wäre ein möglicher Einfluss des Beschäftigungsturms denkbar, indem der Zugang zu dem Beschäftigungsmaterial limitiert war. Bei der Nutzung des Beschäftigungsturms sollte daher darauf geachtet werden, dass eine regelmäßige Befüllung, z.B. auch am Wochenende, stattfindet. Darüber hinaus könnte der Zugang zu dem Beschäftigungsmaterial und dessen Verfügbarkeit durch den Einbau mehrerer Beschäftigungstürme erhöht werden, wodurch das Beschäftigungsmaterial eine weniger limitierte Ressource darstellt und somit zusätzlicher Stress reduziert werden kann.

Die Bonitur der Teilverluste an den Schwänzen der Schweine erfolgte anhand des Deutschen Schweine-Boniturschlüssels (DSBS). Dieser berücksichtigt fünf Kategorien, in denen zum einen der unversehrte Schwanz eine Kategorie bildet und die weitere Einteilung in Dritteln des Schwanzes erfolgt (Verlust bis zu einem Drittel, bis zu zwei Drittel, mehr als zwei Drittel und Totalverlust). Häufig traten in der vorliegenden Arbeit jedoch kleine Teilverluste an der Schwanzspitze auf, die anhand des DSBS in dieselbe Kategorie fielen, wie Teilverluste bis zu einem Drittel. Dies kann zu einer Überinterpretation der Ergebnisse führen. Dabei sollen Verletzungen an der Schwanzspitze keinesfalls marginalisiert werden, versprechen jedoch ausgehend von Beobachtungen während der Datenerfassung für die vorliegende Arbeit eine größere Wahrscheinlichkeit der schnellen Heilung und weniger weitreichende Folgeinfektionen. Aus diesem Grund wäre eine differenzierte Erfassung von Verlusten im Bereich der Schwanzspitze und weiteren Teilverlusten gemäß dem DSBS empfehlenswert.

Letztendlich stellt Schwanzbeißen bei Schweinen ein multifaktorielles Problem dar. Neben der Erfassung der Beschäftigungsdauer beim Einsatz unterschiedlicher Beschäftigungsmaterialien wäre die Erhebung weiterer Risikofaktoren für Schwanzbeißen empfehlenswert, um das Zusammenwirken einzelner Einflussfaktoren auf die Verhaltensanomalie zu verstehen.

Schlussfolgerung

Mit der vorliegenden Arbeit konnte anhand einer erhöhten Beschäftigungsdauer attraktives organisches Beschäftigungsmaterial für Schweine identifiziert werden, welches in konventionellen Ställen genutzt werden kann. Dabei unterschieden sich die stark explorierten Materialien zwischen Aufzucht- und Mastschweinen. Des Weiteren kann der Einsatz fressbarer Zusätze sowie ein Wechsel von Strukturen oder Aromen die Habituation von Schweinen an Beschäftigungsmaterialien verhindern. Schwanzschäden konnten durch eine Erhöhung der Beschäftigungszeit nicht reduziert werden und wurden vor allem in der Aufzucht (fünfte bis elfte Lebenswoche) beobachtet. Hier wurden Effekte der untersuchten Materialien auf Schwanzlängenverluste und Hautdurchbrechungen am Schwanz analysiert. Möglicherweise kann die Art des Beschäftigungsmaterials oder die Art der Darreichung auch zu Konkurrenz innerhalb der Gruppe führen. Ohrschäden traten insgesamt nur sehr selten auf.

In der Aufzucht kann durch die Verwendung pelletierter Materialien oder durch das Aromatisieren von Beschäftigungsmaterialien mit Bratzwiebel- oder Mandel-Aroma die Beschäftigungsdauer gesteigert werden. Dabei empfiehlt sich zur Reduktion der Habituation ein wöchentlicher Wechsel des Materials. Bei Mastschweinen kann sowohl mit pelletierten als auch mit gehäckselten Materialien eine Steigerung der Beschäftigungsdauer erzielt werden. Dabei stellt die Verwendung applizierter Aromen keinen Vorteil gegenüber den natürlichen Aromen von Beschäftigungsmaterialien dar. Das Beimischen fressbarer Materialien steigert die Beschäftigungsdauer sowohl von Aufzucht- als auch von Mastschweinen. Jedoch sollte eine ausreichende Menge des angebotenen Beschäftigungsmaterials und genügend Platz am Beschäftigungsturm zur Verfügung gestellt werden, wodurch den Tieren ein ständiger Zugang zu den Materialien gewährleistet wird. Zur Reduktion von Schwanzschäden sind neben der Bereitstellung geeigneter Beschäftigungsmaterialien zur Steigerung der Beschäftigungsdauer weitere Maßnahmen zur Verbesserung der Haltungsbedingungen unkupierter Schweine notwendig.

Die Ergebnisse der vorliegenden Arbeit verdeutlichen, dass organische Beschäftigungsmaterialien zum einen arttypisches Verhalten von Schweinen fördern und damit das Wohlergehen konventionell gehaltener Schweine steigern können. Andererseits reicht der Einsatz von Beschäftigungsmaterial als alleinige Maßnahme gegen Schwanzbeißen nicht aus, um das Auftreten von Schwanzschäden bei unkupierten Schweinen zu reduzieren. Ein komplexer Zusammenhang mehrerer Risikofaktoren verursacht das Auftreten dieser Verhaltensanomalie, weshalb bei der Implementierung von Lösungsansätzen gegen Schwanzbeißen neben dem Angebot von Beschäftigungsmaterial weitere Risikofaktoren erfasst und analysiert werden müssen. Letztendlich haben Schweine in einer vorgegebenen Haltungsumwelt wenige Möglichkeiten, auftretenden Stressoren auszuweichen. Hierbei stellt sich die Frage, ob unter Berücksichtigung der multifaktoriellen Problematik die Haltung von Schweinen mit unkupierten Schwänzen in konventionellen Ställen ohne das Auftreten von Schwanzschäden überhaupt möglich ist. Oder ob das Problem darin liegt, dass Schweine mit einer hohen Sinnesleistung in einer reizarmen Umwelt gehalten werden und die heute sogenannten alternativen Haltungssysteme keine Alternative darstellen, sondern eine Notwendigkeit bei der Haltung von Schweinen mit langem Schwanz sind.

Aufgrund der Möglichkeit einer tierindividuellen Datenerfassung ist die Verwendung eines UHF-RFID-Systems zur Etablierung eines Frühwarnsystems denkbar, um Verhaltensanomalien wie Schwanzbeißen frühzeitig anhand von Aktivitätsindikatoren erkennen und somit eliminieren zu können. Darüber hinaus werden in der Praxis Möglichkeiten gesucht, wie die lückenlose Rückverfolgbarkeit von der Geburt eines Schweines bis zum Einzelhandel gewährleistet werden kann. Der Einsatz der UHF-RFID hätte dabei großes Potential Schweine anhand von UHF-RFID-Ohrmarken individuell zu kennzeichnen, wodurch gleichzeitig eine kontinuierliche Verhaltensüberwachung auf Einzeltierebene möglich wäre.

Zusammenfassung

Schwanzbeißen ist eine Verhaltensanomalie, die häufig bei konventionell gehaltenen Hausschweinen auftritt. Dabei kann es das Wohlergehen betroffener Schweine beeinträchtigen und ökonomische Verluste für den landwirtschaftlichen Betrieb bedeuten. Die Ursachen von Schwanzbeißen sind multifaktoriell, weshalb die bis heute gängigste Methode zur Reduktion von Schwanzschäden bei Schweinen das präventive Kupieren des Schwanzes darstellt. Neben dem invasiven Eingriff wirkt jedoch auch der Einsatz von Beschäftigungsmaterialien reduzierend auf Schwanzschäden, indem das arttypische Explorationsverhalten gesteigert wird. Dabei stellt die schnelle Habituation von Schweinen eine Herausforderung bei der Auswahl geeigneter Beschäftigungsmaterialien dar.

Im Rahmen des Projekts „Label-Fit – Schweinehaltung fit für das Tierschutzlabel“, wurden unterschiedliche organische Beschäftigungsmaterialien für Aufzucht- und Mastschweine untersucht, die in konventionellen Haltungssystemen mit Spaltenböden eingesetzt werden können. Das Ziel der vorliegenden Arbeit war die Identifikation von attraktivem Beschäftigungsmaterial anhand der Explorationsdauer der Tiere. Gleichzeitig wurde der Einfluss der eingesetzten Beschäftigungsmaterialien auf Schwanz- und Ohrschäden bei Schweinen mit unkupiertem Schwanz untersucht.

Vor der Durchführung von drei Langzeituntersuchungen, wurden zwei Wahlversuche zur Eingrenzung der für Schweine attraktiven organischen Beschäftigungsmaterialien durchgeführt. Dabei wurden unkupierten Schweinen in einem Trog mit sechs Fächern zum einen unterschiedlich strukturierte Materialien und zum anderen verschiedene fressbare Zusätze in Stroh parallel angeboten. Anhand der individuell erfassten Beschäftigungsdauer zeigten Schweine klare Präferenzen für pelletierte Materialien und bevorzugten gehäckseltes Stroh mit einem fressbaren Zusatz, wie Maiskörner. Diese Ergebnisse wurden zur Auswahl von Beschäftigungsmaterialien für die anschließenden Langzeituntersuchungen herangezogen.

Für die drei Langzeituntersuchungen wurden Beschäftigungstürme mit einem integrierten UHF-RFID-System ausgestattet, um die Beschäftigungsdauer der Schweine an dem mit Beschäftigungsmaterial gefüllten Beschäftigungsturm

aufzuzeichnen. Beim Wechsel der alternierend angebotenen Beschäftigungsmaterialien wurden die Schwänze und Ohren der Schweine gemäß dem „Deutschen Schweine Boniturschlüssel“ hinsichtlich Teilverluste und Hautdurchbrechungen bewertet.

In der ersten Langzeituntersuchung erhielten Aufzucht- und Mastschweine vier Beschäftigungsmaterialien mit unterschiedlichen Strukturen (Luzernepellets, Strohpellets, gehäckseltes Heu und gehäckseltes Stroh) im zweiwöchigen Wechsel. Dabei präferierten Aufzuchtschweine pelletierte Materialien, während Mastschweine Präferenzen für gehäckseltes Heu und Luzernepellets zeigten. Darüber hinaus stieg die Beschäftigungsdauer von der Aufzucht zur Mast an. Beim Einsatz der Materialien, die die höchste Beschäftigungsdauer in der Aufzucht erzielten (Luzernepellets oder Strohpellets), wurden die wenigsten Teilverluste am Schwanz erfasst. Jedoch traten beim Einsatz von Strohpellets in der Aufzucht die meisten Hautdurchbrechungen an den Schwänzen auf.

Die zweite Langzeituntersuchung befasste sich mit der Frage, ob die Beschäftigungsdauer von Aufzucht- und Mastschweinen beim Einsatz von gehäckseltem Stroh gesteigert werden kann, wenn Maiskörner als fressbarer Zusatz untergemischt werden. Im Vergleich zu Schweinen, die gehäckseltes Stroh ohne Mais erhielten, zeigten Schweine, denen gehäckseltes Stroh mit Mais bereitgestellt wurde, in der Aufzucht und Mast eine höhere Beschäftigungsdauer am Beschäftigungsturm. Die Beschäftigungsdauer konnte zudem von der Aufzucht zur Mast gesteigert werden, obwohl kein Materialwechsel innerhalb der Gruppen stattfand. Darüber hinaus wurden saisonale Unterschiede in der Tagesrhythmik von Schweinen festgestellt. Erstaunlicherweise traten bei den Schweinen, die gehäckseltes Stroh ohne Mais erhielten, im Vergleich zu den Schweinen, die gehäckseltes Stroh mit Mais erhielten, geringere Teilverluste am Schwanz auf.

In der dritten Langzeituntersuchung wurden Aufzucht- und Mastschweinen unterschiedlich aromatisierte Strohpellets im wöchentlichen Wechsel angeboten. Es stellten sich unterschiedliche Präferenzen für Aromen zwischen Aufzucht- und Mastschweinen heraus. Die höchsten Beschäftigungsdauern wurden in der Aufzucht für Strohpellets mit Bratzwiebel-Aroma oder Mandel-Aroma erfasst. In der Mast beschäftigten sich die Schweine am längsten mit Strohpellets ohne

Aroma oder mit Erdbeer-Aroma. Dabei konnte die Beschäftigungsdauer von der Aufzucht bis zur Mast konstant gehalten werden. Die meisten Hautdurchbrechungen am Schwanz traten in der Aufzucht bei der Verwendung von Vanille-Aroma oder Bratzwiebel-Aroma auf, wobei Vanille im Unterschied zu Bratzwiebel zu den Aromen mit den geringsten Beschäftigungsdauern zählte.

Anhand der vorliegenden Untersuchungen konnten klare Präferenzen von Schweinen für bestimmte organische Beschäftigungsmaterialien gezeigt werden, die arttypisches Explorationsverhalten steigerten. Jedoch konnten Beschäftigungsmaterialien, für die eine hohe Beschäftigungsdauer erfasst wurde, Schwanzschäden in Form von Längenverlusten und Hautdurchbrechungen nicht reduzieren. Dies verdeutlicht, dass neben dem Zugang zu Beschäftigungsmaterial weitere Faktoren auf die Prävalenz für Schwanzschäden einwirken, welche zusammenhängend betrachtet werden müssen.

Summary

Tail biting is a behavioural disorder that often occurs in commercially housed domestic pigs. It may affect welfare of involved pigs and cause economic losses for the farm. The causes of tail biting are multifactorial, which is why preventive tail docking is the most comon method to reduce tail damages in pigs until today. However, besides invasive interventions, the use of enrichment materials can reduce tail biting by increasing species-specific exploration behaviour. Thereby, the rapid habituation of pigs poses a challenge in the selection of enrichment materials.

Within the research project “Label-Fit – Schweinehaltung fit für das Tierschutzlabel”, different plant-based enrichment materials for rearing and fattening pigs were investigated, which can be used in conventional housing systems with slatted floors. The aim of the present study was to identify attractive enrichment material based on the exploration duration. Furthermore, the influence of the enrichment materials on tail and ear damages was investigated in pigs with undocked tails.

Prior to three long-term investigations, two choice tests were carried out for better delimination of plant-based enrichment materials considered attractive for pigs. Therefore, pigs were offered enrichment materials of different structure or, in the second test, straw with different edible additives. In both tests materials were offered in parallel in six boxes. By means of the individually recorded exploration durations, pigs showed clear preferences for pelleted materials and preferred chopped straw with edible additives, such as maize kernels. These results were used to select enrichment materials for further long-term investigations.

In the three long-term investigations, material dispensers were equipped with an UHF-RFID system to record exploration durations of the pigs at the material dispenser filled with enrichment materials. Enrichment materials were offered in an alternating order and at each change of material the tails and ears of the pigs were recorded according to the “Deutscher Schweine Bonitur Schlüssel” (DSBS) regarding partial losses and skin injuries.

In the first long-term investigation, rearing and fattening pigs received four enrichment materials with different structures (lucerne pellets, straw pellets, chopped hay and chopped straw) in a two-weekly change. Rearing pigs preferred pelletized materials, while fattening pigs showed preferences for chopped hay and lucerne pellets. Furthermore, exploration duration increased from rearing to fattening. When offering the enrichment materials that achieved the highest exploration durations in rearing (lucerne pellets or straw pellets), the fewest partial losses of the tails were recorded. However, when offering straw pellets in rearing, most injuries at the tails occurred.

The second long-term investigation dealed with the question, if exploration duration of rearing and fattening pigs for chopped straw can be increased by adding maize kernels. Compared with pigs that received chopped straw without maize, pigs that received chopped straw with maize kernels showed higher exploration durations at the material dispenser during rearing and fattening. Furthermore, exploration duration could be increased from rearing to fattening, although there was no change of the material within the groups. Additionally, saisonal differences in the diurnal pattern of exploration of pigs were found. Interestingly, pigs that received chopped straw without maize kernels showed fewer length losses of the tails compared to pigs that received chopped straw with maize kernels.

In the third long-term investigation, rearing and fattening pigs received different flavoured straw pellets in a weekly change. Different preferences for flavours were found between rearing and fattening pigs. During rearing, highest exploration durations were recorded for straw pellets with fried onion flavour or almond flavour. During fattening, pigs explored straw pellets without flavour or with strawberry flavour longest. Exploration duration could be maintained at a constant level from rearing to fattening. Most skin injuries at the tails occurred when using vanilla flavour or fried onion flavour during rearing, whereby vanilla, unlike fried onion, was one of the flavours with the lowest exploration durations.

On the basis of the present investigations clear preferences of pigs for specific plant-based enrichment materials could be shown, which increased species-specific exploration behaviour. However, enrichment materials for which high exploration durations were recorded could not reduce tail damages, such as partial

losses or skin injuries. This illustrates that, apart from the access to enrichment material, further factors influence the prevalence of tail damages, which have to be considered in relation to each other.

Literaturverzeichnis

999/2001, V. E. N., 2001. Verordnung (EG) Nr. 999/2001 des europäischen Parlaments und des Rates vom 22. Mai 2001 mit Vorschriften zur Verhütung, Kontrolle und Tilgung bestimmter transmissibler spongiformer Enzephalopathien.

2008/120/EG, R., 2008. Richtlinie 2008/120/EG vom 18. Dezember 2008 über Mindestanforderungen für den Schutz von Schweinen.

Abriel, M. und C. Jais, 2013. Einfluss der Haltungsbedingungen auf das Auftreten von Kannibalismus bei Aufzuchtferkeln. Landtechnik 68 (6), 389-394.

Adrion, F., N. Hammer, F. Eckert, S. Götz und E. Gallmann, 2015. Adjustment of a UHF-RFID system for hotspot monitoring of fattening pigs. Precision Livestock Farming ´15 Conference Paper of the 7th European Conference on Precision Livestock Farming.

Adrion, F., A. Kapun, F. Eckert, E. Holland, M. Staiger, S. Götz und E. Gallmann, 2018. Monitoring trough visits of growing-finishing pigs with UHF-RFID. Comput. Electron. Agr. 144, 144-153. doi:10.1016/j.compag.2017.11.036.

Ahmed, S. T., H. S. Mun, H. Yoe und C. J. Yang, 2015. Monitoring of behavior using a video-recording system for recognition of Salmonella infection in experimentally infected growing pigs. Animal 9 (1), 115-121. doi:10.1017/S1751731114002213.

Apple, J. K. und J. V. Craig, 1992. The influence on pen size on toy preference of growing pigs. Appl. Anim. Behav. Sci. 35, 149-155.

Baldwin, B. A., 1976. Quantitative studies on taste preference in pigs. Proc Nutr Soc 35 (1), 69-73. doi:10.1079/pns19760011.

Beattie, V. E., N. Walker und I. A. Sneddon, 1995. Effects of environmetnal enrichment on behaviour and productivity of growing pigs. Anim. Welfare. 4, 207-220.

Beattie, V. E., N. Walker und I. A. Sneddon, 1998. Preference testing of substrates by growing pigs. Anim. Welfare. 7, 27-34.

Beattie, V. E., K. Breuer, N. E. O'Connell, I. A. Sneddon, J. T. Mercer, K. A. Rance, M. E. M. Sutcliffe und S. A. Edwards, 2007. Factors identifying pigs predisposed to tail biting. Anim. Sci. 80 (3), 307-312. doi:10.1079/asc40040307.

Birbaumer, N., 1975. Aufmerksamkeit und Habituation. Physiologische Psychologie. Springer, Berlin, Heidelberg. doi:https://doi.org/10.1007/978-3-662-06095-7_6

Blackie, N. und M. de Sousa, 2019. The Use of Garlic Oil for Olfactory Enrichment Increases the Use of Ropes in Weaned Pigs. Animals (Basel) 9 (4). doi:10.3390/ani9040148.

Blackshaw, J. K., 1981. Some behavioural deviations in weaned domestic pigs. Persistent inguinal nose thrusting, and tain and ear biting. J. Anim. Sci. 33 (3), 325-332. doi:10.1017/S000335610003172X.

Blasetti, A., L. Boitani, M. C. Riviello und E. Visalberghi, 1988. Activity Budgets and Use of Enclosed Space by Wild Boars (Sus scrofa) in Captivity. Zoo Biology 7, 69-79.

BMEL, 2010. Landwirtschaftszählung. Landwirtschaftliche Betriebe mit Haltungsplätzen für Schweine nach Haltungsverfahren und Bestandsgrößenklassen. Statistik un Berichte des BMEL. Retrieved from https://www.bmel-statistik.de/fileadmin/daten/SJT-3101420-2010.xlsx

Bolhuis, J. E., W. G. P. Schouten, J. W. Schrama und V. M. Wiegant, 2005. Behavioural development of pigs with different coping characteristics in barren and substrate-enriched housing conditions. Appl. Anim. Behav. Sci. 93 (3-4), 213-228. doi:10.1016/j.applanim.2005.01.006.

Braekevelt, C. R., 1983. Fine structure of the retinal rods and cones in the domestic pig. Graefe´s Archive for Clinical and Experimental Ophthalmol 220, 273-278.

Breuer, K., M. E. M. Sutcliffe, J. T. Mercer, K. A. Rance, V. E. Beattie, I. A. Sneddon und S. A. Edwards, 2003. The effect of breed on the development of adverse social behaviours in pigs. Appl. Anim. Behav. Sci. 84 (1), 59-74.

Breuer, K., M. E. M. Sutcliffe, J. T. Mercer, K. A. Rance, N. E. O'Connell, I. A. Sneddon und S. A. Edwards, 2005. Heritability of clinical tail-biting and its relation to performance traits. Livestock Production Science 93 (1), 87-94. doi:10.1016/j.livprodsci.2004.11.009.

Brown-Brandl, T. M., G. A. Rohrer und R. A. Eigenberg, 2013. Analysis of feeding behavior of group housed growing–finishing pigs. Comput. Electron. Agr. 96, 246-252. doi:10.1016/j.compag.2013.06.002.

Brunberg, E. I., T. B. Rodenburg, L. Rydhmer, J. B. Kjaer, P. Jensen und L. J. Keeling, 2016. Omnivores going astray: a review and new synthesis of abnormal behavior in pigs and laying hens. Front. Vet. Sci. 3, 57. doi:10.3389/fvets.2016.00057.

Bünger, B., B. Zacharias und H. Schrade, 2017. Wann fressen Mastschweine wenn sie können wie sie wollen? Aktuelle Arbeiten zur artgemäßen Tierhaltung 2017, KTBL-Schrift 513, Darmstadt, 236-246.

D'Eath, R. B., G. Arnott, S. P. Turner, T. Jensen, H. P. Lahrmann, M. E. Busch, J. K. Niemi, A. B. Lawrence und P. Sandoe, 2014. Injurious tail biting in pigs: how can it be controlled in existing systems without tail docking? Animal 8 (9), 1479-1497. doi:10.1017/S1751731114001359.

D'Eath, R. B., M. Jack, A. Futro, D. Talbot, Q. Zhu, D. Barclay und E. M. Baxter, 2018. Automatic early warning of tail biting in pigs: 3D cameras can detect lowered tail posture before an outbreak. PLoS One 13 (4), e0194524. doi:10.1371/journal.pone.0194524.

Dardaillon, M., 1986. Seasonal veriations in habitat selection and spatial distribution of wild boar (Sus scrofa) in the Camargue, southern France. Behavioural Processes 13, 251-268.

Dardaillon, M., 1988. Wild boar social groupings and their seasonal changes in the Camargue, southern France. Zeitschrift für Säugetierkunde 53, 22-30.

Day, J. E. L., I. Kyriazakis und A. B. Lawrence, 1995. The effect of food deprivation on the expression of foraging and exploratory behaviour in the growing pig. Appl. Anim. Behav. Sci. 42, 193-206.

Day, J. E. L., A. Burfoot, C. M. Docking, X. Whittaker, H. A. M. Spoolder und S. A. Edwards, 2002. The effects of prior experience of straw and the level of straw provision on the behaviour of growing pigs. Appl. Anim. Behav. Sci. 76, 189-202.

Day, J. E. L., H. A. Van de Weerd und S. A. Edwards, 2008. The effect of varying lengths of straw bedding on the behaviour of growing pigs. Appl. Anim. Behav. Sci. 109 (2-4), 249-260. doi:10.1016/j.applanim.2007.02.006.

De Briyne, N., C. Berg, T. Blaha, A. Palzer und D. Temple, 2018. 'Phasing out pig tail docking in the EU - present state, challenges and possibilities'. Porcine Health Manag 4, 27. doi:10.1186/s40813-018-0103-8.

Devor, M. und Z. H. Rappaport, 1990. 3- Pain and the pathophyiology of damaged nerve. In Butterworths International Medical Reviews, Pain Syndromes in Neurology, Butterworth-Heinemann, 47-83. Retrieved from http://www.sciencedirect.com/science/article/pii/B9780407011243500095

Docking, C. M., H. A. Van de Weerd, J. E. L. Day und S. A. Edwards, 2008. The influence of age on the use of potential enrichment objects and synchronisation of behaviour of pigs. Appl. Anim. Behav. Sci. 110 (3-4), 244-257. doi:10.1016/j.applanim.2007.05.004.

DSBS, 2017. Deutscher Schweine Bonitur Schlüssel. Retrieved from https://www.fli.de/fileadmin/FLI/ITT/DSBS_EN_Kombi_170530.pdf

Dudde, A., L. Schrader, S. Weigend, L. R. Matthews und E. T. Krause, 2018. More eggs but less social and more fearful? Differences in behavioral traits in relation to the phylogenetic background and productivity level in laying hens. Appl. Anim. Behav. Sci. 209, 65-70. doi:10.1016/j.applanim.2018.08.017.

Düpjan, S., P.-C. Schön, B. Puppe, A. Tuchscherer und G. Manteuffel, 2008. Differential vocal responses to physical and mental stressors in domestic pigs (Sus scrofa). Appl. Anim. Behav. Sci. 114 (1-2), 105-115. doi:10.1016/j.applanim.2007.12.005.

Escobar, J., W. G. Van Alstine, D. H. Baker und R. W. Johnson, 2007. Behaviour of pigs with viral and bacterial pneumonia. Appl. Anim. Behav. Sci. 105 (1-3), 42-50. doi:10.1016/j.applanim.2006.06.005.

Fernández-Llario, P., J. Carranza und S. J. Hidalgo de Trucios, 1996. Social organization of the wild boar (Sus scrofa) in Doña National Park. Miscel lània Zoològica 19.2.

Folkman, S. und R. S. Lazarus, 1988. The relationship between coping and emotion: implications for theory and research. Social Science and Medicine 26 (3), 309-317.

Fraser, A. F., 1987. Attraction to blood as a factor in tail-biting by pigs. Appl. Anim. Behav. Sci. 17, 61 - 68.

Fraser, D., P. A. Phillips, B. K. Thompson und T. Tennessen, 1991. Effect of straw on the behaviour of growing pigs. Appl. Anim. Behav. Sci. 30, 307-318.

Giuffra, E., J. M. H. Kijas, V. Amarger, Ö. Carlborg, J.-T. Jeon und L. Andersson, 2000. The Origin of the Domestic Pig - Indepndent Domestication and Subsequent Introgression. Genetics 154, 1785-1791.

Glaser, D., M. Wanner, J. M. Tinti und C. Nofre, 2000. Gustatory responses of pigs to various natural and artificial compounds known to be sweet in man. Food Chemistry 68, 375-385.

Glendinning, J. I., 1994. Is the Bitter Rejection Response Always Adaptive? Physiol. Behav. 56 (6), 1217-1227.

Gonyou, H. W., E. Beltranena, D. L. Whittington und J. F. Patience, 1998. The behaviour of pigs weaned at 12 and 21 days of age from weaning to market. Canadian Journal of Animal Science 78, 517-523.

Hansson, I., C. Hamilton, T. Ekman und K. Forslund, 2000. Carcass quality in certified organic production compared with conventional livestock production. Journal of Veterinary Medicine. Series B 47 (2), 111-120. doi:10.1046/j.1439-0450.2000.00313.x.

Hare, B., M. Brown, C. Williamson und M. Tomasello, 2002. The Domestication of Social Cognition in Dogs. Science 298.

Heffner, R. S., H. E. Heffner, 1990. Hearing in domestic pigs *(Sus scrofa*) and goats (*Capra hircus*). Hearing Research 48, 231-240.

Hellekant, G. und V. Danilova, 1999. Taste in domestic pig, Sus scrofa. J. Anim. Physiol. An. N. 82, 8-24.

Hessing, M. J. C., A. M. Hagelsø, J. A. M. van Beek, P. R. Wiepkema, W. G. P. Schouten und R. Krukow, 1993. Individual behavioural characteristics in pigs. Appl. Anim. Behav. Sci. 37, 285-295.

Holinger, M., B. Früh, P. Stoll, M. Kreuzer und E. Hillmann, 2018. Grass silage for growing-finishing pigs in addition to straw bedding: Effects on behaviour and gastric health. Livest. Sci. 218, 50-57. doi:10.1016/j.livsci.2018.10.012.

Hsia, L. C. und D. G. M. Wood-Gush, 1983. The temporal patterns of food intake and allelomimetic feeding by pigs of different ages. Appl. Anim. Behav. Sci. 11, 271-282.

Hunter, E. J., T. A. Jones, H. J. Guise, R. H. Penny und S. Hoste, 2001. The relationship between tail biting in pigs, docking procedure and other management practices. Vet. J. 161 (1), 72-79. doi:10.1053/tvjl.2000.0520.

Hyun, Y., M. Ellis, F. K. McKeith und E. R. Wilson, 1997. Feed Intake Pattern of Group-Housed Growing-Finishing Pigs Monitored Using a Computerized Feed Intake Recording System. J. Anim. Sci. 75, 1443-1451.

Jans-Wenstrup, I., 2018. Untersuchungen zur Prävention der Caudophagie bei Absetzferkeln unter besonderer Berücksichtigung einer Pelletzulage. Dissertation. Justus-Liebig-Universität Gießen.

Jensen, M. B. und L. J. Pedersen, 2007. The value assigned to six different rooting materials by growing pigs. Appl. Anim. Behav. Sci. 108 (1-2), 31-44. doi:10.1016/j.applanim.2006.10.014.

Jensen, M. B., M. Studnitz, U. Halekoh, L. J. Pedersen und E. Jørgensen, 2008. Pigs' preferences for rooting materials measured in a three-choice maze-test. Appl. Anim. Behav. Sci. 112 (3-4), 270-283. doi:10.1016/j.applanim.2007.07.012.

Jensen, M. B., M. Studnitz und L. J. Pedersen, 2010. The effect of type of rooting material and space allowance on exploration and abnormal behaviour in growing pigs. Appl. Anim. Behav. Sci. 123 (3-4), 87-92. doi:10.1016/j.applanim.2010.01.002.

Jensen, P., 1986. Observations on the maternal behaviour of free ranging domestic pigs. Appl. Anim. Behav. Sci. 16, 131-142.

Jensen, P. und B. Recén, 1989. When to wean - Observations from Free-Ranging Domestic Pigs. Appl. Anim. Behav. Sci. 23, 49-60.

Jensen, P., 2014. Behavior genetics and the domestication of animals. Annu Rev Anim Biosci 2, 85-104. doi:10.1146/annurev-animal-022513-114135.

Kapun, A., F. Adrion, L. A. Schmid, M. Staiger, E. Holland, E. Gallmann und T. Jungbluth, 2016. Test of a UHF-RFID system for health monitoring of finishing pigs. CIGR-AgEng conference, Denmark.

Kauselmann, K., E. T. Krause, B. Glitz, E. Gallmann, H. Schrade und L. Schrader, 2020a. Short-term choice of fattening pigs for additional plant-based materials. Appl. Anim. Behav. Sci. 226. doi:10.1016/j.applanim.2020.104975.

Kauselmann, K., L. Schrader, B. Glitz, E. Gallmann, H. Schrade and E. T. Krause, 2020b. Turning the gaze to maize: The effects of maize kernels in straw as enrichment on exploration and tail status in pigs. Berl. Munch. Tierarztl. Wochenschr. 133. doi:10.2376/1439-0299-2020-24.

Kauselmann, K., E. T. Krause, B. Glitz, E. Gallmann, H. Schrade and L. Schrader, 2021. Effect of plant-based enrichment materials on exploration in rearing and fattening pigs (*Sus scrofa* domesticus). Appl. Anim. Behav. Sci. 236, 105261.

Kauselmann, K., L. Schrader, B. Glitz, E. Gallmann, H. Schrade and E. T. Krause, accepted on 26 March 2021. Tasty straw pellets – Exploration of flavoured rooting material by pigs. Animal.

Kennedy, J. M. und B. A. Baldwin, 1972. Taste preferences in pigs for nutritive and non-nutritive sweet solutions. Anim. Behav. 20, 706-718.

Kittawornrat, A. und J. J. Zimmerman, 2011. Toward a better understanding of pig behavior and pig welfare. Anim Health Res Rev 12 (1), 25-32. doi:10.1017/S1466252310000174.

Kjaer, J. B., 2017. Divergent selection on home pen locomotor activity in a chicken model: Selection program, genetic parameters and direct response on activity and body weight. PLoS One 12 (8), e0182103. doi:10.1371/journal.pone.0182103.

Koolhaas, J. M., S. M. Korte, S. F. De Boer, B. J. Van Der Vegt, C. G. Van Reenen, H. Hopster, I. C. De Jong, M. A. W. Ruis und H. J. Blokhuis, 1999. Coping styles in animals: current status in behaviour and stress-physiology. Neuroscience and biobehavioral reviews 23, 925-935.

Kritas, S. K. und R. B. Morrison, 2007. Relationship between tail biting in pigs and disease lesions and condemnations at slaughter. Veterinary Record 160, 149-152.

Lahrmann, H. P., L. C. Oxholm, H. Steinmetz, M. B. Nielsen und R. B. D'Eath, 2015. The effect of long or chopped straw on pig behaviour. Animal 9 (5), 862-870. doi:10.1017/S1751731114003024.

Lahrmann, H. P., C. F. Hansen, R. B. D´Eath, M. E. Busch, J. P. Nielsen und B. Forkman, 2018. Early intervention with enrichment can prevent tail biting outbreaks in weaner pigs. Livest. Sci. 214, 272-277. doi:10.1016/j.livsci.2018.06.010.

Larsen, M. L. V., H. M. Andersen und L. J. Pedersen, 2018. Which is the most preventive measure against tail damage in finisher pigs: tail docking, straw provision or lowered stocking density? Animal 12 (6), 1260-1267. doi:10.1017/S175173111700249X.

Larsen, M. L. V., H. M. Andersen und L. J. Pedersen, 2019. Changes in activity and object manipulation before tail damage in finisher pigs as an early detector of tail biting. Animal 13 (5), 1037-1044. doi:10.1017/S1751731118002689.

Lee, J., L. Jin, D. Park und Y. Chung, 2016. Automatic Recognition of Aggressive Behavior in Pigs Using a Kinect Depth Sensor. Sensors (Basel) 16 (5). doi:10.3390/s16050631.

Lemel, J., J. Truvé und B. Söderberg, 2003. Variation in ranging and activity behaviour of European wild boarSus scrofain Sweden. Wildlife Biology 9 (1), 29-36. doi:10.2981/wlb.2003.061.

Li, D. und J. Zhang, 2014. Diet shapes the evolution of the vertebrate bitter taste receptor gene repertoire. Mol Biol Evol 31 (2), 303-309. doi:10.1093/molbev/mst219.

Li, Y. Z., H. F. Zhang, L. J. Johnston, W. Martin, J. D. Peterson und J. F. Coetzee, 2017. Effects of tail docking and tail biting on performance and welfare of growing-finishing pigs in a confinement housing system. J Anim Sci 95 (11), 4835-4845. doi:10.2527/jas2017.1571.

Lyons, C. A. P., J. M. Bruce, V. R. Fowler und P. R. English, 1995. A comparison of productivity and welfare of growing pigs in four intensive systems. Livestock Production Science 43, 265-274.

Marques, B. M. F. P. P., M. L. Bernardi, C. F. Coelho, M. Almeida, O. E. Morales, T. J. Mores, S. M. Borowski und D. E. S. N. Barcellos, 2012. Influence of tail biting on weight gain, lesions and condemnations at slaughter of finishing pigs. Pesq. Vet. Bras. 32 (10), 967-974.

Massei, G. und P. V. Genov, 2004. The environmental impact of wild boar. Galemys 16, 135-145.

Moinard, C., M. Mendl, C. J. Nicol und L. E. Green, 2003. A case control study of on-farm risk factors for tail biting in pigs. Appl. Anim. Behav. Sci. 81 (4), 333-355. doi:10.1016/s0168-1591(02)00276-9.

Munsterhjelm, C., O. Simola, L. Keeling, A. Valros und M. Heinonen, 2013. Health parameters in tail biters and bitten pigs in a case-control study. Animal 7 (5), 814-821. doi:10.1017/S1751731112002194.

Munsterhjelm, C., M. Heinonen und A. Valros, 2015. Effects of clinical lameness and tail biting lesions on voluntary feed intake in growing pigs. Livest. Sci. 181, 210-219. doi:10.1016/j.livsci.2015.09.003.

Naguib, M. und E. T. Krause, 2020. Methoden der Verhaltensbiologie. 2. Auflage, Springer Spektrum Heidelberg.

Naya, A., I. Traulsen, M. Gertz, M. Hasler, O. Burfeind, E. g. Beilage und J. Krieter, 2019. Is tail biting in growing pigs reduced by a prolonged suckling period? Appl. Anim. Behav. Sci. 211, 41-46. doi:10.1016/j.applanim.2018.10.020.

Nelson, S. L. und J. D. Sanregret, 1997. Response of Pigs to Bitter-tasting Compounds. Chemical Senses 22, 129-132.

Newberry, R. C. und D. G. M. Wood-Gush, 1985. The Suckling Behaviour of Domestic Pigs in a Semi-Natural Environment. Behaviour 95 (1/2), 11-25.

Nowicki, J., S. Swierkosz, R. Tuz und T. Schwarz, 2015. The influence ofaromatized environmental enrichment objects with changeable aromas on the behaviour of weaned piglets. Veterinarski Arhiv 85 (4), 425-435.

Ohashi, H., M. Saito, R. Horie, H. Tsunoda, H. Noba, H. Ishii, T. Kuwabara, Y. Hiroshige, S. Koike, Y. Hoshino, H. Toda und K. Kaji, 2012. Differences in the activity pattern of the wild boar Sus scrofa related to human disturbance. European Journal of Wildlife Research 59 (2), 167-177. doi:10.1007/s10344-012-0661-z.

Olsen, A. W., E. M. Vestergaard und L. Dybkjaer, 2000. Roughage as additional rooting substrates for pigs. Anim. Sci. 70, 541 - 456.

Palander, P. A., M. Heinonen, I. Simpura, S. A. Edwards und A. E. Valros, 2013. Jejunal morphology and blood metabolites in tail biting, victim and control pigs. Animal 7 (9), 1523-1531. doi:10.1017/S1751731113000669.

Pedersen, L. J., M. S. Herskin, B. Forkman, U. Halekoh, K. M. Kristensen und M. B. Jensen, 2014. How much is enough? The amount of straw necessary to satisfy pigs' need to perform exploratory behaviour. Appl. Anim. Behav. Sci. 160, 46-55. doi:10.1016/j.applanim.2014.08.008.

Peeters, E., B. Driessen, C. P. H. Moons, F. O. Ödberg und R. Geers, 2006. Effect of temporary straw bedding on pigs' behaviour, performance, cortisol and meat quality. Appl. Anim. Behav. Sci. 98 (3-4), 234-248. doi:10.1016/j.applanim.2005.10.002.

Petersen, V., H. B. Simonsen und L. G. Lawson, 1995. The effect of environmental stimulation on the development of behaviour in pigs. Appl. Anim. Behav. Sci. 45, 215-224.

Price, E. O., 2002. Animal Domestication and Behaviour. CABI Publishing.

Prunier, A., X. Averos, I. Dimitrov, S. A. Edwards, E. Hillmann, M. Holinger, V. Ilieski, R. Leming, C. Tallet, S. P. Turner, M. Zupan und I. Camerlink, 2020. Review: Early life predisposing factors for biting in pigs. Animal 14 (3), 570-587. doi:10.1017/S1751731119001940.

Reiner, G., K. Hübner und S. Hepp, 2009. Suffering in diseased pigs as expressed by behavioural, clinical and clinical–chemical traits, in a well defined parasite model. Appl. Anim. Behav. Sci. 118 (3-4), 222-231. doi:10.1016/j.applanim.2009.02.010.

Riekert, M., A. Klein, F. Adrion, C. Hoffmann und E. Gallmann, 2020. Automatically detecting pig position and posture by 2D camera imaging and deep learning. Comput. Electron. Agr. 174. doi:10.1016/j.compag.2020.105391.

Rodríguez-Estévez, V., A. García, F. Peña und A. G. Gómez, 2009. Foraging of Iberian fattening pigs grazing natural pasture in the dehesa. Livest. Sci. 120 (1-2), 135-143. doi:10.1016/j.livsci.2008.05.006.

Roguet, C. und M. Rieu, 2014. The German pork industry reports to societal demands: from private labels to sectoral initiative. Les Cahiers de I'IFIP, Revue R&D de la filière porcine française 1 (1), 1-12.

Röhrs, M. und D. Kruska, 1969. Der Einfluss der Domestikation auf das Zentralnervensystem und Verhalten von Schweinen. Deutsche Tierärztliche Wochenschrift 19 (1).

Ruiz-Garcia, L. und L. Lunadei, 2011. The role of RFID in agriculture: Applications, limitations and challenges. Comput. Electron. Agr. 79 (1), 42-50. doi:10.1016/j.compag.2011.08.010.

Scheepens, C. J. M., M. J. M. Tielen und M. J. C. Hessing, 1991. Influence of intermittent daily draught on the health status of weaned pigs. Livestock Production Science 29, 241-254.

Schmolke, S. A., Y. Z. Li und H. W. Gonyou, 2003. Effect of group size on performance of growing-finishing pigs. J. Anim. Sci. 81, 874-878.

Schrader, L. und D. Todt, 1998. Vocal Quality is Correlated with Levels of Stress Hormones in Domestic Pigs. Ethology 104, 859-876.

Schrøder-Petersen, D. L. und H. B. Simonsen, 2001. Tail biting in pigs. Vet. J. 162 (3), 196-210. doi:10.1053/tvjl.2001.0605.

Schrøder-Petersen, D. L., H. B. Simonsen und L. G. Lawson, 2010. Tail-in-mouth behaviour among weaner pigs in relation to age, gender and group composition regarding gender. Anim. Sci. 53 (1), 29-34. doi:10.1080/09064700310002017.

Scollo, A., B. Contiero und F. Gottardo, 2016. Frequency of tail lesions and risk factors for tail biting in heavy pig production from weaning to 170 kg live weight. Vet J 207, 92-98. doi:10.1016/j.tvjl.2015.10.056.

Scollo, A., F. Gottardo, B. Contiero und S. A. Edwards, 2017. A cross-sectional study for predicting tail biting risk in pig farms using classification and regression tree analysis. Prev Vet Med 146, 114-120. doi:10.1016/j.prevetmed.2017.08.001.

Scott, K., L. Taylor, B. P. Gill und S. A. Edwards, 2006. Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems, 1. Hanging toy versus rootable substrate. Appl. Anim. Behav. Sci. 99 (3-4), 222-229. doi:10.1016/j.applanim.2005.10.013.

Scott, K., L. Taylor, B. P. Gill und S. A. Edwards, 2007. Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems, 2. Ratio of pigs to enrichment. Appl. Anim. Behav. Sci. 105 (1-3), 51-58. doi:10.1016/j.applanim.2006.05.042.

Scott, K., L. Taylor, B. P. Gill und S. A. Edwards, 2009. Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems 3. Hanging toy versus rootable toy of the same material. Appl. Anim. Behav. Sci. 116 (2-4), 186-190. doi:10.1016/j.applanim.2008.07.002.

Simonsen, H. B., 1990. Behaviour and distribution of fattening pigs in the multi-activity pen. Appl. Anim. Behav. Sci. 27, 311-324.

Simonsen, H. B., L. Klinken und E. Bindseil, 1991. Histopathology of intact and docked pigtails. British Veterinary Journal 147, 407-412.

Sinisalo, A., J. K. Niemi, M. Heinonen und A. Valros, 2012. Tail biting and production performance in fattening pigs. Livest. Sci. 143 (2-3), 220-225. doi:10.1016/j.livsci.2011.09.019.

Smulders, D., V. Hautekiet, G. Verbeke und R. Geers, 2008. Tail and ear biting lesions in pigs: An epidemiological study. Anim. Welfare.

Solà-Oriol, D., E. Roura und D. Torrallardona, 2008. Feed preference in pigs: effect of cereal sources at different inclusion rates. J. Anim. Sci. 87 (2), 562-570. doi:10.2527/jas.2008-0949.

Stolba, A. und D. G. M. Wood-Gush, 1989. The behaviour of pigs in a semi-natural environment. Anim. Sci. 48 (2), 419-425.

Studnitz, M., M. B. Jensen und L. J. Pedersen, 2007. Why do pigs root and in what will they root? Appl. Anim. Behav. Sci. 107 (3-4), 183-197. doi:10.1016/j.applanim.2006.11.013.

Tallet, C., P. Linhart, R. Policht, K. Hammerschmidt, P. Simecek, P. Kratinova und M. Spinka, 2013. Encoding of situations in the vocal repertoire of piglets (Sus scrofa): a comparison of discrete and graded classifications. PLoS One 8 (8), e71841. doi:10.1371/journal.pone.0071841.

Taylor, N. R., D. C. Main, M. Mendl und S. A. Edwards, 2010. Tail-biting: a new perspective. Vet. J. 186 (2), 137-147. doi:10.1016/j.tvjl.2009.08.028.

Telkänranta, H., M. B. M. Bracke und A. Valros, 2014. Fresh wood reduces tail and ear biting and increases exploratory behaviour in finishing pigs. Appl. Anim. Behav. Sci. 161, 51-59. doi:10.1016/j.applanim.2014.09.007.

TierSchG, 1972. Tierschutzgesetz in der Fassung der Bekanntmachung vom 18. Mai 2006 (BGBI. I S. 1206, 1313), das zuletzt durch Artikel 280 der Verordnung vom 19. Juni 2020 (BGBI. I S. 1328) geändert worden ist.

Tinti, J. M., D. Glaser, M. Wanner und C. Nofre, 2000. Comparison of Gustatory Responses to Amino Acids in Pigs and in Humans. LWT - Food Science and Technology 33 (8), 578-583. doi:10.1006/fstl.2000.0713.

Trickett, S. L., J. H. Guy und S. A. Edwards, 2009. The role of novelty in environmental enrichment for the weaned pig. Appl. Anim. Behav. Sci. 116 (1), 45-51. doi:10.1016/j.applanim.2008.07.007.

Ursinus, W. W., H. J. Wijnen, A. C. Bartels, N. Dijvesteijn, C. G. van Reenen und J. E. Bolhuis, 2014. Damaging biting behaviors in intensively kept rearing gilts: The effect of jute sacks and relations with production characteristics. J. Anim. Sci. 92, 5193-5202. doi:10.2527/jas2014-7918.

Van de Perre, V., B. Driessen, J. Van Thielen, G. Verbeke und R. Geers, 2011. Comparison of pig behaviour when given a sequence of enrichment objects or a chain continuously. Anim. Welfare. 20, 641-649.

Van de Weerd, H. A., C. M. Docking, J. E. L. Day und S. A. Edwards, 2005. The development of harmful social behaviour in pigs with intact tails and different enrichment backgrounds in two housing systems. Anim. Sci. 80 (3), 289-298. doi:10.1079/asc40450289.

Van de Weerd, H. A., C. M. Docking, J. E. L. Day, K. Breuer und S. A. Edwards, 2006. Effects of species-relevant environmental enrichment on the behaviour and productivity of finishing pigs. Appl. Anim. Behav. Sci. 99 (3-4), 230-247. doi:10.1016/j.applanim.2005.10.014.

van de Weerd, H. A. und J. E. L. Day, 2009. A review of environmental enrichment for pigs housed in intensive housing systems. Appl. Anim. Behav. Sci. 116 (1), 1-20. doi:10.1016/j.applanim.2008.08.001.

Veit, C., I. Traulsen, M. Hasler, K.-H. Tölle, O. Burfeind, E. g. Beilage und J. Krieter, 2016. Influence of raw material on the occurrence of tail-biting in undocked pigs. Livest. Sci. 191, 125-131. doi:10.1016/j.livsci.2016.07.009.

Wallenbeck, A. und L. J. Keeling, 2013. Using data from electronic feeders on visit frequency and feed consumption to indicate tail biting outbreaks in commercial pig production. J. Anim. Sci. 91, 2879-2884. doi:10.2527/jas2012-5848.

Weissenbacher-Lang, C., T. Voglmayr, F. Waxenecker, U. Hofstetter, H. Weissenbock, K. Hoelzle, L. E. Hoelzle, M. Welle, M. Ogris, G. Bruns und M. Ritzmann, 2012. Porcine ear necrosis syndrome: a preliminary investigation of putative infectious agents in piglets and mycotoxins in feed. Vet J 194 (3), 392-397. doi:10.1016/j.tvjl.2012.05.026.

William, A. und H. Simianer, 2011. Tierzucht. Verlag Eugen Ulmer Stuttgart.

Winter, M., C. Fry und S. P. Carruthers, 1998. European agricultural policy and farm animal welfare. Food Policy 23 (3/4), 305-323.

Wood-Gush, D. G. M. und K. Vestergaard, 1989. Exploratory behavior and the welfare of intensively kept animals. J. Agr. Ethics. 2, 161-169.

Young, R. J. und A. B. Lawrance, 1994. Feeding behaviour of pigs in groups monitored by computerized feeding system. Animal Production 58, 145-152.

Zonderland, J. J., M. B. M. Bracke, L. A. den Hartog, B. Kemp und H. A. M. Spoolder, 2010. Gender effects on tail damage development in single- or mixed-sex groups of weaned piglets. Livest. Sci. 129 (1-3), 151-158. doi:10.1016/j.livsci.2010.01.018.

Zwicker, B., L. Gygax, B. Wechsler und R. Weber, 2013. Short- and long-term effects of eight enrichment materials on the behaviour of finishing pigs fed ad libitum or restrictively. Appl. Anim. Behav. Sci. 144 (1-2), 31-38. doi:10.1016/j.applanim.2012.11.007.

Zwicker, B., R. Weber, B. Wechsler und L. Gygax, 2015. Degree of synchrony based on individual observations underlines the importance of concurrent access to enrichment materials in finishing pigs. Appl. Anim. Behav. Sci. 172, 26-32. doi:10.1016/j.applanim.2015.08.037.

Anhang

Electronic Supplement

Short-term choice of fattening pigs for additional plant-based materials

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Supplementary Tab. 1. Composition of the two feed rations during fattening (feed conversion at an average weight of 80 kg).

Item	ration 1	ration 2
Ingredients		
Barley (%)	17	59
Wheat (%)	59	22
Soya extraction meal (%)	19	15
Rapeseed oil (%)	2	1.5
Mineral feed* (%)	3	2.5
Nutrient component		
ME (MJ/kg)	14.0	13.3
Crude protein (g/kg)	175.7	157.5
Crude fibre (g/kg)	37.0	49.0
Crude fat (g/kg)	41.8	39.4

*8.0 % lysine, 2.0 % methionine, 2.0 % threonine

Electronic Supplement

Effect of plant-based enrichment materials on exploration in rearing and fattening pigs (*Sus scrofa* domesticus)

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Ultra-high-frequency radio-frequency identification (UHF RFID) antenna-transponder systems run either at low frequencies (LF, 125 - 135 Kilohertz (kHz)), high frequencies (HF, 13.56 Megahertz (MHz)), or ultra-high frequencies (UHF, 865 - 868 and 902 - 928 MHz). Compared to UHF systems LF and HF systems have a higher resistance against external influences (e.g. water, metal shielding or reflection) but they only have short reading distances. Additionally, LF systems can only detect one transponder (i.e. animal) per time at a given antenna. In contrast, UHF RFID systems allow monitoring of several transponders at the same time and at greater distances. However, the lower resistance against external influences compared to LF and HF systems can lead to false positive and false negative detections (Adrion et al., 2018).

The antennas have an opening angle of 100° with a circular polarization of their radiation and an antenna gain of 2.5 decibel isotropic circular (dBiC). Converted, this corresponds to a value of 2.7 decibel dipole (dBd), what means that the antenna has 2.7 decibel (dB) less power compared to a pure dipole. Via a coaxial cable (attenuation -0.29 dBm/m) of 10 m the antennas were connected to the same type of reader (deister electronic GmbH, agrident GmbH) with an integrated multiplexer, that Adrion et al. (2015) used. Four antennas could be connected to one multiplexer (one multiplexer per pen). The multiplexing process was set to activate each antenna for 250 milliseconds, before switching to the next antenna, what means that every antenna was activated once in a second. The output power of the readers was 28 dBm. Minus the attenuation of the coaxial cable (2.9 dBm) and of the antenna (2.7 dBm) we reached a radiated output power of 22.4 dBm at the antennas.

Supplementary Tab. 1. Composition of the two feed rations during rearing (feed conversion after two weeks of rearing) and fattening (feed conversion at an average weight of 80 kg).

	rearing		fattening	
Item	ration 1	ration 2	ration 1	ration 2
Ingredients				
Barley (%)	18	32	17	59
Wheat (%)	20	40	59	22
Squeezed oats (%)	20	-	-	-
Maize flour (%)	5	-	-	-
Soya extraction meal (%)	-	16	19	15
Feed oil	-	2	-	-
Rapeseed oil (%)	2.5	-	2	1.5
Mineral feed* (%)	4	5	3*	2.5*
Feed supplements (%)	30.5”	5	-	-
Nutrient component				
ME (MJ/kg)	14.1	13.9	14.0	13.3
Crude protein (g/kg)	161.0	177.7	175.7	157.5
Crude fibre (g/kg)	44.0	40.7	37.0	49.0
Crude fat (g/kg)	84.0	43.6	41.8	39.4

*8.0 % lysine, 2.0 % methionine, 2.0 % threonine; “protein supplement, energy supplement, fiber mix, lignocellulose, zeolite, acids

Supplementary Tab. 2. Experimental plan of the offered materials in the pens during the two-week blocks of the weaning and fattening period.

Trial	Treat-ment	Rearing pen 1	Rearing pen 2	Rearing pen 3	Rearing pen 4	Fattening pen 1	Fattening pen 2	Fattening pen 3	Fattening pen 4	Fattening pen 5	Fattening pen 6	Fattening pen 7	Fattening pen 8
1	1	*	*	*	*	SP	CH	CS	LP	CH	CS	SP	LP
1	2	*	*	*	*	LP	SP	CH	CS	SP	CH	LP	CS
1	3	*	*	*	*	CH	CS	LP	SP	CS	LP	CH	SP
1	4	*	*	*	*	CS	LP	SP	CH	LP	SP	CS	CH
2	1	SP	LP	CH	CS	CS	CH	LP	SP	LP	CS	CH	SP
2	2	LP	CS	SP	CH	CH	SP	CS	LP	CS	CH	SP	LP
2	3	CH	SP	CS	LP	LP	CS	SP	CH	SP	LP	CS	CH
2	4	CS	CH	LP	SP	SP	LP	CH	CS	CH	SP	LP	CS

* no data collected (material offered in weekly change, uniform across the weaning pens)

Supplementary Tab. 3. Average amounts per animal and day of the four enrichment materials (lucerne pellets (LP), straw pellets (SP), chopped hay (CH) and chopped straw (CS)).

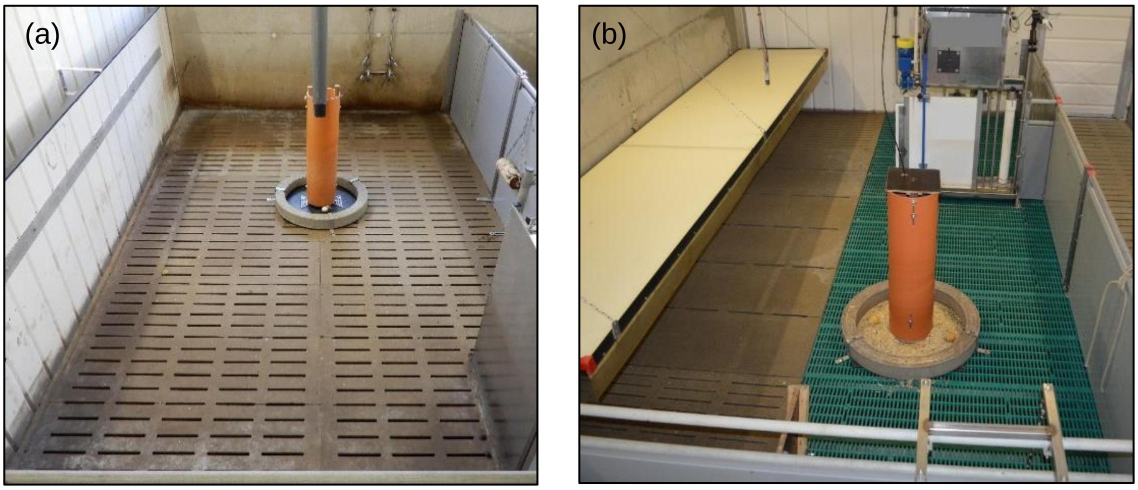
	Material (g/animal and day)			
Trial	LP	SP	CH	CS
rearing				
1	*	*	*	*
2	53.03	54.00	11.58	12.60
fattening				
1	131.05	101.75	29.03	15.72
2	163.39	193.81	29.27	27.65

* no data collection

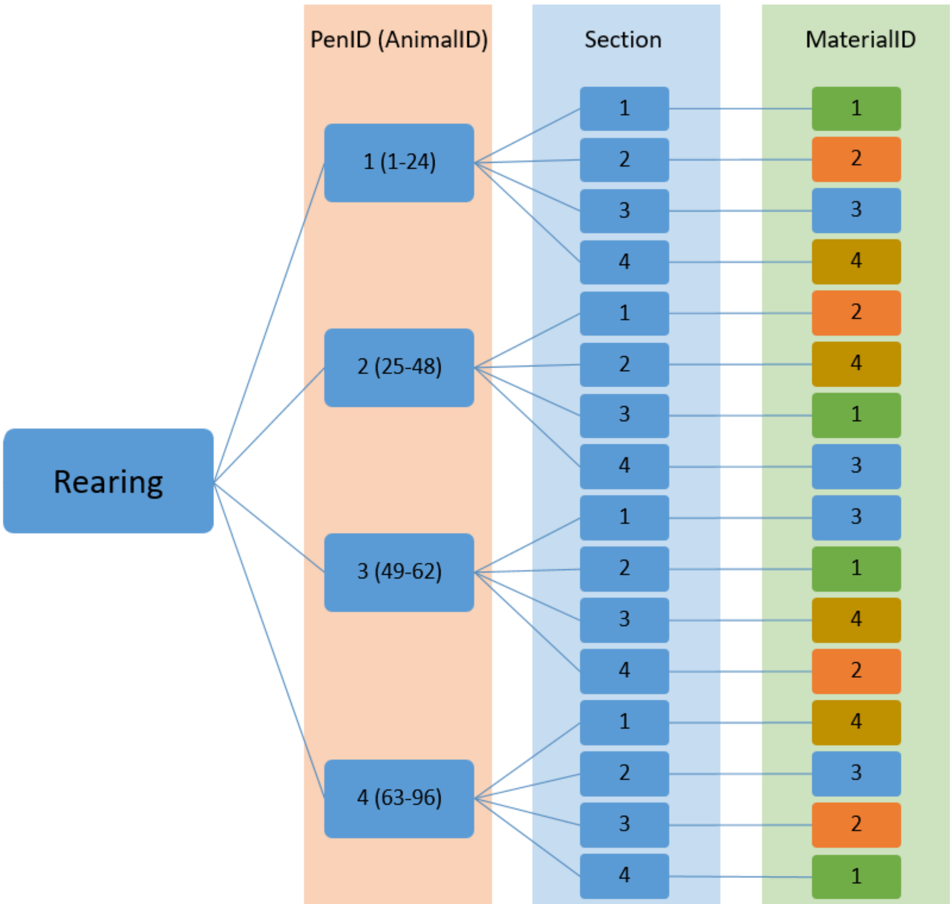
Supplementary Tab. 4. Average weights and daily weight gains of the animals during the test phase.

Trial	Date	Weight (kg ± S.D.)		Daily weight gain (g ± S.D.)
		begin	end	
rearing				
1*	03.08.2017 – 20.09.2017	7.8 ± 1.7	29.1 ± 5.7	434.5 ± 93.8
2	07.12.2017 – 24.01.2018	7.9 ± 2.2	31.6 ± 7.2	483.4 ± 113.6
fattening				
1	20.09.2017 – 22.11.2017+ (9 weeks)	29.1 ± 5.7	92.6 ± 10.6	1001.0 ± 113.6
2	24.01.2018 – 21.03.2018 (8 weeks)	31.6 ± 7.2	78.5 ± 13.7	835.2 ± 134.8

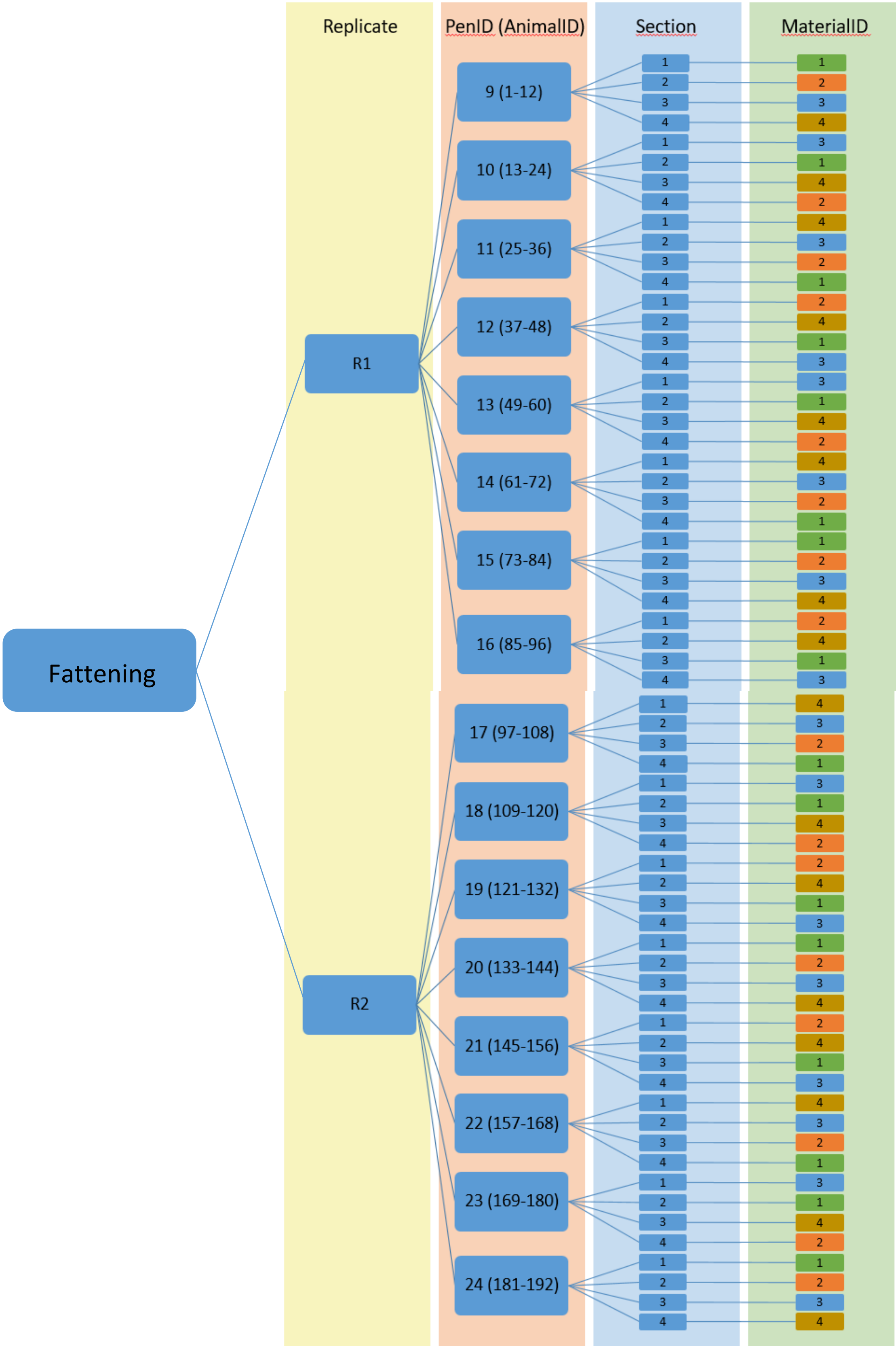
* no data collection; + data collection started at 27.09.2017 (second week of fattening)



Supplementary Figure 1. (a) fattening pen and (b) rearing pen with material dispenser.



Supplementary Figure 2. Hierarchical structure of the statistical model for data analysis of rearing.



Supplementary Figure 3. Hierarchical structure of the statistical model for data analysis of fattening.

References

Adrion, F., N. Hammer, F. Eckert, S. Götz and E. Gallmann, 2015. Adjustment of a UHF-RFID system for hotspot monitoring of fattening pigs. Precision Livestock Farming ´15 Conference Paper of the 7th European Conference on Precision Livestock Farming.

Adrion, F., A. Kapun, F. Eckert, E. Holland, M. Staiger, S. Götz and E. Gallmann, 2018. Monitoring trough visits of growing-finishing pigs with UHF-RFID. Comput. Electron. Agr. 144, 144-153. doi:10.1016/j.compag.2017.11.036.

Electronic Supplement

Turning the gaze to maize: The effects of maize kernels in straw as enrichment on exploration in pigs

Mais im Fokus: Auswirkungen von Maiskörnern in Stroh als Beschäftigungsmaterial auf die Exploration bei Schweinen

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Supplementary Tab. 1. Composition of the two feed rations during rearing (feed conversion after two weeks of rearing) and fattening (feed conversion at an average weight of 80 kg).

	rearing		fattening	
Item	ration 1	ration 2	ration 1	ration 2
Ingredients				
Barley (%)	18	32	17	59
Wheat (%)	20	40	59	22
Squeezed oats (%)	20	-	-	-
Maize flour (%)	5	-	-	-
Soya extraction meal (%)	-	16	19	15
Feed oil (%)	-	2	-	-
Rapeseed oil (%)	2.5	-	2	1.5
Mineral feed* (%)	4	5	3	2.5
Feed supplements (%)	30.5”	5	-	-
Nutrient component				
ME (MJ/kg)	14.1	13.9	14.0	13.3
Crude protein (g/kg)	161.0	177.7	175.7	157.5
Crude fibre (g/kg)	44.0	40.7	37.0	49.0
Crude fat (g/kg)	84.0	43.6	41.8	39.4

*8.0 % lysine, 2.0 % methionine, 2.0 % threonine

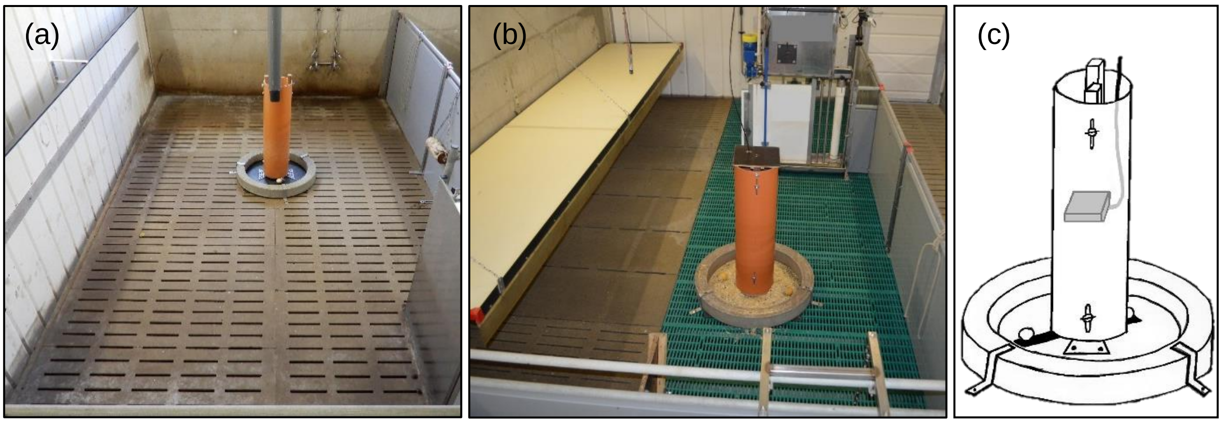
“protein supplement, energy supplement, fiber mix, lignocellulose, zeolite, acids

Supplementary Tab. 2. Daily weight gains of the pigs and consumed enrichment material of the two conditions (CS and CS+MK) during the three replicates in rearing and fattening.

period	replicate	date	condition	animals (n)	Daily weight gain (g ± SD)	Enrichment material consumption (g/pig/day)
rearing	1	14.06.2018 – 01.08.2018	CS+MK	45	47.3 ± 8.0	26.0
			CS	46	47.6 ± 7.8	14.6
	2	16.08.2018 – 02.10.2018	CS+MK	46	44.4 ± 7.6	24.1
			CS	47	47.8 ± 6.7	12.1
	3	18.10.2018 – 05.12.2018	CS+MK	46	47.4 ± 5.6	24.0
			CS	47	51.0 ± 6.9	13.2
fattening	1	01.08.2018 – 17.10.2018	CS+MK	44	914.8 ± 94.1	59.4
			CS	38	942.5 ± 102.2	39.7
	2	02.10.2018 – 20.12.2018	CS+MK	44	997.9 ± 106.9	53.6
			CS	48	1049.2 ± 112.6	37.2
	3	05.12.2018 – 21.02.2019	CS+MK	44	906.8 ± 82.6	41.6
			CS	41	922.2 ± 84.1	24.6

Supplementary Tab. 3. Percentage of Δ tail length (score changes within section) and injuries at the tails (category 0: no injuries, category 1: superficial perforation of the skin, punctually or in the form of a line, category 2: deeper, planar perforation of the skin, maximum as large as the diameter of the tail at the respective point, category 3: deeper, planar perforation of the skin, larger than the diameter of the tail at the respective point) during rearing (section 1) and fattening (section 2 and 3).

	rearing		fattening			
	section 1		section 2		section 3	
	CS	CS+MK	CS	CS+MK	CS	CS+MK
Δ tail length						
0 categories	92,14	59,56	70,59	75,56	90,63	96,95
1 category	7,14	39,71	29,41	24,44	9,38	3,05
2 categories	0,71	0,74	0,00	0,00	0,00	0,00
Injuries at the tail						
Category 0	85,71	72,06	85,29	87,41	88,28	96,18
Category 1	5,71	6,62	2,21	3,70	0,78	0,76
Category 2	5,71	6,62	8,09	5,19	10,16	3,05
Category 3	2,86	14,71	4,41	3,70	0,78	0,00



Supplementary Figure 1. (a) Fattening pen with material dispenser, (b) rearing pen with material dispenser and (c) drawing of the material dispenser with UHF RFID antenna (grey).

Electronic supplement

Tasty straw pellets – Exploration of flavoured rooting material by pigs

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Supplement S1

Ultra-high-frequency radio-frequency identification (UHF RFID) antenna-transponder systems run either at low frequencies (LF, 125 - 135 Kilohertz (kHz)), high frequencies (HF, 13.56 Megahertz (MHz)), or ultra-high frequencies (UHF, 865 - 868 and 902 - 928 MHz). Compared to UHF systems LF and HF systems have a higher resistance against external influences (e.g. water, metal shielding or reflection) but they only have short reading distances. Additionally, LF systems can only detect one transponder (i.e. animal) per time at a given antenna. In contrast, UHF RFID systems allow monitoring of several transponders at the same time and at greater distances. However, the lower resistance against external influences compared to LF and HF systems can lead to false positive and false negative detections (Adrion et al., 2018).

The used antennas had an opening angle of 100° with a circular polarization of their radiation and an antenna gain of 2.5 decibel isotropic circular (dBiC). Converted, this corresponds to a value of 2.7 decibel dipole (dBd), what means that the antenna has 2.7 decibel (dB) less power compared to a pure dipole. Via a coaxial cable (attenuation -0.29 decibel milliwatt (dBm)/m) of 10 m the antennas were connected to the same type of reader (deister electronic GmbH, Barsinghausen, Germany; Agrident GmbH, Barsinghausen, Germany) with an integrated multiplexer, that Adrion et al. (2015) used. Four antennas were connected to one multiplexer (one multiplexer per pen). The output power of the readers was 28 dBm. Minus the attenuation of the coaxial cable (2.9 dBm) and of the antenna (2.7 dBm) we reached a radiated output power of 22.4 dBm at the antennas. The area around the material dispenser, delimited by the concrete ring, was defined as the detection area for the UHF RFID system.

Supplementary Table S1. Composition of the two feed rations of the pigs during rearing (feed conversion after two weeks of rearing) and fattening (feed conversion at an average weight of 80 kg).

	rearing		fattening	
Item	ration 1	ration 2	ration 1	ration 2
Ingredients				
Barley (%)	18	32	17	59
Wheat (%)	20	40	59	22
Oat flakes (%)	20	-	-	-
Maize flour (%)	5	-	-	-
Soya extraction meal (%)	-	16	19	15
Feed oil (%)	-	2	-	-
Rapeseed oil (%)	2.5	-	2	1.5
Mineral feed (%)	4	5	3	2.5[1]
Feed supplements (%)	30.5[2]	5	-	-
Nutrient component				
ME[3] (MJ/kg)	14.1	13.9	14.0	13.3
Crude protein (g/kg)	161.0	177.7	175.7	157.5
Crude fibre (g/kg)	44.0	40.7	37.0	49.0
Crude fat (g/kg)	84.0	43.6	41.8	39.4

[1]8.0 % lysine, 2.0 % methionine, 2.0 % threonine

[2]protein supplement, energy supplement, fiber mix, lignocellulose, zeolite, acids

[3]metabolizable energy

Supplementary Table S2. Selected ingredients of the used food flavours, which were applied on the straw pellets and offered to the pigs.

Flavour	Fried onion	Strawberry	Ginger	Vanilla	Almond
Ingredients					
Propylene glycol E1520 (%)	–[1]	90	58	85	70
Benzyl alcohol E1519 (%)			10		
Flavour (%)	30	10	32	15	27

[1] contained in the food flavour; amount not specified

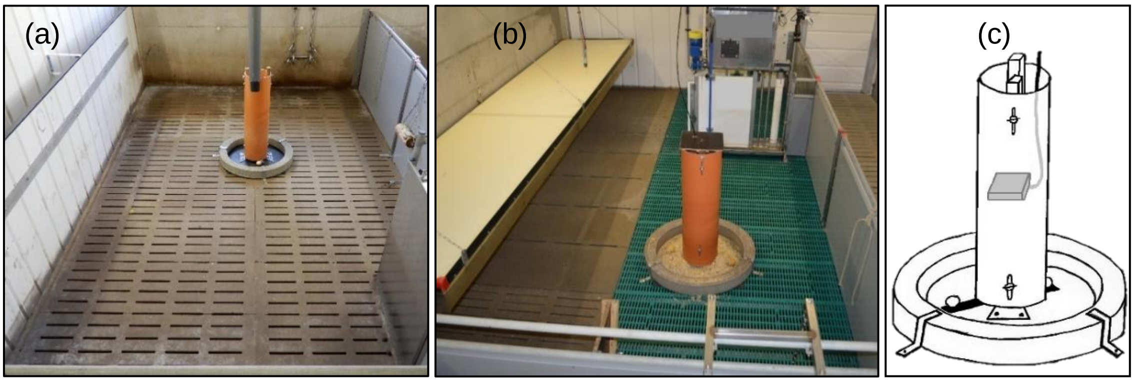
Supplementary Table S3. Experimental plan of the used flavours (almond (AL), fried onion (FO), ginger (GO), strawberry (SB), vanilla (VA) and control (C)) applied on straw pellets offered to the pigs during the weekly intervals of the rearing and fattening period in both replicates.

Period	Week	Replicate 1				Replicate 2			
		Pen 1	Pen 2	Pen 3	Pen 4	Pen 1	Pen 2	Pen 3	Pen 4
Rearing	1	SB	FO	GI	C	VA	AL	SB	GI
	2	C	SB	VA	FO	GI	VA	FO	AL
	3	AL	GI	C	VA	C	SB	GI	FO
	4	VA	AL	FO	GI	FO	C	AL	SB
	5	FO	C	AL	SB	AL	GI	C	VA
	6	GI	VA	SB	AL	SB	FO	VA	C
	7	SB	FO	GI	C	VA	AL	SB	GI
Fattening[1]	1	C	SB	VA	FO	GI	VA	FO	AL
	2	AL	GI	C	VA	C	SB	GI	FO
	3	VA	AL	FO	GI	FO	C	AL	SB
	4	FO	C	AL	SB	AL	GI	C	VA
	5	GI	VA	SB	AL	SB	FO	VA	C
	6	SB	FO	GI	C	VA	AL	SB	GI
	7	C	SB	VA	FO	GI	VA	FO	AL
	8	AL	GI	C	VA	C	SB	GI	FO
	9	VA	AL	FO	GI	FO	C	AL	SB
	10	FO	C	AL	SB	AL	GI	C	VA
	11	GI	VA	SB	AL	SB	FO	VA	C

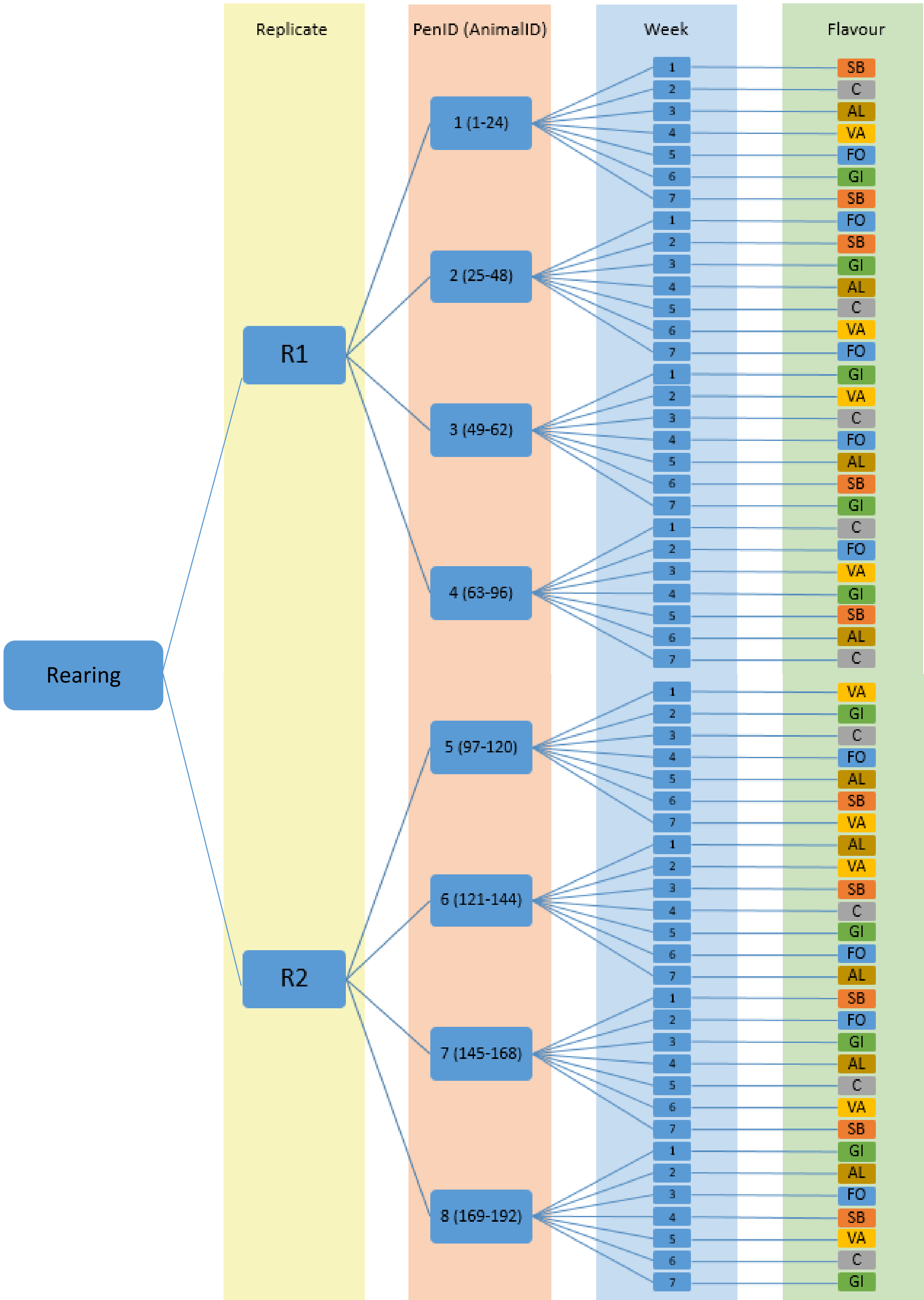
[1] two of eight pens received the same treatment

Supplementary Table S4. Median exploration duration per pig and day in the seven weeks of rearing and eleven weeks of fattening.

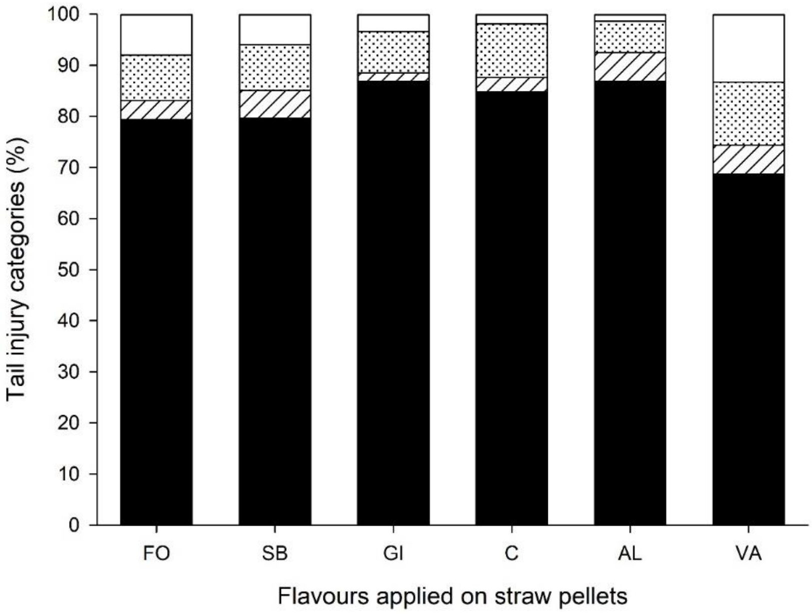
Period	Week	Exploration duration (min/pig and day)
Rearing	1	26.7
	2	14.4
	3	17.3
	4	16.3
	5	12.6
	6	12.5
	7	13.1
Fattening	1	13.7
	2	20.1
	3	17.1
	4	22.3
	5	21.9
	6	22.6
	7	18.1
	8	19.9
	9	19.0
	10	16.3
	11	20.0



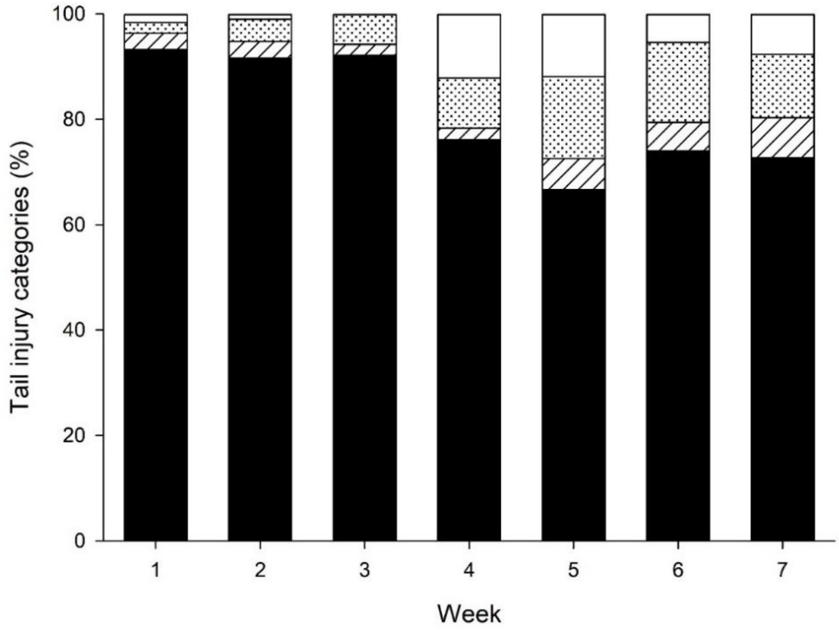
Supplementary Figure S1. (a) Fattening pen of the pigs with material dispenser, (b) rearing pen of the pigs with material dispenser and (c) drawing of the material dispenser with the ultra-high-frequency radio-frequency identification (UHF RFID) antenna (grey).



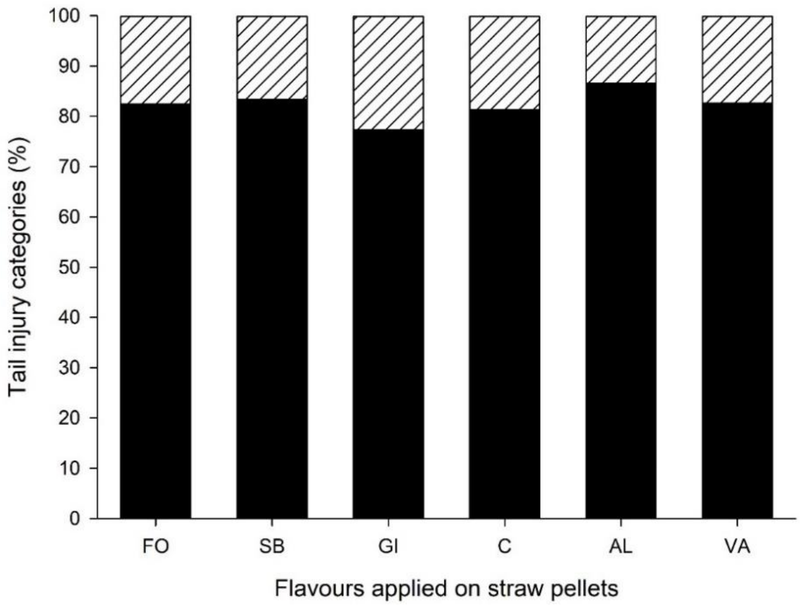
Supplementary Figure S2. Hierarchical structure of the statistical model for data analysis of pigs' exploration during rearing showing both replicates (R1 and R2), continuously numbered PenID and AnimalID (considering that pigs within pen were not independent from each other) and the flavours (almond (AL), fried onion (FO), ginger (GO), strawberry (SB), vanilla (VA) and control (C)) offered during the seven weeks of rearing.



Supplementary Figure S3. Percentage of pigs with tail injuries during the rearing period with regard to the different flavours offered as enrichment, ((category 0; black) no injuries, (category 1; diagonal stripes) superficial perforation of the skin, punctually or in the form of a line, (category 2; dotted) deeper perforation of the skin, the size of the injury does not exceed the diameter of the tail at the respective location (category 3; white) deeper perforation of the skin, the size of the injury exceeds the diameter of the tail at the respective location) when straw pellets flavoured with fried onion (FO), strawberry (SB), ginger (GI), almond (AL), vanilla (VA) and straw pellets without flavour (C) were offered.



Supplementary Figure S4. Percentage of pigs with tail injuries during rearing with respect to the development over time (weeks), ((category 0; black) no injuries, (category 1; diagonal stripes) superficial perforation of the skin, punctually or in the form of a line, (category 2; dotted) deeper perforation of the skin, the size of the injury does not exceed the diameter of the tail at the respective location (category 3; white) deeper perforation of the skin, the size of the injury exceeds the diameter of the tail at the respective location) during the seven intervals of the rearing period.



Supplementary Figure S5. Percentage of pigs with tail injuries during the fattening period with regard to the different flavours offered as enrichment ((category 0; black) no injuries, (category 1; diagonal stripes) injuries at the skin of the tail) when straw pellets flavoured with fried onion (FO), strawberry (SB), ginger (GI), almond (AL), vanilla (VA) and straw pellets without flavour (C) were offered.

References

Adrion, F., Hammer, N., Eckert, F., Götz, S. and Gallmann, E., 2015. Adjustment of a UHF-RFID system for hotspot monitoring of fattening pigs. Proceedings of the 7th European Conference on Precision Livestock Farming, 15-18 September 2015, Milan, Italy, pp. 573-582.

Adrion, F., Kapun, A., Eckert, F., Holland, E., Staiger, M., Götz, S. and Gallmann, E., 2018. Monitoring trough visits of growing-finishing pigs with UHF-RFID. Computers and Electronics in Agriculture 144, 144-153. doi:10.1016/j.compag.2017.11.036.