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Rectal and vaginal body temperature in early postpartum sows and its relation to serum concentration of acute phase proteins

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Meinen Eltern

gewidmet in Liebe und Dankbarkeit

1 Introduction

Postpartum diseases belong to the economical most important diseases of sows (Hoy, 2006). They affect animal health and welfare of sows and piglets. These diseases are mostly termed as postpartum dysgalactia syndrome (**PPDS**) (Preissler et al., 2012; Reiner et al., 2009), coliform mastitis (Gerjets and Kemper, 2009), or mastis-metritis-agalactia syndrome **(MMA)** (Hirsch et al., 2003). Today the term MMA is often seen as incorrect, because of the variability of clinical symptoms (Reiner et al., 2009). Mastitis can be the single symptom and hypogalactia is more frequently than agalactia. Furthermore the sows often suffer from endometritis instead of metritis because only the endometrial tissue shows signs of inflammation like an increased number of neutrophilic granulocytes and damaged endometrial epithels or glands (de Winter et al., 1992). The reduced milk production is the main problem because the piglets are reliant on the sow for access to colostrum and milk (Heinritzi and Hagn, 1999; Ross et al., 1981). Moreover the composition of the milk is changed in sows with puerperal disorders. Significantly higher concentrations of lactose and lower concentrations of protein, fat and sodium were observed in the colostrum of sows which developed PPDS. This malnutrition can lead to diarrhea, starvation of the piglets and an increased mortalitiy (Gooneratne et al., 1982). In opposite, other authors stated that acute masitis is much less common and clinically apparent today (Martineau et al., 2013).

Furthermore, in sows with PPDS a higher frequency of fertility problems such as late onset of oestrus or failure of oestrus after weaning the piglets are reported (Hoy, 2002). These aspects reflect the economic importance of the disease on the pig industry.

First clinical signs of PPDS appear commonly 24 to 30 h after parturition (Furniss, 1987). In another study the sows showed clinical signs 12 to 24 h after parturition (Gooneratne et al., 1982). Most probably this variation in the onset of clinical signs was caused by the fact that the exact farrowing times were not recorded (Furniss, 1987).

Timely diagnosis and effective medical treatment are necessary to prevent economical losses (Hoy, 2006). In previous studies (Furniss, 1987) it has been suggested that it is possible to predict the occurrence of PPDS from elevation of rectal temperature which appears earlier than other clinical signs such as vulval discharge, mastitis or emeciated piglets as a consequence of the unsufficient milk production. Rectal temperature above 39.4°C was postulated as an appropriate threshold to administer preventive medical treatment such as antibiotic and anti-inflammatory drugs (Furniss, 1987). Pathogens, like bacterial infections induce fever for antibody production. Fever is triggered by the release of the endogenous pyrogens interleukin 1 and interleukin 6 which interact with the hypothalamus to raise the thermoregulatory set point (Kluger, 1991). In contrast, more recent publications provided evidence of a physiological hyperthermia in sows after farrowing (Martineau et al., 2012). Therefore, not every elevation of body temperature should be interpreted as fever. Furthermore, it has been hypothesised that PPDS is a consequence of an unsuccessful transition from the homeorhesis of gestation to the homeorhesis of lactation which affects multiple organs (Collier et al., 1984; Martineau et al., 2013). Many of these modifications appear before farrowing, but remain asymptomatic until piglets are present. It has been postulated that for the diagnosis of PPDS in sows more clinical symptoms like feed intake, reduced milk production or vaginal discharge should be considered (Gerjets and Kemper, 2009; Hoy, 2002). However, these symptoms are subjective by nature or hard to measure. Therefore measuring rectal temperature is a common method in most studies and in the veterinarian practice. Up to date there is a lack of information on factors influencing measured values of rectal temperature in sows.

For that reason, the first objective of my studies was to investigate the repeatability of measures of rectal temperature and to determine the influence of different factors (e.g. type of thermometer, investigator, insertion depth) on results measured.

Furthermore, measures of rectal temperature result in only distinct values at a given time, which might not reflect the real situation. Various attemps were made to improve the continous measurement of body temperature in pigs. Hannemann et al. (2005) measured body temperature by a sensor inserted at the base of the ear. In this study they demonstrated and quantified a circadian temperature rhythm of pigs. However, the procedure was invasive. In another study the use of infrared thermography was described as fast and practical, but not suitable for the observation of the health status of individual animals (Dewulf et al., 2003; Traulsen et al., 2010). Bekkering and Hoy (2007) measured the skin temperature of the ear in seventy boars continously with a special ear tag which had an integrated temperature sensor. They showed that the coefficient of correlation between skin and rectal temperature was low ($r = 0.36$). Therefore, they concluded that the skin temperature at the ear cannot be used as a significant parameter for predicting the rectal temperature of pigs.

Vaginal temperature loggers were recently validated for measuring vaginal temperature continously in cows (Suthar et al., 2013; Vickers et al., 2010), dogs (Maeder et al., 2013) and gilts after vaccination (Schmidt et al., 2013). Only minor differences were observed between rectal and vaginal temperature in cows (Suthar et al., 2013; Vickers et al., 2010).

The coefficients of correlations were high.

Therefore, the second objective of my first study was to validate vaginal temperautre loggers in early post partum sows. After a successfull validation the vaginal temperature logger should be inserted for the duration of 6 days in early postpartum sows in a second study to continuously monitor vaginal temperature. Specifically, I set out to identify plausible factors that may influence body temperature. Furthermore, I aimed to examine if even sows without clinical signs of PPDS exhibit body temperature that can be considered as fever as it has been described for healthy postpartum dairy cows (Burfeind et al., 2012). In cows the serum haptoglobin concentration was used to categorize animals as healthy or ill independently from body temperature (Burfeind et al., 2012). Haptoglobin is an acute phase protein. These

proteins have been investigated in recent studies as biomarkers for infectious diseases in pigs, like swine influenca virus (Barbé et al., 2011) or porcine reproductive and respiratory syndrome virus (Gómez-Laguna et al., 2010). Acute phase proteins are a group of blood proteins that change in concentration as reaction of external and internal irritations such as infection, inflammation, surgical trauma or stress (Murata et al., 2004). They are mainly produced in the liver and regulated by pro-inflammatory cytokines (Baumann and Gauldie, 1994). Acute phase proteins are differentiated by their dynamics which is described by the level they increase and decrease in consequence of a stimulation such as an infection.

C-reactive protein is considered as major acute phase protein in pigs whereas haptoglobin is classified as moderate acute phae protein. Major acute phase proteins have a low serum concentration (< 1 μ/L) in healthy animals, rise 100 to 1000 – fold on stimulation and decline rapidly during recovery phase. Moderate acute phase proteins increase 5 to 10 – fold on activation and decrease more slowly than major acute phase proteins (Eckersall and Bell, 2010). Haptoglobin, alpha I-acid glycoprotein and serum cortisol were higher in affected sows with PPDS in comparison to healthy sows (van Gelder and Bilkei, 2005). They stated that haptoglobin may be a valuable indicator of stress in pigs (van Gelder and Bilkei, 2005).

A further objective of the second study was to investigate the concentration of acute phase proteins (haptoglobin and C-reactive protein) in early postpartum sows in relation to rectal temperature, vaginal temperature, general health status, feed intake and vaginal discharge.

2 Research papers

a Repeatability of measures of the rectal temperature and comparison of vaginal and rectal temperature in puerperal sows

b The course of rectal and vaginal temperature in early postpartum sows

The manuscriptes of the papers are formatted according to the guidelines for authors of Tierärztliche Praxis Großtiere (a) and Journal of Swine Health and Production (b).

2. a Wiederholbarkeit der Messung der Rektaltemperatur und Vergleich von vaginaler und rektaler Temperatur bei Sauen im Frühpuerperium

(Tierärztliche Praxis Großtiere, 2013)

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Schlüsselwörter: Sau, Puerperium, Rektale Temperatur, Diagnostik, Postpartales Dysgalaktiesyndrom

Keywords: sow, puerperium, rectal temperature, diagnostic, postpartum dysgalactia syndrome

Zusammenfassung:

Gegenstand und Ziel: Postpartale Erkrankungen bei Sauen haben in der Schweineproduktion nach wie vor eine große wirtschaftliche Bedeutung. Beeinflusst werden nicht nur die Leistung und das Wohlbefinden des Muttertieres, sondern auch die Gesundheit und Entwicklung der Ferkel. Die regelmäßige rektale Temperaturmessung post partum zur Früherkennung infektiöser Erkrankungen ist bei Sauen ein häufig empfohlenes und angewendetes diagnostisches Kriterium. Die Studie bestand aus fünf Experimenten. Das Ziel der ersten vier Experimente war die Untersuchung der Wiederholbarkeit der rektalen Temperaturmessung sowie der Einfluss verschiedener Faktoren (z.B. Untersucher, Art des Thermometers oder Messtiefe) auf das Messergebnis. Das Ziel des fünften Experimentes war die Validierung eines Temperaturloggers zur Messung der vaginalen Temperatur bei der Sau post partum. **Material und Methoden:** Für die ersten vier Experimente wurden 30 Sauen verwendet, die am Tag zuvor geferkelt hatten. Die rektale Temperatur wurde mehrmalig von einem Untersucher, von verschiedenen Untersuchern, mit verschiedenen Thermometern oder in verschiedenen Eindringtiefen gemessen. Für das fünfte Experiment wurden 21 Sauen verwendet, die sich ebenfalls im ersten Tag post partum befanden. Ihnen wurde für eine Dauer von sechs Stunden ein Temperaturlogger vaginal eingelegt. Parallel dazu wurde die rektale Temperatur gemessen. **Ergebnisse:** Die Daten zeigen, dass die Messung der rektalen Körpertemperatur wiederholbar ist (Mittelwert ± Standardabweichung = 38,7 ± 0,1°C, Variationskoeffizient = 0,2%). Bei verschiedenen Untersuchern und Thermometern wurden nur geringe Unterschiede gemessen (0,0 bzw. 0,1°C). Die Eindringtiefe des Messfühlers hat einen Einfluss auf das Messergebnis (Differenz von 0,4°C bei 5 und 10 cm). Rektale und

vaginale Temperatur zeigten eine deutliche Korrelation (r= 0,80, p<0,01), bei einer mittleren Abweichung von 0,3°C. **Schlussfolgerung und klinische Relevanz:** Die Messung der rektalen Temperatur kann als wiederholbare diagnostische Methode angesehen werden. Die Durchführung sollte standardisiert werden (Thermometertyp, Eindringtiefe). Die vaginale Messung mit einem Temperaturlogger ist eine Möglichkeit zur kontinuierlichen Überwachung der Körpertemperatur bei Sauen im Frühpuerperium.

Summary

Objective: Postpartum diseases of sows are economically important in the pig industry. They affect animal health and animal welfare of sows and piglets. Measuring the rectal temperature in sows post partum is a commonly used diagnostic method to identify early infectious diseases. The study consisted of five parts. The objective of the first four parts was to evaluate the influence of different factors on measures of rectal temperatures (e.g. investigator, thermometer, penetration depth of the thermometer). The secondary objective of this sudy was to validate the application of a temperature logger to continously measure vaginal temperature. **Material and methods:** Thirty sows at the first day post partum were used in the first four parts of the study. Rectal temperature was measured repeatedly by one investigator, by different investigators, with different thermometers and at different penetration depths. 21 sows at the first day post partum were used for the fifth part of the study. A temperature logger was inserted in the vagina for the duration of six hours. Additionally, rectal temperature was measured. **Results:** The data showed that rectal temperature can be measured repeatedly (mean ± standard deviation = 38.7 ± 0.1°C, coefficient of variation = 0.2%). Different investigators or thermometers measured low differences (0.0°C and 0.1°C). The penetration depth of the thermometer can influence the result (difference of 0.4°C at 5 and 10 cm). Rectal and vaginal temperatures, measured in 21 sows, were higly correlated (r = 0.80, p<0.01) with a mean difference of 0.3°C.

Conclusion and clinical relevance: The measurement of rectal temperature can be seen as a reapeatable diagnostic method. The measuring process should be standardized (type of thermometer, penetration depth). The measurement of vaginal temperature with a data logger in early puerperal sows is a possibility for a continous and non-invasive monitoring of body temperature.

Englischer Titel: Repeatability of measures of rectal temperature and comparison of vaginal and rectal temperature in puerperal sows

Gegenstand und Ziel

Postpartale Erkrankungen bei Sauen haben in der Schweineproduktion eine große wirtschaftliche Bedeutung (16). Angaben zur Inzidenz postpartaler Erkrankungen variieren mit 0,5 bis 60% stark. Im Mittel wird eine Inzidenz von etwa 13% angegeben (1, 24). In der Vergangenheit wurden fieberhafte Puerperalstörungen der Sau meist unter dem Begriff Mastitis-Metritis-Agalaktie-Syndrom (MMA) zusammengefasst. In der Literatur gibt es mittlerweile verschiedene Namen für diesen Krankheitskomplex, wie puerperale Toxämie und Septikämie (14), postpartales Dysgalaktie-Syndrom (21), puerperale Mastitis oder coliforme Mastitis (10), sowie Urogenitalsyndrom (11). Nach Reiner et al. (30) ist die Bezeichnung MMA unzutreffend, da puerperale Erkrankungen bei Sauen nicht in einem einheitlichen Krankheitsbild verlaufen. Die Mastitis kann auch ohne das Vorhandensein einer Metritis auftreten. Zudem handelt es sich meist um eine Hypogalaktie und um eine Endometritis anstatt einer Metritis (3). Mehrere Studien haben bereits gezeigt, dass die stark reduzierte Milch- und Kolostrumproduktion das Hauptproblem dieser puerperalen Erkrankung darstellt (14, 31). Aus diesem Grund hat sich der Begriff „Postpartales Dysgalaktiesyndrom“ durchgesetzt. Kolostrum und Milch von erkrankten Sauen zeigen veränderte Konzentrationen von Laktose, Protein, Kalium und Natrium im Vergleich zu gesunden Sauen (12). Direkte Folgen sind Durchfall, Abmagern und erhöhte Mortalität der Ferkel (18). Beeinflusst werden somit nicht nur die Gesundheit und das Wohlbefinden des Muttertieres, sondern auch das der Ferkel. Finanzielle Verluste ergeben sich vor allem aus der erhöhten Ferkelmortalität und der verminderten Absetzgewichte (35). Weiterhin sind Sauen mit vorangegangener puerperaler Erkrankung prädisponiert für fehlende Östrussymptome, Spätrauschen, Umrauschen sowie Aborte in der folgenden Trächtigkeit (17).

Die klinischen Symptome dieser Erkrankung erscheinen in der Regel 18 - 48 Stunden nach der Geburt (9). Typische Anzeichen sind Mastitis, Endometritis, Hypogalaktie, Obstipation, Cystitis, Fieber und Anorexie (16). Als Haupterreger der Mastitis und Endometritis werden in

der Literatur coliforme Keime, wie *Escherichia coli, Enterococcus spp.* oder *Klebsiella spp.* angegeben. Zusätzlich beteiligt sind *Staphylococcus* und *Streptococcus spp.* (16, 21). Umweltfaktoren wie Haltung, Hygienemanagment und Fütterung sind ebenfalls an der Entstehung von postpartalen Erkrankungen beteiligt (17). Laut Papadopoulas et al. erhöht sich bei ad libitum gefütterten Sauen in den ersten Laktationstagen das Risiko für eine postpartale Erkrankung im Vergleich zu restriktiv gefütterten Sauen (27). Weiterhin wird dem Rohfasergehalt im Laktationsfutter eine besondere Bedeutung in der Prophylaxe beigemessen. Ein Rohfaseranteil von 7-11% mindert die Gefahr von Obstipationen, steigert zudem die Wasseraufnahme und somit auch die Milchproduktion der Sau (29). Zugluft im Abferkelstall und unzureichende Reinigungs- und Desinfektionsmaßnahmen tragen zu einer erhöhten Erkrankungsrate bei (17). Weiterhin wurde nachgewiesen, dass die Haltung in Einzelbuchten für die Sau stressfreier ist als im Ferkelschutzkäfig. Daraus resultieren niedrigere Cortisolwerte und eine höhere Oxytocinausschüttung im Blut der Sau. Dies wiederum bewirkt eine kürzere Geburtsdauer und senkt somit das Risiko für postpartale Erkrankungen (29). Aufgrund der ökonomischen Verluste sind eine schnelle Diagnose und eine effektive Therapie erkrankter Sauen von essentieller Bedeutung (18). Die Therapie besteht in der Regel aus einer Kombination von antibiotisch und antiphlogistisch wirksamen Präparaten, sowie Oxytocin zur Anregung der Milchejektion (16). Die Messung der Rektaltemperatur wird als wichtige Methode zur Erkennung des postpartalen Dysgalaktiesyndroms beschrieben. Nach Furniss (9) sollten Sauen behandelt werden, die nachmittags oder 18 Stunden nach dem Ferkeln eine Körpertemperatur >39,4°C haben. Als alleiniges diagnostisches Kriterium wird die Körpertemperatur jedoch kritisch gesehen (10). Verschiedene Studien haben gezeigt, dass die Körpertemperatur der Sau um die Phase der Abferkelung auch unter physiologischen Bedingungen ansteigt. Nach 24 Stunden fällt die Temperatur wieder ab und bleibt bis zum Absetzen höher als vor der Geburt (4, 22). Werte zwischen 39,3°C und 39,7°C sind schwierig zu interpretieren (3). Auch aufgrund des Geburtstresses kann es zu einem physiologischen,

temporären Anstieg der Körpertemperatur kommen (sog. Laktationshyperthermie) (26). Somit sollte nicht jeder Anstieg der Körpertemperatur als Fieber gewertet werden. Zur Vermeidung von Fehlern vom Typ 1 (Tier ist gesund und wurde fälschlicherweise als am postpartalem Dysgalaktiesyndrom erkrankt diagnostiziert) und dem damit verbundenen unnötigen Antibiotikaeinsatz wird in aktuelleren Veröffentlichungen empfohlen, die Körpertemperatur 12 - 24 Stunden post partum zu messen. Eine puerperale Erkrankung sollte erst dann diagnostiziert werden, wenn neben einer erhöhten Körpertemperatur (>39,5°C) weitere klinische Symptome vorliegen, wie z.B. reduzierte Futter- und Wasseraufnahme, reduzierte Milchproduktion oder vermehrter Vaginalausfluss (10, 17).

In den meisten Studien über postpartale Erkrankungen bei Sauen wurde die Körpertemperatur rektal gemessen. Auch in der täglichen veterinärmedizinischen Praxis wird die rektale Temperaturmessung routinemäßig eingesetzt. Beim Schwein fehlen jedoch wissenschaftlich fundierte Informationen über die Wiederholbarkeit der rektalen Temperaturmessung und die Auswirkung verschiedener Einflussfaktoren auf das Messergebnis. Beim Rind wurde bereits nachgewiesen, dass die Messung der rektalen Körpertemperatur weitgehend wiederholbar ist. Verschiedene Faktoren, wie die Art des Thermometers und die Messtiefe können das Messergebnis jedoch erheblich beeinflussen (5, 7).

Bei der rektalen Temperaturmessung ergeben sich nur punktuelle Werte. Mit Hilfe einer kontinuierlichen Messung der Körpertemperatur können Änderungen des Gesundheitszustandes möglicherweise früher erkannt werden (23). Weiterhin ist es möglich, den Tagesrhythmus der Körpertemperatur und verschiedene Einflussfaktoren, wie Fütterung oder Stresssituationen zu untersuchen (13, 28). Dieses Wissen könnte helfen, die Bedeutung der rektalen Temperaturmessung besser einzuschätzen, sowie Empfehlungen für die Praxis zu formulieren. Beim Schwein wurden bisher verschiedene Methoden zur kontinuierlichen Temperaturmessung getestet. Eine nichtinvasive, schnelle und praktikable Methode ist die Verwendung der Infrarotthermographie. Sie bietet die Möglichkeit, die Hauttemperatur von

Tieren berührungslos regelmäßig zu erfassen (34). Zudem können Tiergruppen überwacht werden. Die Untersuchungen haben ergeben, dass die innere Körpertemperatur und Messungen der Körperoberflächentemperatur mittels Thermographie korrelieren. Der Grad der Korrelation ist abhängig von der Lokalisation der Messung auf der Körperoberfläche (rektale Temperatur und mittlere Thermogrammtemperatur gemessen im Bereich der Vulva ($r = 0,31$), im Bereich des Ohrgrundes ($r = 0,30$) oder im Bereich des Auges ($r = 0,15$) (34). Diese Methode eignet sich jedoch nicht, um einzelne Tiere mit Fieber zu detektieren (8). Eine weitere Möglichkeit zur kontinuierlichen Messung ist die Verwendung von Thermosensoren, die an verschiedenen Körperregionen implantiert werden (19, 20). Diese Methode ermöglicht eine kontinuierliche Temperaturüberwachung, ist jedoch invasiv und nur für Laborbedingungen mit geringen Tierzahlen geeignet. Zudem ist laut Sonneberg eine klare Aussage über die Rektaltemperatur mittels Messung der Hauttemperatur durch Transponder nicht möglich, da zu viele Einflussfaktoren wie z.B. Umwelteinflüsse (Sonneneinstrahlung) auf die Messungen einwirken könnten. Eine Erkennung kranker Tiere mit dieser Technik ist somit nicht möglich (32). Bei Milchkühen wurde bereits die Verwendung eines vaginal eingelegten Temperaturloggers erfolgreich getestet (36). Diese Methode kann am nicht narkotisierten Tier unter Praxisbedingungen durchgeführt werden. Rektal und vaginal gemessene Temperaturen sind bei Kühen korreliert ($r = 0,81$, $p < 0,001$) und zeigen keine oder nur eine zu vernachlässigbare Abweichung (Mittelwert ± Standardabweichung = 0,0 ± 0,0 (36).

Ein erstes Ziel dieser Studie war es, die Einflussfaktoren auf das Ergebnis der rektalen Temperaturmessung bei Sauen zu untersuchen. Insbesondere sollte die Wiederholbarkeit der Messung, sowie die Bedeutung verschiedener Untersucher, Thermometer und Messtiefen ermittelt werden. Das zweite Ziel dieser Studie war die Validierung eines vaginal eingelegten Temperaturfühlers zur kontinuierlichen Messung der vaginalen Temperatur bei Sauen.

Material und Methoden

Die Studie wurde im Juni 2011 im Abferkelstall einer Sauenzuchtanlage durchgeführt. Die Untersuchungen wurden nach den Richtlinien der International Cooperation on Harmonization of Technical Requirements for Registration of Veterinary Medicinal Products durchgeführt (15). Alle Studienabläufe waren mit der zuständigen Tierschutzbeauftragten abgestimmt. Der Bestand umfasste etwa 1370 Zuchtsauen, die im Wochenrhythmus gemanagt wurden. Im Abferkelstall wurden die Sauen in Einzelbuchten gehalten. Die Säugezeit betrug vier Wochen. Die Fütterung erfolgte zweimal täglich um 6.00 und 13.00 Uhr (Laktationsfutter, Energiegehalt: 13,0 MJ/ kg, Rohprotein: 17,5%, Rohfaser: 6%, Rohasche: 6%, Rohöle und Rohfette: 5%). Bei Aufnahme in die Studie befanden sich alle Sauen zwischen 1 und 24 Stunden postpartum und die Nachgeburt war bereits abgegangen.

Die Studie bestand aus 5 Experimenten. Ziel von Experiment 1 war es, die Wiederholbarkeit der rektalen Temperaturmessung durch einen Untersucher zu bestimmen. Dafür wurden 30 Sauen (6 Jungsauen und 24 Altsauen) verwendet. Ein Untersucher maß die rektale Temperatur jeweils zehnmal pro Sau mit dem gleichen Thermometer (Typ: MT1831, Microlife AG, Wildenau, Schweiz) innerhalb von 5 Minuten. Die Messung war beendet, wenn das akustische Signal des Thermometers erklang. Das Thermometer wurde aus dem Rektum entfernt und erneut eingeführt. Unmittelbar danach wurde die folgende Messung gestartet.

Im zweiten Experiment erfolgte die Messung der rektalen Körpertemperatur von zwei verschiedenen Untersuchern. Beide Untersucher bestimmten die Temperatur jeweils zweimal und unabhängig voneinander. Thermometer und Messvorgang waren identisch zu denen des ersten Abschnittes.

Im dritten Experiment wurde der Einfluss verschiedener digitaler Thermometer (Thermometer A: MT1831, Microlife AG, Wildenau, Schweiz; Thermometer B: SC112, Scala Electronics GmbH, Stahnsdorf, Deutschland) auf den Messwert der rektalen Körpertemperatur getestet. Die rektale Temperatur wurde hierbei von einem Untersucher jeweils zweimal pro Sau mit beiden Thermometern gemessen.

Im vierten Experiment bestimmte ein Untersucher die rektale Körpertemperatur mit dem Thermometer SC112 bei zwei unterschiedlichen Eindringtiefen der Sonde (5 cm und 10 cm). Beide Messungen wurden jeweils doppelt vorgenommen. Alle Einzelmessungen der vier Teilexperimente wurden in einem Zeitraum von 4 ± 1 min pro Sau erfasst.

Ziel des fünften Experimentes war die Validierung eines Temperaturloggers (Minilog 8, Vemco Ltd., Halifax, Kanada, Abb. 1) für die Messung der vaginalen Temperatur bei Sauen im Frühpuerperium. Der Datenlogger (Größe = 92 mm × 20 mm; Gewicht = 40,5 g) zeichnet Temperaturen in einem frei programmierbaren Zeitintervall auf und wurde bereits in vitro im Wasserbad validiert (36). Zur Validierung der mit Temperaturloggern gemessenen Vaginaltemperatur beim Schwein wurden 5 Jung- und 16 Altsauen genutzt, die am Tag zuvor oder in der Nacht vor dem Experiment geferkelt hatten. Voraussetzungen waren die abgeschlossene Geburt und der vollständige Abgang der Nachgeburt. Die Gründe hierfür waren, dass der Abgang der Nachgeburt nicht gestört werden sollte und der Logger sonst wieder herausgepresst werden könnte. Die Messung der rektalen Temperatur erfolgte bei jeder Sau 18- bis 19-mal mit einem digitalen Thermometer (MT1831, Microlife AG, Wildenau, Schweiz) über einen Zeitraum von 6 Stunden. Die Zeit der Messung wurde mit einer Genauigkeit von ± 30 Sekunden dokumentiert. Die vaginale Temperatur wurde in demselben Zeitraum einmal pro Minute gemessen. Die Logger wurden an einer Scheidenspange ohne Progesteron (CIDR-blank, InterAg, Hamilton, Neuseeland) befestigt. Dazu wurde ein Teil des Plastikgerüstes der Scheidenspange entfernt und anschließend der

flexible Gummimantel über den Temperaturlogger gestülpt (Abb. 1). An dem Logger selbst wurde ein Faden befestigt, sodass der Logger nach Beendigung des Experimentes einfach herausgezogen werden konnte. Vor Verwendung wurden die Temperaturlogger in einer Povidon-Jod-Lösung (Braunol®, B. Braun, Melsungen AG, Melsungen, Deutschland) desinfiziert. Anschließend wurden die Logger mit Hilfe eines Vaginalspekulums (Röhrenspekulum für Schweine, Länge 40 cm, Innendurchmesser: 2,5 cm, WDT, Garbsen, Deutschland) am stehenden oder liegenden Tier in die Vagina eingelegt. Die Scheidenspangen wurden mit Hilfe eines CIDR - Applikators durch das Spekulum geschoben und vor die Zervix platziert (Abb. 2). Nach Beendigung des Experimentes und Herausnahme der Logger (Abb. 3) wurden diese mit einer speziellen Software ausgelesen. Messwerte unter 38,0°C wurden als Artefakte gewertet und von der Analyse ausgeschlossen. Wie bereits für das Rind beschrieben, vermuten wir, dass sich der Logger bei diesen tiefen Temperaturen nach kaudal bewegt und teilweise die Umgebungstemperatur gemessen hatte (36).

Alle Daten wurden in Excel (Version 2002, Microsoft Office, Redmond, WA) dokumentiert und mit Hilfe des Programms MedCalc Software (Version 10.1.3.0, MedCalc, Mariakerke, Belgien) statistisch ausgewertet. Zur Bewertung der Wiederholbarkeit der rektalen Temperaturmessung durch einen Untersucher wurden die minimale, die mittlere und die maximale Differenz, sowie der Varianzkoeffizient berechnet. Der Korrelationskoeffizient nach Pearson wurde berechnet, um den Zusammenhang von verschiedenen Untersuchern, Thermometern und Eindringtiefen des Messfühlers auf das Ergebnis zu bewerten. Die Unterscheide zwischen zwei Untersuchern, zwei Thermometern und zwei Eindringtiefen wurden mit einem gepaarten t-Test bestimmt. Weiterhin erfolgte eine graphische Auswertung nach dem Verfahren von Bland und Altman (2). Die vaginale Temperatur wurde mit der zur selben Uhrzeit gemessenen rektalen Temperatur verglichen. Die Korrelation zwischen rektal und vaginal gemessener Temperatur wurde mit dem Korrelationskoeffizienten nach Pearson bewertet. Auch in diesem Experiment wurden die Unterschiede zwischen rektaler und

vaginaler Temperatur mit einem gepaarten t-Test und graphisch nach dem Verfahren von Bland und Altman (2) analysiert.

Ergebnisse

Wiederholbarkeit der Messung der rektalen Temperatur von Sauen

Die rektale Temperatur war durch einen Untersucher wiederholbar messbar (Mittelwert ± Standardabweichung = 38,7 ± 0,1°C, Varianzkoeffizient = 0,2%). Innerhalb von 10 Messungen bei einer Sau lag die maximale Differenz zwischen 0 und 0,5°C. Bei drei Sauen betrug die maximale Differenz 0,5°C, bei einer Sau 0,4°C und bei drei Tieren 0,3°C. Bei den restlichen 23 Tieren war die maximale Differenz ≤ 0,2°C.

Die Messergebnisse von zwei unabhängigen Untersuchern waren miteinander korreliert ($r = 0.98$, $n = 30$; $p < 0,01$). Die mittlere Differenz betrug 0,0 ± 0,1°C ($n = 30$, $p = 0,09$, Untersucher A: 38,7 ± 0,5 °C, Untersucher B: 38,7 ± 0,6 °C; Abb. 4).

Mit beiden Thermometern wurden vergleichbare Werte gemessen (Thermometer A: 38,7 ± 0,5 °C, Thermometer B: 38,6 ± 0,5 °C). Die Messwerte waren miteinander korreliert ($r = 0,97$, $n = 30$, $p < 0,01$). Die mittlere Differenz betrug 0,1 ± 0,1°C, $n = 30$, $p < 0,01$, Abb. 5).

Bei einer Messtiefe von 5 cm (38,3 ± 0,6°C) war die durchschnittliche Temperatur niedriger als bei einer Messtiefe von 10 cm (38,6 ± 0,5°C). Die mittlere Differenz betrug 0,3 ± 0,3°C ($n = 30$, $p < 0,01$, Abb. 6). Die Messwerte bei den beiden Messtiefen waren miteinander korreliert ($r = 0,89$, $n = 30$, $p < 0,01$).

Vergleich von vaginaler und rektaler Körpertemperatur von Sauen im Frühpuerperium

Insgesamt wurden 386 parallele Messungen (18 bis 19 Messungen pro Sau) der rektalen und vaginalen Temperatur durchgeführt. Davon lagen 6 Messungen (1,6%) der vaginalen Temperatur unter 38,0°C. Diese Werte wurden als Artefakte interpretiert und von der weiterführenden Analyse ausgeschlossen. Somit ergaben sich 380 Wertepaare, die zur

Analyse genutzt wurden. Die Messergebnisse der vaginalen und der rektalen Temperatur waren miteinander korreliert ($r = 0,80$, $n = 380$, $p < 0,01$). Die rektale Temperatur (39,1 ± 0,4 °C) war im Mittel niedriger als die vaginale Temperatur (39,4 ± 0,4 °C, $n = 380$, $p < 0,01$). Die mittlere absolute Abweichung war 0,3 ± 0,3°C (Abb. 7).

Schlussfolgerung

Die ersten vier Experimente zeigen deutlich, dass die rektale Körpertemperatur bei der Sau wiederholbar messbar ist. Die Verwendung von unterschiedlichen Thermometern ergab zwar signifikante, aber klinisch vernachlässigbare Unterschiede. Die Unterschiede zwischen zwei verschiedenen Untersuchern sind ebenfalls gering und für die Praxis nicht relevant. Die Eindringtiefe des Messfühlers in das Rektum hat einen Einfluss auf das Messergebnis und sollte deshalb standardisiert werden, um vergleichbare Resultate zu erhalten.

Unsere Ergebnisse machen deutlich, dass die Messung der rektalen Körpertemperatur eine wiederholbare diagnostische Methode ist. Daten über die falsche Klassifizierung von Sauen in gesund oder an postartalem Dysgalaktiesyndrom erkrankt sind bisher nicht bekannt. Dies wird vor allem dadurch erschwert, dass die Temperatur in der Regel ein wichtiges Kriterium für die Klassifizierung in gesund oder krank ist (10, 17). Um den Anteil der falsch diagnostizierten Sauen zu ermitteln, wäre ein unabhängiger Goldstandard notwendig (25). In einem ähnlichen Ansatz wurden hierzu bei Milchkühen die Serumhaptoglobinkonzentration bestimmt und nur Kühe mit niedrigen Konzentrationen als gesund eingestuft (6). Es wird somit deutlich, dass ein Bedarf an Studien besteht, in denen Sauen unabhängig von der rektalen Temperatur als gesund oder krank klassifiziert werden. Im Umkehrschluss kann die diagnostische Aussagekraft einer einmaligen Messung der rektalen Temperatur unter diesem Gesichtspunkt neu bewertet werden.

Die Ergebnisse des fünften Experimentes zeigen, dass die rektale und vaginale Temperatur bei Sauen eine signifikante Korrelation aufweisen. Die vaginale Temperatur war

durchschnittlich 0,4°C höher als die rektale Temperatur. Auch bei Milchkühen war die vaginal gemessene Temperatur mittels Temperaturlogger 0,2 ± 0,2°C höher als die rektale Temperatur (33). Hingegen gab es bei Vickers et al. keinen Unterschied zwischen rektal und vaginal gemessener Temperatur (0,0 ± 0,0) (36). Dies könnte daran gelegen haben, dass in dieser Studie die rektale und vaginale Messung nicht exakt zeitgleich erfolgte.

Eine mögliche Ursache für die höhere vaginale Temperatur war, dass der Temperaturlogger im Vergleich zur Eindringtiefe des Temperaturfühlers des Thermometers bei der rektalen Temperaturmessung weiter kranial lag. Unter Berücksichtigung dieses Aspektes ist die Messung der vaginalen Temperatur mit einem Temperaturlogger eine praktikable und nicht-invasive Methode zur kontinuierlichen Überwachung der Körpertemperatur bei Sauen im Frühpuerperium. Nach Durchführung des Experimentes zeigten die Sauen keine Hinweise auf eine Fremdkörperreaktion, wie Ausfluss oder gestörtes Allgemeinbefinden. Bei dieser Studie handelte es sich um eine Validierungsstudie, um die Durchführbarkeit dieser Methode bei Sauen und den quantitativen Zusammenhang zwischen rektaler und vaginaler Temperatur zu ermitteln. Weitere Studien sind notwendig, um zu klären, ob die Temperaturlogger auch mehrere Tage in der Vagina belassen werden können.

Klinische Relevanz

Die rektale Temperaturmessung ist bei Sauen eine wiederholbare und objektive Methode. Die Messdurchführung (Thermometer, Eindringtiefe) sollte standardisiert werden. Die Verwendung von vaginal eingesetzten Temperaturloggern ist eine nichtinvasive und einfache Möglichkeit zur kontinuierlichen Überwachung der Körpertemperatur bei Sauen im Frühpuerperium.

Danksagung

Wir danken den Mitarbeitern des Betriebes für Ihre umfassende Unterstützung.

Interessenkonflikt

Die Autoren bestätigen, dass kein Interessenkonflikt besteht.

Literatur

1. Backstrom L, Morkoc AC, Connor J, Larson R, Price W. Clinical-study of mastits-metritis-agalactia in sows in illinois. J Am Vet Med Assoc 1984; 185 (1): 70-73.
2. Bland JM, Altman DG. Measuring agreement in method comparison studies. Stat Methods Med Res 1999; 8 (2): 135-160.
3. Bostedt H, Maier G, Herfen K, Hospes R. Klinische Erhebungen bei Sauen mit puerperaler Septikämie und Toxämie. Tierärztl Prax 1998; 26 (6): 332-338.
4. Bressers HPM, Tebrake JHA, Jansen MB, Nijenhuis PJ, Noordhuizen J. Monitoring individual sows - Radiotelemetrically recorded ear base temperature-changes around farrowing. Livest Prod Sci 1994; 37 (3): 353-361.
5. Burfeind O, Suthar V, Heuwieser W. Messungen der Körpertemperatur bei Milchkühen - Methoden und Einflussfaktoren. Tierarztl Prax Ausg G Grosstiere Nutztiere 2013; 41 (1): 56-60.
6. Burfeind O, Suthar VS, Heuwieser W. Effect of heat stress on body temperature in healthy early postpartum dairy cows. Theriogenology 2012; 78 (9): 2031-2038.
7. Burfeind O, von Keyserlingk MAG, Weary DM, Veira DM, Heuwieser W. Short communication: Repeatability of measures of rectal temperature in dairy cows. J Dairy Sci 2010; 93 (2): 624-627.
8. Dewulf J, Koenen F, Laevens H, de Kruif A. Infrared thermometry is not suitable for the detection of fever in pigs. Vlaams Diergenskund Tijds 2003; 72 (5): 373-379.
9. Furniss SJ. Measurement of rectal temperature to predict mastitis, metritis and agalactia (MMA) in sows after farrowing. Prev Vet Med 1987; 5 (2): 133-139.
10. Gerjets I, Kemper N. Coliform mastitis in sows: A review. J Swine Health Prod 2009; 17 (2): 97-105.
11. Glock XTP, Bilkei G. The effect of postparturient urogenital diseases on the lifetime reproductive performance of sows. Can Vet J-Rev Vet Can 2005; 46 (12): 1103-1107.
12. Gooneratne AD, Hartmann PE, Nottage HM. The initiation of lactation in sows and the mastitis-metritis-agalactia syndrome. Anim Reprod Sci 1982; 5 (2): 135-140.
13. Hanneman SK, McKay K, Costas G, Rosenstrauch D. Circadian temperature rhythm of laboratory swine. Comparative Med 2005; 55 (3): 249-255.
14. Heinritzi K, Hagn J. Untersuchungen zur Wirksamkeit und Verträglichkeit des neu entwickelten Cephalosprins Cephquinom bei an puerperaler Sepikämie und Toxämie erkrankten Sauen. Tierärztl Prax 1999; 27 (2): 114-121.

15. Hellmann K, Radeloff I. 2000. International Cooperation on Harmonisation of Technical Requirements of Veterinary Medicinal Products (VICH).
16. Hirsch AC, Philipp H, Kleemann R. Investigation on the efficacy of meloxicam in sows with mastitis-metritis-agalactia syndrome. J Vet Pharmacol Ther 2003; 26 (5): 355-360.
17. Hoy S. Untersuchungen zum Einfluss verschiedener Haltungsfaktoren auf die Häufigkeit von Puerperalerkrankungen bei Sauen. Prakt Tierarzt 2002; 83 (11): 990-996.
18. Hoy S. The impact of puerperal diseases in sows on their fertility and health up to next farrowing. Anim Sci 2006; 82: 701-704.
19. Ingram DL, Mount LE. Effects of food intake and fasting on 24-Hourly variations in body-temperature in young pig. Pflugers Arch 1973; 339 (4): 299-304.
20. Jessen C, Kuhnen G. Seasonal variations of body temperature in goats living in an outdoor environment. J Therm Biol 1996; 21 (3): 197-204.
21. Kemper N, Gerjets I. Bacteria in milk from anterior and posterior mammary glands in sows affected and unaffected by postpartum dysgalactia syndrome (PPDS). Acta Vet Scand 2009; 51.
22. King GJ, Willough.Ra, Hacker RR. Fluctuations in rectal temperature of swine at parturition. Can Vet J 1972; 13 (3): 72-74.
23. Lohse L, Uttenthal A, Enoe C, Nielsen J. A study on the applicability of implantable microchip transponders for body temperature measurements in pigs. Acta Vet Scand 2010; 52.
24. Madec F, Leon E. Farrowing Disorders in the sow - A field - study. J Vet Med Ser A-Zent bl Vet Med Reihe A-Physiol Pathol Clin Med 1992; 39 (6): 433-444.
25. Martin SW. Evaluation of tests. Can J Comp Med 1977; 41 (1): 19-25.
26. Martineau GP, Farmer C, Peltoniemi O. Mammary System. In: Diseases of Swine, 10. Aufl. Zimmerman JJ, Karriker LA, Ramirez A, Schwartz KJ, Stevenson GW, Wiley Blackwell 2012; 270-293.
27. Papadopoulos GA, Vanderhaeghe C, Janssens GPJ, Dewulf J, Maes DGD. Risk factors associated with postpartum dysgalactia syndrome in sows. Vet J 2010; 184 (2): 167-171.
28. Parrott RF, Lloyd DM. Restraint, but not frustration, induces prostaglandin-mediated hyperthermia in pigs. Physiol Behav 1995; 57 (6): 1051-1055.
29. Peltoniemi O, Oliviero C, Heinonen M. Managment der hochproduktiven Sau während des Abferkelns, der Laktation und des Östrus. Prakt Tierarzt 2010; 91 (10): 906-907.

30. Reiner G, Hertrampf B, Richard HR. Postpartales Dysgalaktiesyndrom der Sau - eine Übersicht mit besonderer Berücksichtigung der Pathogenese. Tierärztl Prax 2009; 37 (5): 305-318.
31. Ross RF, Orning AP, Woods RD, Zimmermann BJ, Cox DF, Harris DL. Bacteriologic Study of sow agalactia. Am J Vet Res 1981; 42 (6): 949-955.
32. Sonnenberg H. Untersuchungen der Körpertemperatur an Versuchsschweinen, ermittelt mit der Transpondertechnik an verschiedenen Implantationsorten im Vergleich zur rektal gemessenen Körpertemperatur. Diss med vet, Freie Universität Berlin 2011.
33. Suthar V, Burfeind O, Bonk S, Voigtsberger R, Keane C, Heuwieser W. Factors associated with body temperature of healthy Holstein dairy cows during the first 10 days in milk. J Dairy Res 2012; 79 (2): 135-142.
34. Traulsen I, Naunin K, Müller K, Krieter J. Untersuchungen zum Einsatz der Infrarotthermographie zur Messung der Körpertemperatur bei Sauen. Züchtungskunde 2010; 82 (6): 437-446.
35. van Gelder KN, Bilkei G. The course of acute-phase proteins and metritis agalactia (M MA) of the sow and serum cortisol in mastitis sow performance. Tijdschr Diergeneeskd 2005; 130 (2): 38-41.
36. Vickers LA, Burfeind O, von Keyserlingk MAG, Veira DM, Weary DM, Heuwieser W. Technical note: Comparison of rectal and vaginal temperatures in lactating dairy cows. J Dairy Sci 2010; 93 (11): 5246-5251.

Abbildungen:

Abb. 1 1: Temperaturlogger mit Scheidenspange verbunden 2: Scheidenspange (CIDR)

3: Temperaturlogger 4: Ausleseeinheit für Temperaturlogger

Fig. 1 1: Temperature Logger attached to a blank CIDR 2: CIDR blank 3:Temperature logger

4: Readout unit for temperature logger

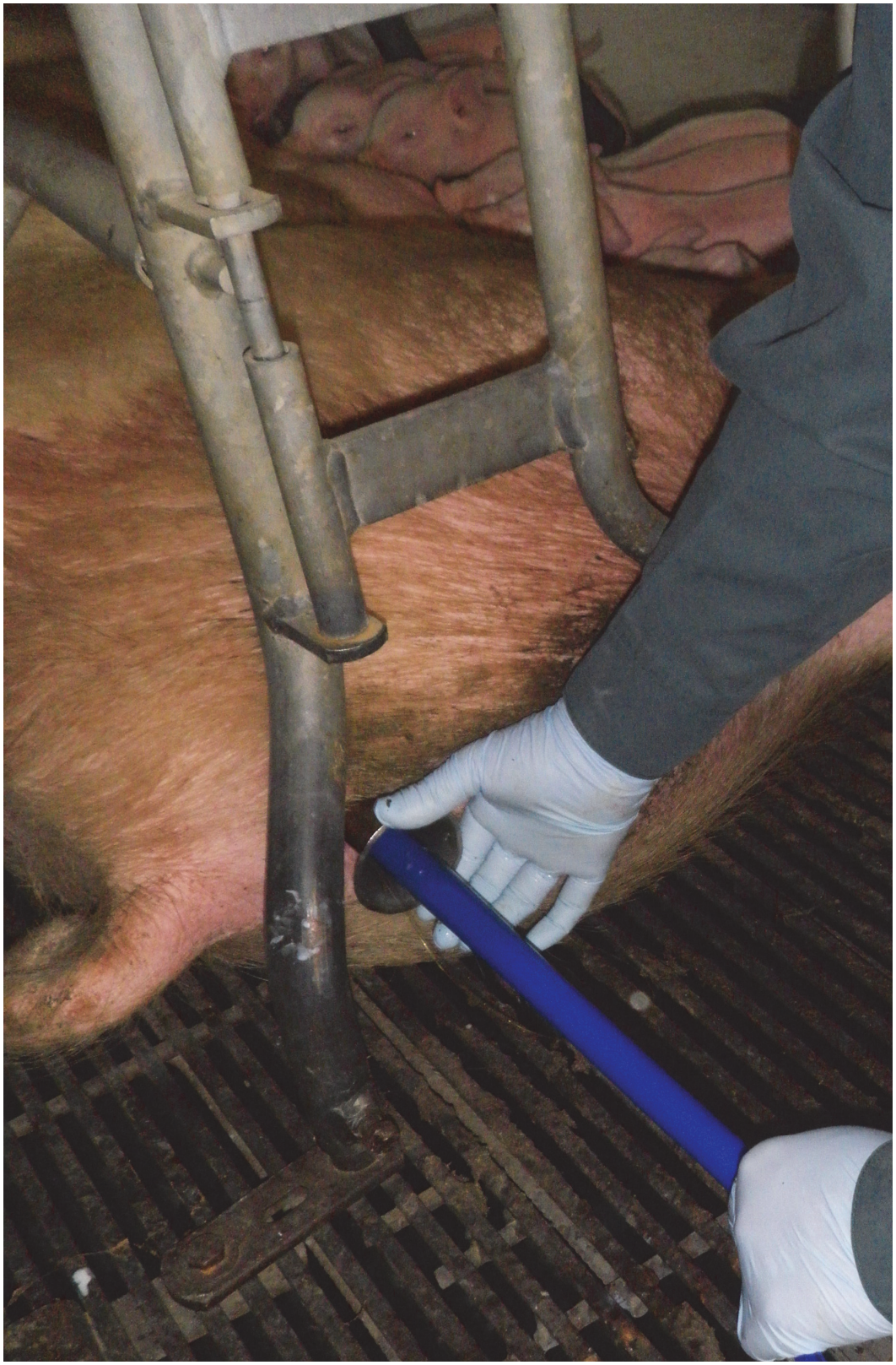

Abb. 2 Einlegen des Temperaturloggers

Fig. 2 Inserting the temperature logger

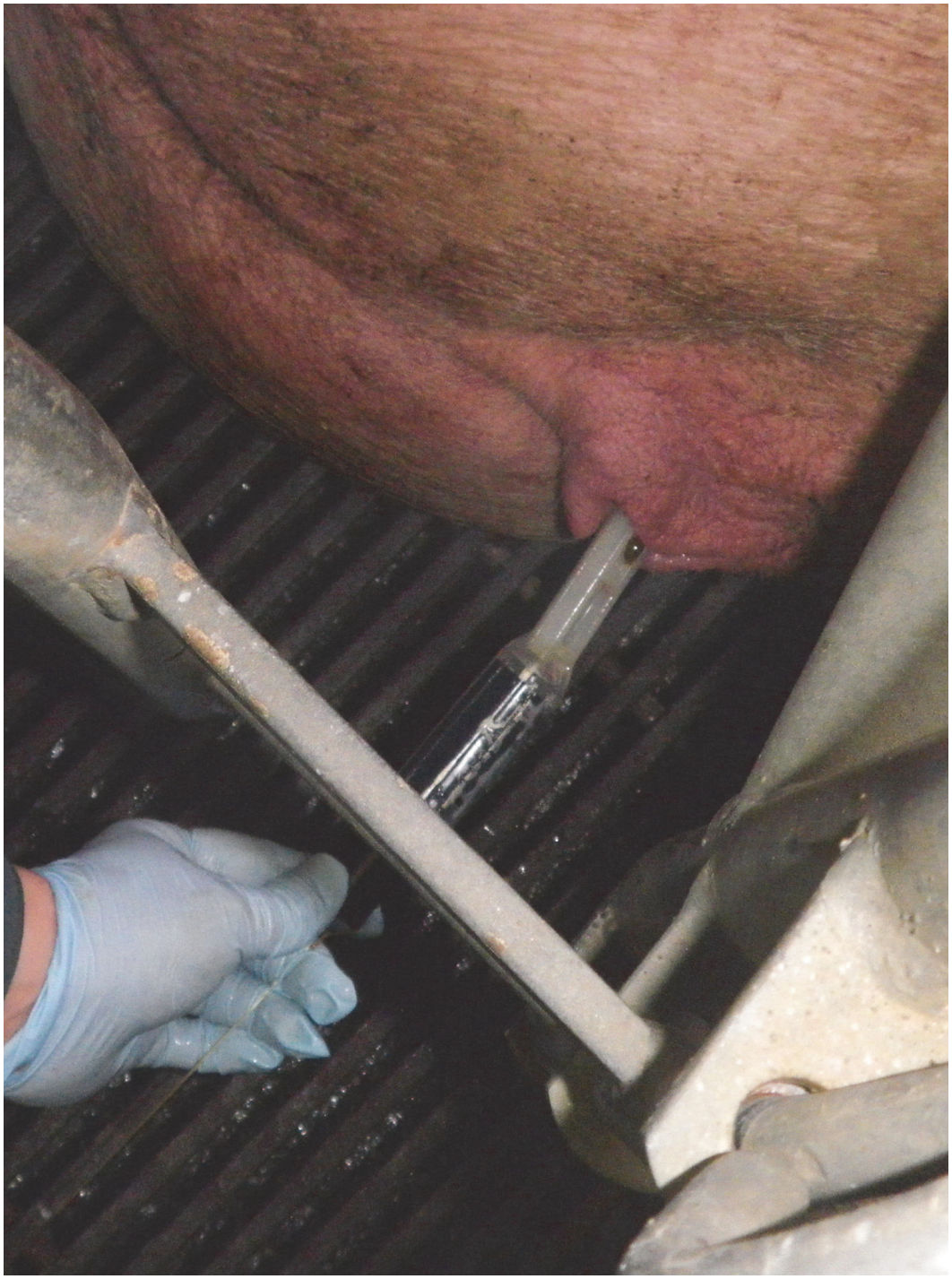

Abb. 3: Entfernen des Temperaturloggers

Fig. 3: Removing the temperature logger

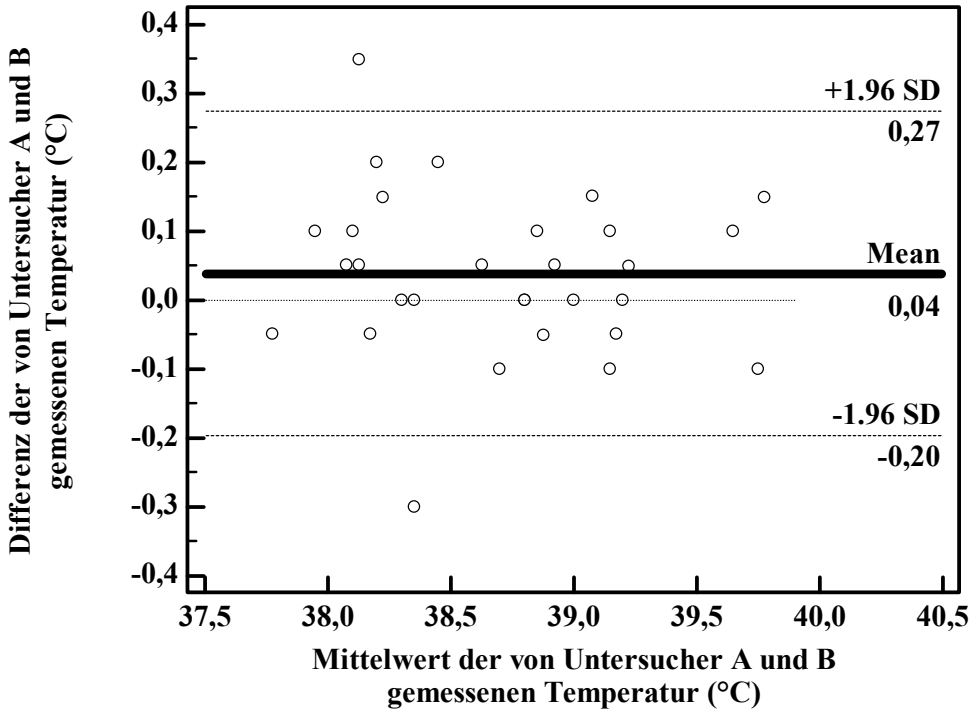

Abb. 4 Unterschiede der von Untersucher A und B gemessenen rektalen Temperatur in Relation zu deren Mittelwert (°C)

Fig. 4 Difference of rectal temperature measured by investigator A and B against their mean (°C)

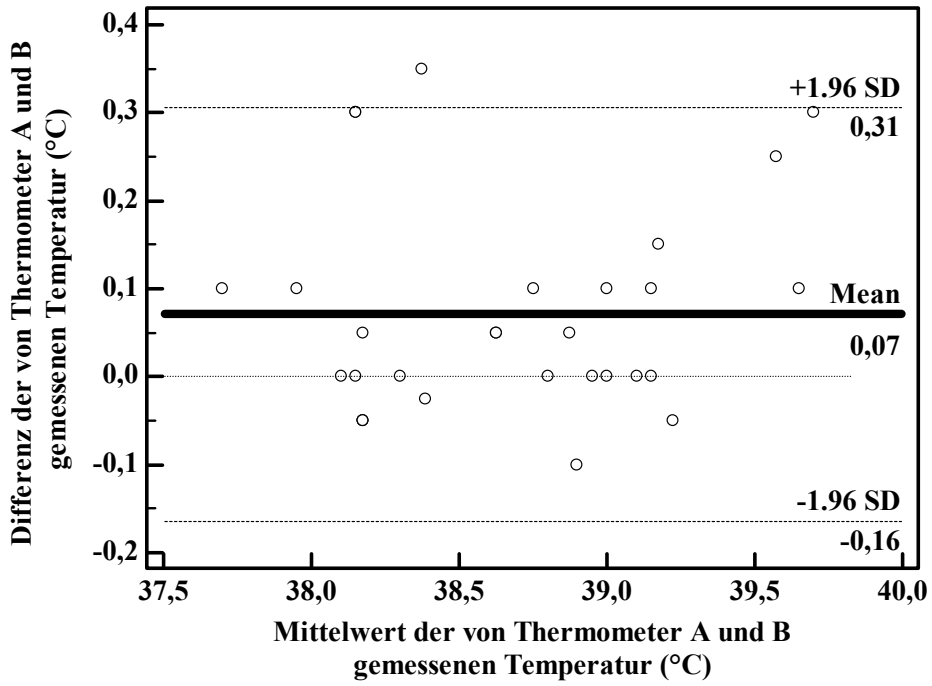

Abb. 5 Unterschiede der mit Thermometer A und B gemessenen rektalen Temperatur in Relation zu deren Mittelwert (°C)

Fig. 5 Difference of rectal temperature measured with thermometer A and B against their mean (°C)

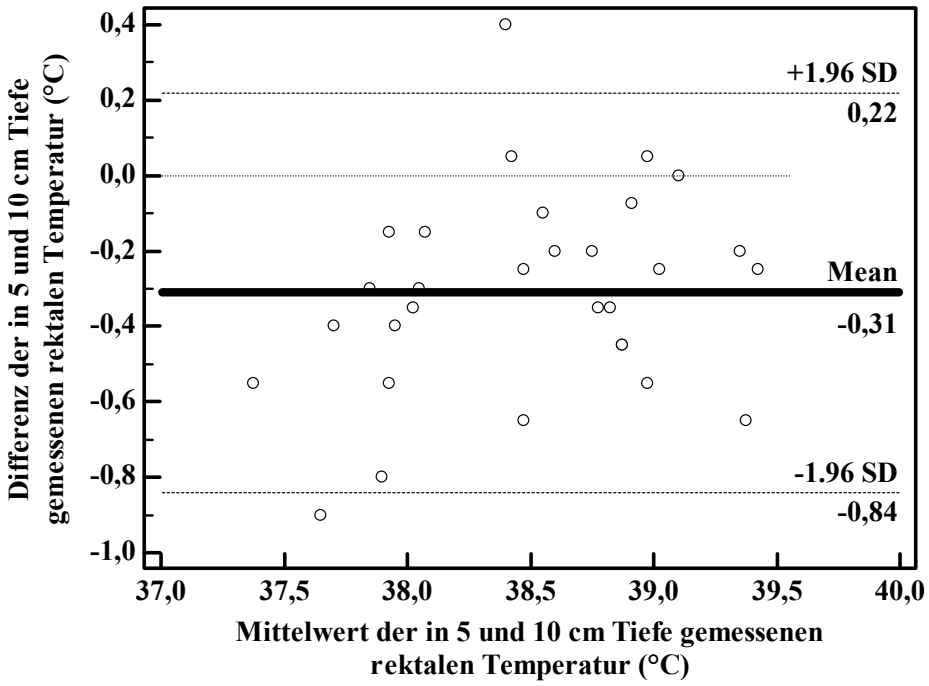

Abb. 6 Unterschiede der bei einer Eindringtiefe von 5 und 10 cm gemessenen rektalen Temperatur in Relation zu deren Mittelwert (°C)

Fig. 6 Difference of rectal temperature measured at 5 and 10 cm penetration depth against their mean (°C)

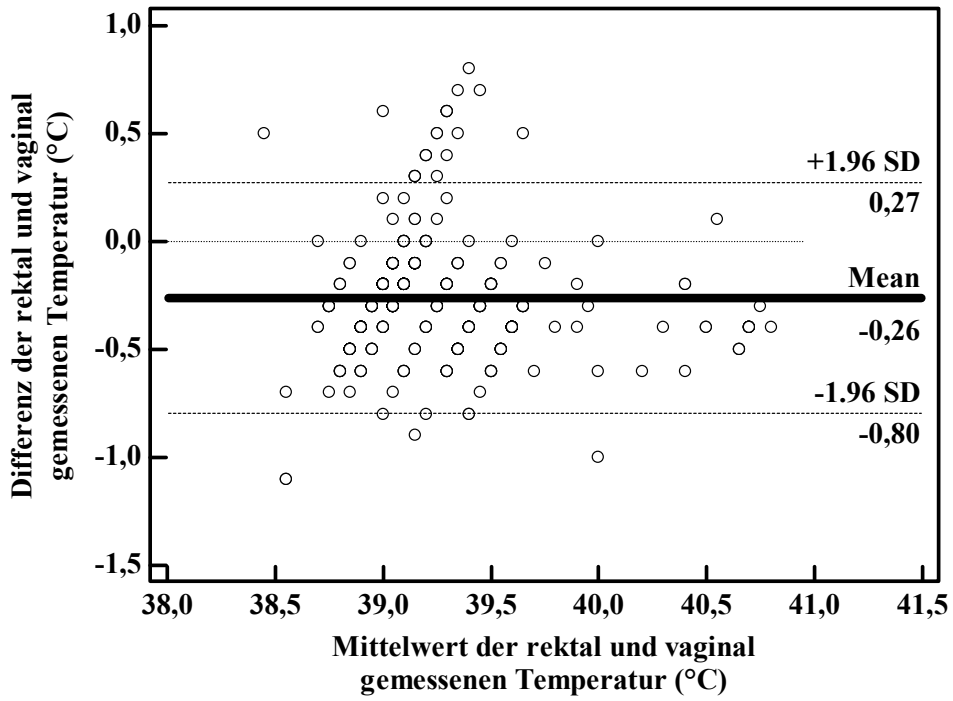

Abb. 7 Unterschiede der rektal und vaginal gemessenen Temperatur in Relation zu Mittelwert (°C)

Fig. 7 Difference of rectal and vaginal temperature measured against their mean (°C)

2. b The course of rectal and vaginal temperature in early postpartum sows

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Summary

Objectives: To investigate the course of body temperature in early postpartum sows and possible factors that may influence it, and to examine the influence of a vaginal temperature logger on body temperature by including a control group of sows without loggers.

Materials and methods: The study was conducted on a commercial pig farm from January to May 2013. A total of 156 sows received a vaginal temperature logger for 6 days post partum and 43 sows remained without loggers (negative control group). Vaginal temperature was measured at 10-minute intervals. Rectal temperature, feed intake, general condition, and vaginal discharge were evaluated daily.

Results: The sows showed a clear circadian rhythm of vaginal temperature, with minimal mean temperature 39.0°C (standard deviation [SD] 0.5°C) from 5:00 AM to 6:00 AM and maximum mean temperature 39.4°C (SD 0.5°C) from 1:00 PM to 7:00 PM ($P < .05$). Day postpartum ($P < .01$), time of day ($P < .01$), age ($P < .01$), general condition ($P < .01$), vaginal

discharge ($P < 0.01$), and treatment for postpartum dysgalactia syndrome ($P < .01$) had effects on rectal and vaginal temperature.

Implications: Measurement of body temperature should be made at the same time every day. Use of vaginal temperature loggers is a practicable method for on-farm studies to gain more information about the course of body temperature in postpartum sows. Body temperature should not be used as the single criterion for the decision to administer medical treatment.

Keywords: swine, postpartum dysgalactia syndrome, rectal temperature, temperature logger, vaginal temperature

Postpartum diseases of sows remain an important problem in the pig industry, affecting animal health and welfare of sows and piglets. Many terms are used to describe these disorders, such as mastitis, metritis, and agalactia,[1] swine urogenital disease,[2] periparturient hypogalactia syndrome,[3] or postpartum dysgalactia syndrome (PPDS).[4,5] The diverse terms reflect the variability of the etiology and clinical signs, which are mastitis, metritis, constipation, cystitis, anorexia, and pyrexia.[6] Today, the term "postpartum dysgalactia syndrome" has been accepted in English-speaking areas to describe this postpartum disorder of sows.[4,5,7] A common method to identify sick animals is measurement of rectal temperature in the first 3 days post partum, but temporary hyperthermia is often observed in postpartum sows.[8]

In recent studies, various methods of continuously measuring body temperature in pigs were evaluated. Hannemann et al[9] measured body temperature by a sensor inserted at the base of the ear. In this study, a circadian temperature rhythm was demonstrated and quantified in growing-finishing pigs, but the procedure was invasive. The use of infrared thermography is fast and practical, but not suitable for observation of the health status of individual animals.[10,11] Vaginal temperature loggers were recently validated for measuring vaginal

temperature in cows[12,13] and sows[14] after parturition and in gilts after vaccination.[15] Only minor differences were observed between rectal and vaginal temperature in cows.[12,13] In sows, correlation between rectal and vaginal temperature was high (r = .80; $P < .01$), but vaginal temperature was 0.3°C higher than rectal temperature, which has to be considered when interpreting measures of vaginal temperature generated with this technology. In gilts, a linear correlation existed both in vaccinated gilts (r = .86, n = 21; $P < .001$) and non-vaccinated gilts (r = .65, n = 22; $P < .001$), and most of the differences between rectal and vaginal temperature were within two standard deviations.[15]

To date, there is a dearth of information about factors that might influence body temperature in early postpartum sows under field conditions. Therefore, the overall objective of this study was to continuously measure body temperature of postpartum sows in a commercial setting, to investigate plausible factors that may influence body temperature, and, in addition, to examine whether body temperature in sows showing no overt clinical signs can be considered pyrexia, as has been described for healthy postpartum dairy cows.[16]

Materials and methods

The study was approved by the Institutional Animal Care and Use Commitee of the Clinic of Animal Reproduction, Freie Universität Berlin. Sows were managed according to the guidelines set by the International Cooperation and Harmonisation of Technical Requirements for Registration of Veterinary Medical Products.[17]

Herd and facilities

The study was carried out on a commercial pig farm with 1370 sows in Brandenburg, Germany. The herd was positive for *Actinobacillus pleuropneumoniae, Haemophilus parasuis, Mycoplasma hyopneumoniae,* porcine circovirus type 2*,* and porcine reproductive and respiratory syndrome virus. The sows were regularly vaccinated against *H parasuis,*

Clostridium perfringens Type A, *Escherichia coli,* and porcine reproductive and respiratory syndrome virus. The sows were moved to farrowing crates approximately 7 days prior to expected farrowing, with five farrowing rooms in three barns. The front third of the farrowing crates had solid concrete floors, with a covered and heated region for the piglets and a fully slatted floor in the back region. When moved into the farrowing room, sows were fed a lactation ration (energy, 13.0 MJ per kg; crude protein, 17.5%; crude fiber, 6%; crude ash, 6%; crude oil and fats, 5%) twice daily, at 6:00 AM and at 1:00 PM, with continuous access to water from a nipple drinker. The amount fed was increased after farrowing. Routine management of piglets included ear notching for identification, iron injection (1 mL Belfer iron (III)-hydroxid-dextran-complex, 100 mg per mL; bela-pharm GmbH & Co KG, Vechta, Germany), and castration of the male piglets during the first 6 days. Sows and piglets remained in the crates until the piglets were weaned at 28 days of age.

Study design

Every Thursday, 12 ± 2 sows, including 2 ± 1 gilts (mean ± standard deviation) were enrolled in the study for the duration of 16 weeks. On this farm, most sows farrowed Wednesday and Thursday, with farrowing not complete in many sows until Thursday afternoon. Only sows that had finished farrowing and completely expelled the placenta were included in the study. Included sows farrowed either on Wednesday or Thursday morning. On the first day after farrowing, in 10 ± 2 of these sows, a microprocessor-controlled temperature logger was inserted into the vagina, as recently validated for sows.[14] A group of sows enrolled as negative controls (2 ± 1 sows) did not receive a logger. The temperature logger (Minilog 8; Vemco, Ltd, Halifax, Nova Scotia, Canada; size = 92 × 20 mm, weight = 40.5 grams) was attached to a modified vaginal controlled internal drug release device (CIDR-blank, InterAg, Hamilton, New Zealand). A part of the plastic frame of the CIDR was removed and the flexible part was pulled over the logger. A thin cord was attached to the plastic frame of the

CIDR so that it could easily be pulled out after use. Before use, the combination of CIDR and logger was submerged in a povidone iodine solution for a minimum of 5 minutes (Braunol; B. Braun, Melsungen AG, Melsungen, Germany) and immediately on removal, without rinsing, inserted into the vagina of the standing or lying sow with the help of a tubular speculum (tubular speculum for pigs: length 40 cm, inner diameter 2.5 cm; WDT, Garbsen, Germany). The logger was pushed through the speculum with a CIDR applicator and positioned caudal to the cervix. This procedure required no restraint or sedation of the study animals. The logger remained in the vaginal cavity for a total of 6 days, measuring vaginal temperature at 10-minute intervals. The number of piglets born alive, stillborn piglets, and the birth weight of the litters were noted at enrolment, with each litter was weighed as a group. Piglet mortality, medical treatment of sows, number of piglets weaned, and litter weight at weaning were documented.

Daily observation of the animals, measurement of rectal temperatures, and medical treatment were conducted by the herd manager (investigator), who had completed 3 years of education comparable to a veterinary technician course. Before starting the study, the investigator underwent a 3-day training period with the first author, including 20 sows each day, assessing general health status, feed intake, and vaginal discharge, measuring rectal temperature, and implementing medical treatment. In the first 2 weeks of the study, the first author and investigator examined all study animals together to ensure that the measurements and examinations were performed consistently. In addition, every Thursday, when new study animals were enrolled, observations were performed simultaneously by the first author and the investigator. A data capture form was attached above the farrowing crate of each sow. From day 1 to day 6 of the study, the animals were clinically examined by the investigator. First, feed intake was evaluated by visual examination on a three-point scale (complete intake of feed, partial intake, or no feed intake). Second, the investigator scored general condition of the sow on a three-point scale: healthy: sow was attentive, standing up for feeding and nursing

the piglets; slightly reduced: sow seemed apathetic, did not nurse the piglets, ie, remained in ventral recumbency, not allowing the piglets to nurse, but stood up for feeding; severely reduced: sow was somnolent, remained recumbent, did not nurse the piglets, and did not stand up for feeding. Rectal temperature was measured twice daily (morning and afternoon) and vaginal discharge was evaluated by the investigator. Vaginal discharge was characterised as purulent or mucopurulent to simplify scoring. On day 7 of the study, the loggers were removed, which required no restraint or sedation. Litters were reweighed at weaning (day 28).

For analysis, a sow was categorized as ill when three clinical criteria were abnormal: reduced general condition, reduced feed intake, vaginal discharge and a rectal temperature > 40.0°C.[18] Not all sows categorized as ill were given medical treatment, as illness was classified retrospectively after the study ended. The herd manager provided all medical treatment of ill animals to ensure that treatment decisions were comparable. The standard operating procedure for treatment of PPDS included an intramuscular (IM) injection of 5 mg per kg body weight (BW) enrofloxacin (Floxibac, 100 mg per mL; Chanelle Pharmaceuticals Manufacturing Ltd, Loughrea, Co Galway, Ireland) once daily for 3 consecutive days; an IM injection of 50 mg per kg BW metamizol (Metapyrin 500 mg per mL; Serumwerk Bernburg AG, Bernburg, Germany) once daily for 3 consecutive days, and a single IM injection of 10 mg dinoprost (Dinolytic, 5 mg per mL; Zoetis Deutschland GmbH, Berlin, Germany) on the first day of treatment. Sows with purulent vaginal discharge for more than 1 day, but without other overt clinical signs, received only a single injection of 10 mg dinoprost. For further analysis, the single injection of dinoprost was classified as medical treatment.

After the piglets were weaned, the study sows were routinely moved to the breeding centre for insemination in the following estrus. Pregnancy diagnosis was performed via ultrasound by the herd veterinarian 4 weeks after insemination. The results of this examination were used to analyse the pregnancy rate of animals with and without loggers for a preliminary indication of

whether or not use of the vaginal loggers might have a detrimental effect on subsequent reproductive performance of the sows.

Statistical analysis

Data were recorded in Excel (Office 2010; Microsoft Deutschland GmbH, Munich, Germany) and analysed using SPSS for Windows (Version 20.0; SPSS Inc, Munich, Germany). Vaginal temperatures below 38.0°C were considered artefacts and excluded from analysis.

To study plausible factors that might be associated with body temperature (rectal and vaginal temperatures), their effects were tested in a univariate analysis of variance: day postpartum, hour of the day (actual time, vaginal temperature only) or time of day (morning or afternoon, rectal temperature only), age, logger (sows with or without loggers), piglets born alive, litter weight at day 1, litter weight at day 28, mean weight gain of the litter, vaginal discharge, feed intake, general condition, illness, medical treatment, PPDS treatment, and week of study. Fixed effects tested included the day postpartum (1 to 6), hour of the day (1 to 24), or time of day (1 = morning, 2 = afternoon), age (1 = gilt; 2 = parity 2 to 4; 3 = parity 5 or greater), logger (0 = no vaginal logger; 1 = vaginal logger), piglets born alive (eight to 19), vaginal discharge (0 = no vaginal discharge; 1 = vaginal discharge), illness (0 = fewer than three clinical signs, 1 = three clinical signs), medical treatment (0 = no; 1 = yes), PPDS treatment (0 = no; 1 = yes), and week of study (1 to 16). The three-point scales of feed intake and general condition were converted into a two-point scale to minimize the problem of subjectivity. Therefore feed intake (1 = complete intake; 2 = partly or no intake) and general condition (1 = healthy; 2 = slightly or severely reduced) were tested as fixed effects. Litter weight at day 1 and at day 28 and mean litter weight gain were tested as covariates. All variables with a univariable $P < .20$ were included in a repeated measures linear mixed model with repeating day post partum (one for rectal temperature and one for vaginal temperature, respectively). Models were constructed in a backward stepwise manner using the scale-identity structure.

Pearson´s and Spearman´s correlation (ρ) between the parameters were determined. If two variables were highly correlated (r > .5), only the variable with the smaller *P* value was included in the final model.

Results

A total of 199 sows were included in the study. In 156 sows, a vaginal temperature logger was inserted after parturition. The remaining 43 sows (negative controls) did not receive a temperature logger. A total of 15 sows were excluded from vaginal temperature analysis because of logger losses (n = 10, 6.4%) or technical problems with the loggers (n = 5, 3.2%). These 15 sows, however, were included in the rectal temperature analysis. A total of 34 gilts and 165 pluriparous sows were used in the study, with 100 sows in parities 2 to 4 and 65 sows in parities 5 to 10 (mean parity 3.8, SD 2.3, including gilts).

Temperature loggers recorded 118,127 ten-minute readings of vaginal temperature from 141 sows. Of these, 468 (0.4%) were below 38.0°C and excluded from analysis. For further statistical analyses of vaginal temperature, only 18,509 readings from day 1 to 6 were used because rectal temperature was measured and examinations performed during this period, whereas vaginal temperature alone was measured until the morning of day 7.

Vaginal temperature showed a clear circadian rhythm, with the lowest temperature in the morning from 5:00 AM to 6:00 AM and the highest temperature in the afternoon from 1:00 PM to 7:00 PM (Figure 1). Vaginal temperature began to increase parallel with activities in the farrowing pen (eg, feeding at 6:00 AM, cleaning of farrowing pens, and medical treatments in the morning). Temperature rose until 3:00 pm and stayed high until 7:00 pm (Figure 1).

A total of 18 sows (9.0%) were treated within the first 6 days postpartum with dinoprost (n = 10, 5.0%) because of vaginal discharge or with antibiotic and anti-inflammatory drugs for 3 consecutive days as described (PPDS-treatment, n = 8, 4.0%).

A total of 191 of the 199 study animals were inseminated after weaning. Seven of the remaining eight sows (4.0%) were slaughtered after weaning due to age (n = 3), lameness (n = 1), small litter size (n = 1), cachexia (n = 1), or infertility (n = 1). One sow died in the farrowing pen in the third week of lactation. Among 151 sows with vaginal temperature loggers, 146 sows became pregnant after the first insemination and five sows after a second insemination. Among 40 sows without loggers, 39 sows became pregnant after the first insemination and one sow after a second insemination. The logger had no effect on fertility after weaning ($P = 1.0$).

Factors associated with rectal temperature

In the univariate analysis, the influence of all plausible factors on rectal temperature was tested (Table 1). Medical treatment and PPDS-treatment were correlated ($P = .65$) and therefore only PPDS-treatment was included in the mixed model. Mean litter weight gain was excluded ($P = .35$). In the repeated measures linear mixed model (Table 1), the day post partum (1 to 6), time of day (morning or afternoon), age (gilt, parity 2 to 4, parity ≥ 5), vaginal temperature logger (yes or no), general condition (healthy or slightly to severely reduced), vaginal discharge (yes or no), PPDS-treatment (yes or no), and week of the study (1 to 16) remained significant (Figures 2, 3, 4, 5, and 6). The highest rectal temperature recorded from day 1 to 6 post partum was in gilts, whereas the lowest rectal temperature recorded throughout the trial sows was in sows of parity ≥ 5 (Table 2; Figure 3).

Factors associated with vaginal temperature

In a univariate analysis, all variables tested had an effect on vaginal temperature (Table 3). Litter weight on day 28 and the mean litter weight gain were correlated (r = .88), and therefore mean litter weight gain was excluded from further analysis. In the repeated measures linear mixed model (Table 4), day post partum (1 to 6), hour of the day (1 to 24), age (gilt, parity 2 to 4, parity ≥ 5), feed intake (complete or partly to no intake), general

condition (healthy or slightly to severely reduced), vaginal discharge (yes or no) and PPDS-treatment (yes or no) remained significant (Figures 1, 3, 5, 6). The factore "age" was associated with vaginal temperature. Thus, the highest vaginal temperature recorded from day 1 to 6 post partum was in gilts, and the lowest vaginal temperature throughout the trial was in sows at parity ≥ 5 (Table 2, Figure 3).

Fever in postpartum sows

In summary, rectal temperature in the first 6 days post partum was > 39.5°C at least once in 59 of 199 sows (29.6%). Among these, 17 sows (8.5%) had a rectal temperature > 40.0°C. In 127 of 141 (90.1%) sows, at least one vaginal temperature measurement was > 39.5°C, the threshold frequently used in previous studies.[1,6] Among these 127 sows, vaginal temperature was between 39.8°C and 40.0°C (68.8%), between 40.1°C and 40.3°C (61.7%), and > 40.3°C (40.4%) at least once in 97, 87, and 57 sows, respectively.

Discussion

A sufficient number of sows with a vaginal temperature logger (n = 156) were used in this study to examine the course of continuously measured vaginal temperature, because information on rectal temperature based on repeated measures at certain time points is already available.[19] In former studies, temperature sensors for measuring body temperature were often inserted under general anesthesia, eg, near the carotid artery[20] or the femoral or pulmonary artery, in the urinary bladder, or by the tympanic method,[21] and animals were housed under laboratory conditions.[9,15] In this study, temperature loggers inserted into the vagina allowed continuous recording of vaginal temperature under field conditions, as recently validated for cows and sows.[13,14] Previous trials used only three,[22] nine,[9] 27,[23] or 43 animals.[15] Furthermore, a larger number of sows (n = 141), including gilts (n = 28) were used in this study to investigate the effect of plausible factors on vaginal temperature. The loggers were

attached to a modified vaginal controlled internal drug release device as described for cows, dogs, and sows.[12,14,24] This minimized expulsion of loggers from the vagina during the study period (10 loggers; 6.4%), while in another study, loggers were not fixed in the vagina and slid out easily.[15] In the current study, insertion of the loggers was minimally invasive and did not require anaesthesia. To the knowledge of the authors, this is the first study using this methodology in sows for 6 days post partum.

Vaginal temperatures showed a clear circadian rhythm. It can be speculated that the minimum temperature in the morning was interrupted by starting of activities in the farrowing room, eg, feeding. In the afternoon, body temperature decreased more slowly because of thermal storage and physiological activity of the sow.

A similar circadian temperature rhythm has been described previously.[9] In a small study, body temperature in eight of nine growing-finishing swine exhibited a circadian rhythm with an amplitude (range between the lowest and highest values of mean temperature) of 0.18°C ± 0.02°C, mean body temperature of 38.7°C ± 0.24°C, and a maximum at 7:44 PM.[9] However, on the basis of frequent body temperature measurements by a temperature transmitter at 30-minute intervals in 10- to 14-week-old pigs for 2 to 3 consecutive days, it was concluded that in pigs there is a very little innate circadian rhythm and that the observed temperature variations are mainly related to feeding and activity.[23] In the present study, a circadian rhythm in sows was observed during the first 6 days post partum with an amplitude of 0.4°C. It was not possible, however, to determine whether this variation was based on an innate circadian rhythm or related to feeding or activity or both.

Infections, trauma, and injury result in an adaptive response that includes loss of appetite, apathy, and fever.[25] Fever is triggered by the release of endogenous pyrogens from different regions of macrophage-like cells. These pyrogens include cytokines IL-1 and IL-6, which act at the level of the anterior hypothalamus to raise the thermoregulatory set point. In a previous study,[1] it was suggested that it is possible to predict the occurrence of PPDS from elevation of

rectal temperature, which occurs earlier than other clinical signs (eg, vaginal discharge, mastitis, or emaciated piglets as a consequence of the unsufficient milk production). It was postulated that rectal temperature > 39.4°C was an appropriate threshold to administer preventive medical treatment such as antibiotic and anti-inflammatory drugs.[1] A previous publication demonstrated a physiological hyperthermia after farrowing.[8] In this study, 59 (29.6%) and 17 (8.5%) of 199 sows had rectal temperatures > 39.5°C and > 40.0°C, respectively, and 57 (40.4%) sows had vaginal temperatures > 40.3°C. Only eight of these sows received antibiotic and anti-inflammatory treatment. Most of the sows with such high temperatures showed no signs of illness, eg, apathy, no feed intake, or vaginal discharge, and were therefore not treated. As evidenced by the subsequent reproductive performance of the sows, these high body temperatures might have no negative consequences. However, this fact needs to be studied on a large scale with more sows and more farms. In the study of Elmore et al,[26] mean pre-farrowing body temperature of 12 mixed-breed sows was 38.83°C ± 0.3°C. Mean postfarrowing temperature was 0.6°C to 1.2°C higher and temperature returned to pre-farrowing values after piglets were weaning. These investigators measured body temperature with surgically implanted temperature transmitters in the left paralumbar fossa. King et al[19] also demonstrated that sows have a significantly higher rectal temperature after farrowing (39.3°C ± 0.7°C) than before farrowing (38.3°C ± 0.6°C). Their study was conducted on 217 sows in which rectal temperature was measured three times a day. The authors speculated that the higher temperatures were caused by the physiological inflammatory reaction accompanying involution of the uterus and increasing mammary gland metabolism. Interestingly, they also postulated that healthy sows may have a body temperature > 39.7°C and that high rectal temperature without other clinical signs should not be considered evidence of disease.[19] Our results are in agreement, ie, in a high number of apparently healthy sows, body temperature exceeded 39.5°C, the common threshold for pyrexia. In the study of King et al,[19] a glass mercury thermometer was used, whereas we used a digital thermometer.

The comparison must be interpreted with care, as it is possible that use of different methods of measuring rectal temperature biased the results. To date, it is an accepted fact that lactation hyperthermia occurs in sows after farrowing,[8] hence the difficulty in defining body temperature limits for medical treatment of sows. The results of this study provide further evidence that diagnosis of PPDS in sows should include a combination of clinical signs, eg, lethargy, diminished milk production, reduced appetite, and vaginal discharge, as previously described.[27] It is emphasized, however, that evaluation of clinical signs might be more subjective than measurement of rectal temperature, which is a repeatable measure.[14] This has already been demonstrated for vaginal discharge in cows.[28] General health condition, feed intake, and vaginal discharge are subjective parameters, but more objective parameters to validate health or illness of early postpartum sows are limited. Clinical examination of the study animals was conducted only by the investigator to reduce observer bias. In additiion, during the first 2 weeks of the study and every Thursday, clinical examinations were performed simultaneously by the herd manager and the first author to provide a consistent evaluation of these parameters. Furthermore, assessments of feed intake, vaginal discharge, and general demeanour are similar to those used in a previous PPDS study as clinical parameters in examination of sows.[6]

In this study, general behavior, feed intake, and vaginal discharge had a significant influence on rectal and vaginal temperature. Gilts had higher rectal and vaginal temperatures than older sows from day 1 to 6. This result agrees with that of a previous study in cows.[29] To the knowledge of the authors, this has not yet been described for sows. The number of piglets born alive, mean litter weight on day 1, mean weight gain, and mean litter weight on day 28 did not influence vaginal and rectal temperatures. These findings agree with those of another study.[30] Insertion of a vaginal temperature logger affected rectal temperature. This could be explained as a physiologic reaction to a foreign body.

It remains unclear if the factors used as covariates occurred as a consequence of, or simultaneously with, higher body temperature (eg, illness, medical treatment). However, in these models, this is of minor consequence because both models seek large-scale associations. Measuring rectal temperature is an objective and repeatable diagnostic method.[14] The measuring process, however, should be standardized to achieve comparable values. Temperature should be measured at the same time of day. The results of this study clearly illustrated that the measures should be interpreted with caution, because rectal and vaginal temperature are associated with several factors. Body temperature is only one sign of the PPDS complex and should not be used as the single criterion for the decision to administer medical treatment in early postpartum sows. General health status, feed intake, and vaginal discharge are more subjective, and their usefulness should be evaluated in combination with body temperature in further studies. It must be emphasized that the definition of PPDS needs refinement.

Implications

- Because of the circadian rhythm of body temperature in sows, measurements should be made at the same time every day.
- Use of temperature loggers inserted into the vagina of sows is very practicable for one-farm studies to gain more information about postpartum body temperature.
- Clinical signs such as general behaviour, feed intake, and vaginal discharge are associated with increased body temperature in sows.
- Body temperature should not be used as the single criterion for the decision to administer medical treatment in early postpartum sows.

Conflict of interest

None reported.

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References

1. Furniss SJ. Measurement of rectal temperature to predict mastitis, metritis and agalactia (MMA) in sows after farrowing. *Prev Vet Med.* 1987;5:133–139.

2. Glock XTP, Bilkei G. The effect of postparturient urogenital diseases on the lifetime reproductive performance of sows. *Can Vet J.* 2005;46:1103–1107.

3. Hoy S. Investigations on influence of different housing factors on frequency of puerperal diseases in sows. *Praktische Tierarzt.* 2002;83:990–996.

4. Papadopoulos GA, Vanderhaeghe C, Janssens GPJ, Dewulf J, Maes DGD. Risk factors associated with postpartum dysgalactia syndrome in sows. *Vet J.* 2010;184:167–171.

5. Preissler R, Looft H, Kemper N. The postpartum dysgalactia syndrome: An overview of the genetic predisposition. *Tierärztliche Umschau.* 2012;67:520–527.

6. Hirsch AC, Philipp H, Kleemann R. Investigation on the efficacy of meloxicam in sows with mastitis-metritis-agalactia syndrome. *J Vet Pharmacol Ther.* 2003;26:355–360.

7. Kemper N, Gerjets I. Bacteria in milk from anterior and posterior mammary glands in sows affected and unaffected by postpartum dysgalactia syndrome (PPDS). *Acta Vet Scand.* 2009;51:26–32.

8. Martineau GP, Farmer C, Peltoniemi O. Mammary System. In: Zimmerman JJ, Karriker LA, Ramirez A, Schwartz KJ, Stevenson GW, eds. *Diseases of Swine*. 10th ed. Ames Iowa: Wiley-Blackwell, 2012:270–293.

9. Hanneman SK, McKay K, Costas G, Rosenstrauch D. Circadian temperature rhythm of laboratory swine. *Comp Med.* 2005;55:249–255.

10. Traulsen I, Naunin K, Müller K, Krieter J. Application of infrared thermography to measure body temperature of sows. *Züchtungskunde.* 2010;82:437–446.

11. Dewulf J, Koenen F, Laevens H, de Kruif A. Infrared thermometry is not suitable for the detection of fever in pigs. *Vlaams Diergeneeskundig Tijdschrift.* 2003;72:373–379.

12. Vickers LA, Burfeind O, von Keyserlingk MAG, Veira DM, Weary DM, Heuwieser W. Technical note: Comparison of rectal and vaginal temperatures in lactating dairy cows. *J Dairy Sci.* 2010;93:5246–5251.

13. Suthar V, Burfeind O, Maeder B, Heuwieser W. Agreement between rectal and vaginal temperature measured with temperature loggers in dairy cows. *J Dairy Res.* 2013;80:240–245.

14. Stiehler T, Heuwieser W, Pfützner A, Voigtsberger R, Burfeind O. Repeatability of measures of the rectal temperature and comparison of vaginal and rectal temperature in puerperal sows. *Tierärztliche Praxis Großtiere.* 2013;41:217–224.

15. Schmidt M, Ammon C, Schon P, Manteuffel C, Hoffmann G. Assessment of continuous vaginal logger-based temperature monitoring in fever-induced guilts. *Am J Anim Vet Sci.* 2013;8:55–65.

16. Burfeind O, Suthar VS, Heuwieser W. Effect of heat stress on body temperature in healthy early postpartum dairy cows. *Theriogenology.* 2012;78:2031–2038.

17. Hellmann K, Radeloff I. International Cooperation on Harmonisation of Technical Requirements for registration of Veterinary Medicinal Products (VICH). 2000; http://www.fda.gov/downloads/AnimalVeterinary/GuidanceComplianceEnforcement/GuidanceforIndustry/UCM052417.pdf. Accessed 16 December 2014.

18. Kiss D, Bilkei G. A new periparturient disease in Eastern Europe, *Clostridium difficile* causes postparturient sow losses. *Theriogenology.* 2005;63:17–23.

19. King GJ, Willoughby RA, Hacker RR. Fluctuations in rectal temperature of swine at parturition. *Can Vet J.* 1972;13:72–74.

20. Ingram DL, Mount LE. Effects of food intake and fasting on 24-hourly variations in body-temperature in young pig. *Pflügers Archiv: European Journal of Physiology.* 1973;339:299–304.

21. Hanneman SK, Jesurum-Urbaitis JT, Bickel DR. Comparison of methods of temperature measurement in swine. *Lab Anim.* 2004;38:297–306.

22. Jessen C, Kuhnen G. Seasonal variations of body temperature in goats living in an outdoor environment. *J Therm Biol.* 1996;21:197–204.

23. Ingram DL, Legge KF. Variations in deep body temperature in young unrestrained pig over 24 hour period. *J Physiol-London.* 1970;210:989–998.

24. Maeder B, Arlt S, Burfeind O, Heuwieser W. Continuous vaginal temperature measurement in bitches before parturition. *Reprod Biol.* 2013;13(Suppl2):31–32.

25. Kluger MJ, Kozak W, Conn CA, Leon LR, Soszynski D. Role of fever in disease. In: Kluger MJ, Bartfai T, Dinarello CA, eds. *Molecular Mechanisms of Fever*. Annals of the New York Academy of Sciences. 1998;856:224–233. doi:10.1111/j.1749-6632.1998.tb08329.x.

26. Elmore RG, Martin CE, Riley JL, Littledike T. Body temperatures of farrowing swine. *JAVMA*. 1979;174:620–622.

27. Larsen I, Thorup F. The diagnosis of MMA. *Proc IPVS Cong.* Copenhagen, Denmark. 2006;256.

28. Sannmann I, Burfeind O, Suthar V, Bos A, Bruins M, Heuwieser W. Technical note: Evaluation of odor from vaginal discharge of cows in the first 10 days after calving by olfactory cognition and an electronic device. *J Dairy Sci.* 2013;96:5773–5779.

29. Suthar V, Burfeind O, Bonk S, Voigtsberger R, Keane C, Heuwieser W. Factors associated with body temperature of healthy Holstein dairy cows during the first 10 days in milk. *J Dairy Res.* 2012;79:135–142.

30. van Gelder KN, Bilkei G. The course of acute-phase proteins and metritis agalactia (M MA) of the sow and serum cortisol in mastitis sow performance. *Tijdschrift Voor Diergeneeskunde (Amsterdam).* 2005;130:38–41.

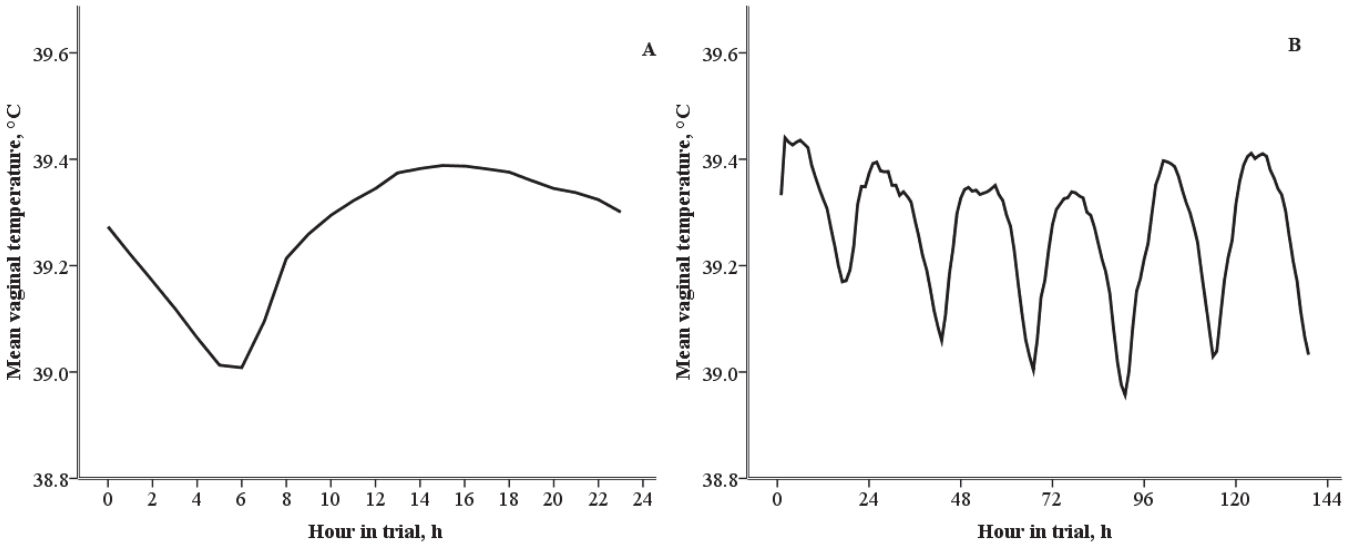

Figure 1: In a study conducted on a commercial pig farm, January to May 2013, a total of 156 sows received a vaginal temperature logger for 6 days post partum and 43 sows did not receive a logger (negative control group). Vaginal temperature was measured at 10-minute intervals. Fifteen sows were excluded from vaginal temperature analysis because of logger losses or technical problems with the logger. Mean vaginal temperature was measured for all sows for all study days (A, n = 141) and for days 1 to 6 postpartum (B, n = 141).

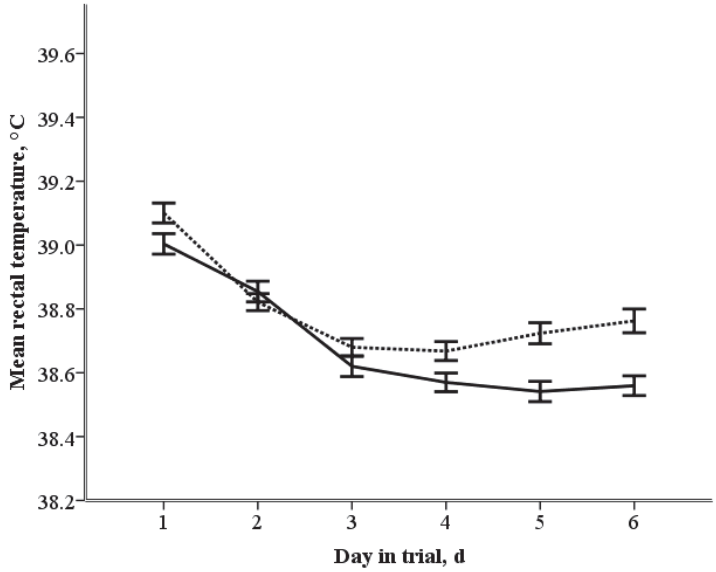

Figure 2: Mean rectal temperature (± standard error of the mean) measured in the morning (———, continous line) and in the afternoon (·····, dotted line) in postpartum sows (n = 199) Study described in Figure 1 and Table 1.

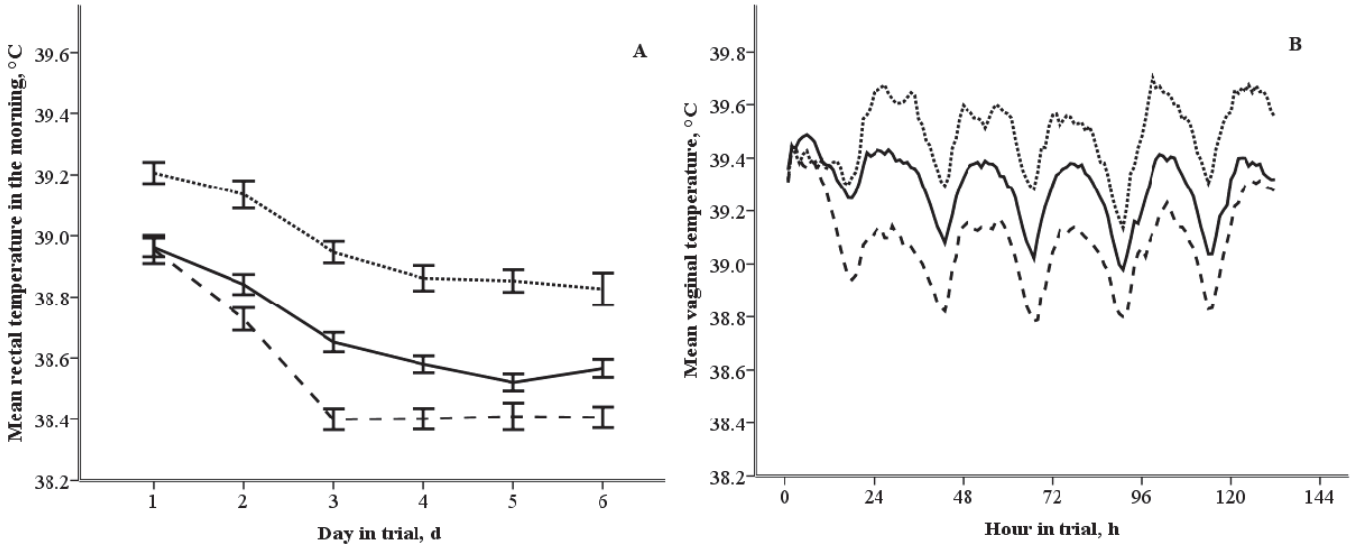

Figure 3: Mean rectal temperature (± standard error of the mean) measured in the morning (A) and mean vaginal temperature measured continously (B) for postpartum sows. Parity 1 (⋯⋯, dotted line, rectal temperature: n = 34, vaginal temperature: n = 28), pariy 2 - 4 (———, continous line, rectal temperature: n = 100, vaginal temperature: n = 71), parity > 4 (------, dashed line, rectal temperature: n = 65, vaginal temperature: n = 42).

Study described in Figure 1 and Table 1.

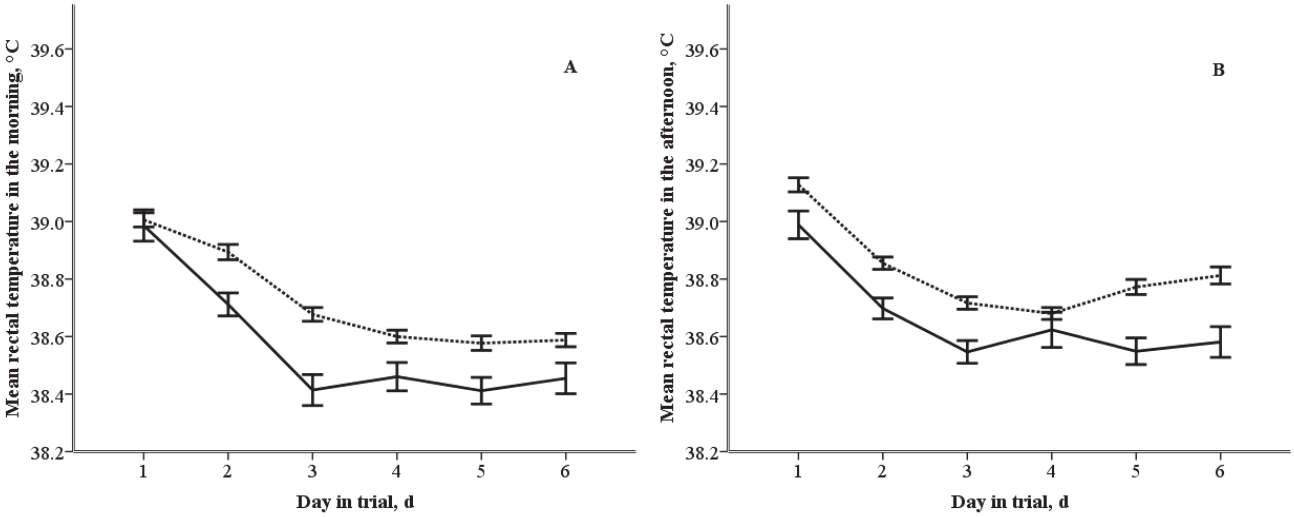

Figure 4: Mean rectal temperature (± standard error of the mean) measured in the moring (A) and in the afternoon (B) in postpartum sows with (· · · · ·, dotted line, n = 141) and without vaginal temperature loggers (——, continous line, n = 43).

Study deycribed in Figure 1 and Table 1.

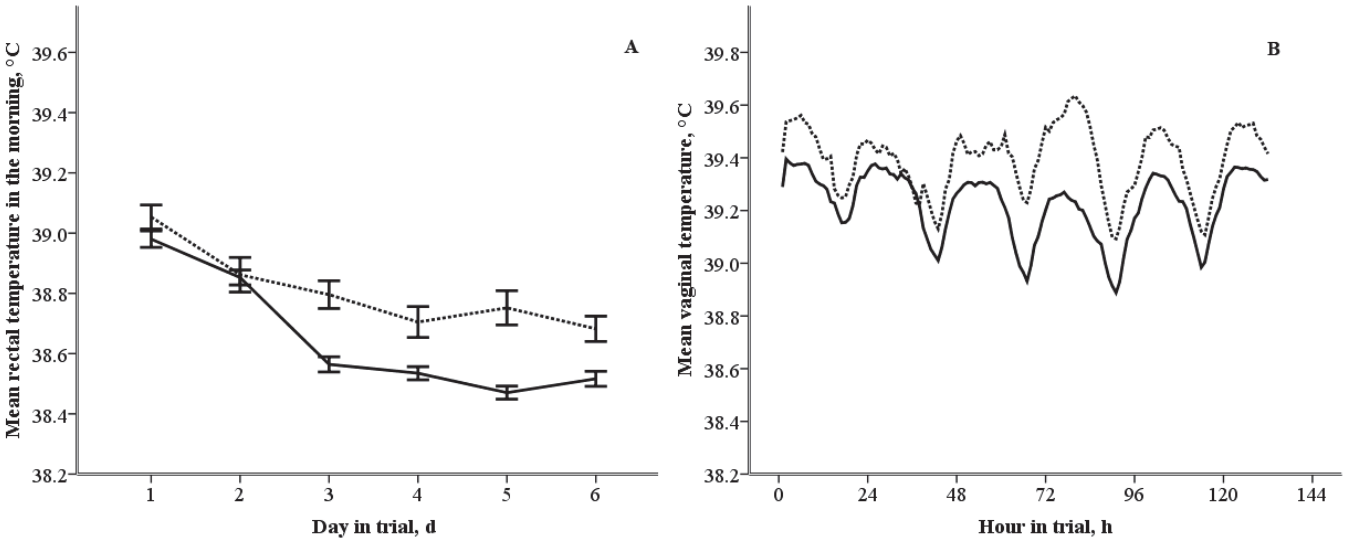

Figure 5: Mean rectal temperature (± standard error of the mean) measured in the morning (A) and mean vaginal temperature measured continously (B) in postpartum sows with (·····, dotted line, rectal temperature: n = 58, vaginal temperature: n = 33) and without vaginal discharge (———, continous line, rectal temperature: n = 141, vaginal temperature: n = 108).

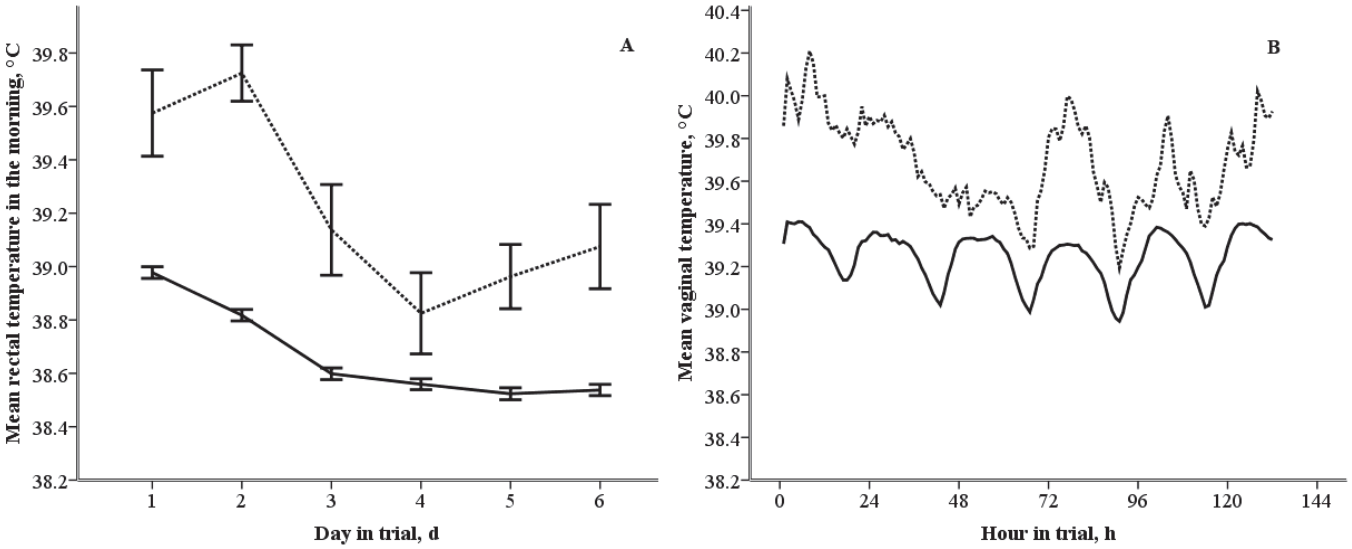

Figure 6: Mean rectal temperature (± standard error of the mean) measured in the morning (A) and vaginal temperature measured continously (B) in sows treated for postpartum dysgalactia syndrome (PPDS) (· · · · ·, dotted line, rectal temperature: n = 8, vaginal temperature: n = 7) and sows not treated for PPDS (———, continous line, rectal temperature: n = 191, vaginal temperature: n = 134). PPDS treatment described in Table 1.

Table 1: Factors influencing rectal temperature in postpartum sows (n = 199)*

Factor	*P*	
	Univariable analysis	ANOVA
Day postpartum	< .01	< .01
Time of day	< .01	<.01
Age (parity)	< .01	<.01
Vaginal temperature logger	< .01	.02
Liveborn piglets	.02	NS
Weight of piglets day 1	.16	NS
Weight of piglets day 28	.13	NS
Mean weight gain of piglets	.35	ND
Vaginal discharge	< .01	< .01
Feed intake	< .01	NS
General condition	< .01	< .01
Illness†	< .01	ND
PPDS treatment‡	< .01	< .01
Week of study	< .01	.03

* Study described in Figure 1.Vaginal temperature was measured at 10-minute intervals. Rectal temperature, feed intake, general condition, and vaginal discharge were evaluated daily. Effects of variables were tested using univariable analysis and repeated measure ANOVA in a multivariate linear mixed model. Piglets were weighed as a litter at 1 and 28 days of age. Litter weight was tested as a covariate.

† Assessment of illness was based on the combination of general behavior, feed intake, and vaginal discharge on at least 1 day of the 6-day trial.

‡ Enrofloxacin (Floxibac 100 mg/mL; Chanelle Pharmaceuticals Manufacturing Ltd, Loughrea, Co Galway, Ireland), 50 mg/kg, IM, 3 consecutive days; metamizol (Metapyrin

500 mg/mL; Serumwerk Bernburg AG, Bernburg, Germany), 50 mg/kg BW, IM, 3 consecutive days); and dinoprost (Dinolytic 5 mg/mL; Zoetis Deutschland GmbH, Berlin, Germany), 10 mg IM, single injection first day of treatment.

ANOVA = analysis of variance; ND = not done; NS = not significant ($P>.05$); PPDS = postpartum dysgalactia syndrome; BW = body weight; IM = intramuscular.

Table 2: Rectal and vaginal temperatures in °C (mean ± standard deviation) in postpartum sows by parity (n = 199)*

Parity	Temperature measurement	Days postpartum					
		1	2	3	4	5	6
All n = 199	RTAM (°C)	39.0 ± 0.5^{a}	38.9 ± 0.5^{b}	38.6 ± 0.5^{c}	38.6 ± 0.4^{cd}	38.5 ± 0.4^{d}	38.6 ± 0.4^{cd}
	RTPM (°C)	39.1 ± 0.4^{a}	38.8 ± 0.4^{b}	38.7 ± 0.4^{cd}	38.7 ± 0.4^{cd}	38.7 ± 0.5^{cde}	38.8 ± 0.5^{be}
	VT (°C)	39.4 ± 0.5^{a}	39.3 ± 0.5^{b}	39.3 ± 0.4^{c}	39.2 ± 0.5^{d}	39.2 ± 0.5^{d}	39.3 ± 0.5^{e}
1 n = 34	RTAM (°C)	39.2 ± 0.3^{a}	39.1 ± 0.4^{a}	38.9 ± 0.3^{b}	38.9 ± 0.3^{bd}	38.9 ± 0.3^{cd}	38.8 ± 0.4^{cd}
	RTPM (°C)	39.2 ± 0.2^{a}	39.1 ± 0.3^{b}	39.0 ± 0.3^{cd}	38.9 ± 0.4^{c}	38.9 ± 0.4^{c}	39.1 ± 0.4^{bd}
	VT (°C)	39.4 ± 0.3^{a}	39.5 ± 0.5^{bc}	39.5 ± 0.4^{c}	39.5 ± 0.3^{d}	39.5 ± 0.4^{d}	39.5 ± 0.5^{b}
2-4 n = 100	RTAM (°C)	39.0 ± 0.4^{a}	38.8 ± 0.5^{b}	38.7 ± 0.4^{c}	38.6 ± 0.4^{d}	38.5 ± 0.4^{d}	38.6 ± 0.4^{d}
	RTPM (°C)	39.1 ± 0.4^{a}	38.8 ± 0.4^{b}	38.7 ± 0.4^{cd}	38.7 ± 0.4^{c}	38.7 ± 0.4^{de}	38.8 ± 0.5^{e}
	VT (°C)	39.4 ± 0.5^{a}	39.4 ± 0.5^{b}	39.3 ± 0.4^{c}	39.3 ± 0.5^{c}	39.2 ± 0.5^{de}	39.3 ± 0.5^{ce}
> 4 n = 65	RTAM (°C)	39.0 ± 0.5^{a}	38.7 ± 0.4^{b}	38.4 ± 0.4^{c}	38.4 ± 0.4^{c}	38.4 ± 0.5^{c}	38.4 ± 0.4^{c}
	RTPM (°C)	39.1 ± 0.6^{a}	38.7 ± 0.3^{b}	38.5 ± 0.3^{c}	38.6 ± 0.5^{bc}	38.6 ± 0.5^{b}	38.6 ± 0.5^{bc}
	VT (°C)	39.4 ± 0.5^{a}	39.1 ± 0.4^{bc}	39.1 ± 0.4^{bc}	39.0 ± 0.4^{d}	39.0 ± 0.4^{bcd}	39.1 ± 0.5^{e}

* Study described in Figure 1 and Table 1. Vaginal temperatures were recorded continously using a vaginal temperature logger.

[abcde] Means within a row with different superscripts differ ($P < .05$; repeated measure ANOVA)

RT_{AM} = rectal temperature measured in the morning; RT_{PM} = rectal temperature measured in the evening; VT = vaginal temperature measured continuously using temperature logger (24-hour average).

Table 3: Factors influencing vaginal temperature in postpartum sows (n = 141)*

Factor	*P*	
	Univariable analysis	Repeated measure ANOVA
Day postpartum	< .01	< .01
Hour of the day	< .01	< .01
Parity	< .01	< .01
Liveborn piglets	.02	NS
Weight of piglets at day 1	< .01	NS
Weight of piglets at day 28	< .01	NS
Mean weight gain of piglets	< .01	ND
Vaginal discharge	< .01	< .01
Feed intake	< .01	< .01
General condition	< .01	< .01
Illness†	< .01	NS
PPDS treatment	< .01	< .01
Week of study	< .01	NS

* Study, statistical analysis, and PDDS treatment described in Figure 1 and Table 1.

† Illness based on the combination of general behavior, feed intake, or vaginal discharge on at least 1 day of the 6-day trial at minimum.

PPDS = postpaertum dysgalactia syndrome, ND = not done; NS = not significant (*P* > .05)

3 Additional unpublished data

3. a Serum haptoglobin and C-reactive protein concentration in relation to rectal and vaginal temperature of early postpartum sows

Abstract

Various attempts were made to improve the diagnosis of the postpartum dysgalactia syndrome in sows. A new approach was the detection of elevated concentrations of acute phase proteins **(APP)**. The objective of this study was to investigate the serum concentrations of haptoglobin **(Hp)** and C-reactive protein **(CRP)** in sows on d 7 postpartum and their relationship to body temperature. From d 1 to d 6 postpartum 199 sows were clinically examined and a blood sample was taken for measuring Hp and CRP at d 7. The median of Hp and CRP were 1.83 mg/mL (interqartile range: 1.42 to 2.13 mg/mL) and 60.0 µg/mL (interqartile range: 15.2 to 216.5 µg/mL). I did not find a correlation between Hp and CRP ($\rho = 0.11$, $P = 0.12$) nor a difference between sows categorized as ill and healthy sows in Hp concentration ($P = 0.1$) and CRP ($P = 0.34$). Sows with Hp > 2.13 mg/mL had a higher RT than sows with Hp ≤ 2.13 mg/mL ($P = 0.037$) but there was no difference in VT ($P = 0.24$). Regarding CRP, sows with CRP > 216.5 µg/mL had higher RT ($P = 0.017$) and VT ($P = 0.02$) than sows with CRP ≤ 216.5 µg/mL.

As demonstrated in this study Hp and CRP do not support the detection of early pospartum disorders in sows.

Key words: sow, acute phase protein, body temperature, postpartum dysgalactia syndrome, metritis mastitis agalactiae syndrome

1. Introduction

The postpartum dysglactia syndrome in sows **(PPDS)** is a well-known and important disease in sows after farrowing. Under field conditions the diagnosis of postpartum diseases is mainly based on clinical signs [1] such as mastitis, metritis, constipation, cystitis, anorexia, and pyrexia [2] alone or in different combinations [3].

Furniss [4] stated that the first clinical signs occured 18 to 40 h after parturition. In another study sows showed clinical signs 12 to 24 h after parturition [5]. This variation could be caused by the fact that the exact farrowing times were not recorded [4]. Various attempts were made to improve the diagnosis of this disease complex.

A promising approach was the detection of elevated concentrations of acute phase proteins **(APP)**. Acute phase proteins are a group of blood proteins that change in concentration as reaction of external and internal challenges such as infection, inflammation, surgical trauma or stress [6]. Acute phase proteins are mainly produced in the liver and regulated by pro-inflammatory cytokines [7]. Eckersall et al. [8] used a turpentine injection (dose: 8.0 mL) to stimulate a sterile inflammatory lesion in pigs. Serum C-reactive protein concentration **(CRP)** increased more than eight-fold and serum haptoglobin concentration **(Hp)** increased more than two-fold after turpentine injection. They concluded that these APPs are the best markers for the idendification of inflammatory lesions in pigs.

Serum haptoglobin concentration increased significantly from day of farrowing (0.78 mg/mL) to 3.84 mg/mL at 7 ± 2 d of lactation ($P < 0.001$) [9]. In another study the highest average concentrations of Hp (2.17 ± 0.93 mg/mL) and CRP (42.52 ± 44.34 ng/mL) were also recorded 7 d after farrowing in comparison to 1 week before and 4 weeks after farrowing [10]. The high serum concentrations of APP could be explained by physiological events during the puerperium [9]. Some of these processes are tissue damage occuring due to the increase of myometrial activity, subsequent relaxation and dilatation of the cervix and the caudal part of the birth canal during expulsion [10].

Up to date several studies about APP and relationships to infectious diseases like swine influenca virus [11, 12], porcine reproductive and respiratory syndrome virus [13] or porcine circovirus [14] were conducted. However, there is a lack of knowledge about the association of APP and postpartum diseases in sows.

Therefore the objective of this study was to investigate the association of Hp and CRP in sows on d 7 postpartum. Specifically I set out 1) to study if diseased sows have higher concentrations of Hp and CRP compared to healthy sows and 2) to determine plausible associations between Hp and CRP and vaginal and rectal temperature in the first week after farrowing, respectively.

2. Materials and methods

The study was carried out on a commercial pig farm with 1,370 sows in Brandenburg, Germany. Sows were managed according to the guidelines set by the International Cooperation and Harmonisation of Technical Requirements for Registration of Veterinary Medical Products [15]. The sows were moved to farrowing crates approximately 7 d prior to expected farrowing. The crates had a closed concrete floor in the front third with a covered and heated region for the piglets and a fully slatted floor in the back region. The sows were fed a lactation ration (energy: 13.0 MJ/kg, raw protein: 17.5%, raw fiber: 6%, raw ash: 6%, raw oil and fats: 5%) twice daily at 0600 and at 1300 h with continuous access to water from a nipple drinker. Routine management of piglets included ear notching for idendification, iron injection (1 mL Belfer® 100 mg/mL, iron (III)-hydroxid-dextran-complex, bela-pham GmbH & Co. KG, Vechta, Germany) and castration of the male piglets during the first 6 d. Sows and piglets remained in the crates until the piglets were weaned at an age of 28 d.

Every Thursday 12 ± 2 sows (including 2 ± 1 gilts) were enrolled in the study for the duration of 16 weeks. Only sows that finished farrowing and completely expulsed the placenta were included. They farrowed either on Wednesday or Thursday morning. After enrolment 10 ± 2

of these sows got a microprocessor controlled temperature logger inserted in the vagina as recently validated for cows [16, 17], dogs [18] and sows [19]. The temperature logger (Minilog 8, Vemco, Ltd., Halifax, Nova scotia, Canada, size = 92 x 20 mm, weight = 40.5 g) was attached to a modified vaginal controlled internal drug release device (CIDR-blank, InterAg, Hamilton, New Zealand). Therefore a part of the plasticframe of the CIDR was removed and the flexible part was pulled over the logger. Before use the logger was disinfected with a Povidon-Jod solution (Braunol®, B. Braun, Melsungen AG, Melsungen, Germany) and then inserted in the vagina of the standing or lying sow with the help of a tubular speculum (tubular speculum for pigs, length: 40 cm, inner diameter: 2.5 cm, Garbsen, Germany). The logger was pushed through the speculum with the help of a CIDR appilcator and positioned in front of the cervix. It remained in the vaginal cavity for 6 d after parturition and measured the vaginal temperature **(VT)** every 10 minutes. The number of live and dead born piglets and the birth weight of the litters were recorded at enrolment. Piglet mortality, medical treatment of sows and number of piglets weaned and litter weight at weaning were documented.

All clinical examinations and medical treatment of study animals were conducted by the herd manager who had a 3 year education in veterinary medicine (i.e. comparable to a bachelor degree) and the first author, a licensed veterinarian. Before initiating the study the herd manager was intensivly trained by the first author. In the first two weeks the investigations were conducted together to ensure comparable measurements. Also clinical examinations were conducted jointly every Thursday when enrolling new sows. Every sow of the study got her own data capture form which was attached above the farrowing crate. From d 1 to d 6 the study animals were clinical examined by the investigators. First, feed intake was categorized by visual check on a 3-point scale (complete, partly, none). Second, the investigators scored the general condition on a 3-point scale (healthy: sow was attentive, standing up for feeding and nursing the piglets, slightly reduced: sow seemed apathic, did not nurse the piglets;

i.e. remained lying in abdominal position although the piglets are searching and crying, but stood up for feeding, severely reduced: sow was somnolent, remained lying down, did not nurse the piglets and did not stood up for feeding). Furthermore, vaginal discharge was visually classified (purulent vaginal discharge or no purulent vaginal discharge) and the study personnel measured rectal temperature **(RT)** twice daily at 0600 and at 1400 h. On d 7 after farrowing the loggers were removed. Piglets were weighed again at weaning on d 28.

A sow was diagnosed as ill when 3 parameters of the clinical examination were abnormal (reduced general condition, reduced feed intake, vaginal discharge, and RT > 40.0 °C). Not all sows we categorized as ill in further analysis were medically treated. Instead, the herd manager treated these animals only when deemed necessary at her own discretion according standard operating procedures developed by the herd veterinarian. The treatment included a combination of enrofloxacin (Floxibac® 100 mg/mL, 5 mg per kg body weight, Chanelle Pharmaceuticals Manufacturing Ltd., Loughrea, Co Galway, Ireland) for 3 consecutive d, metamizol (Metapyrin® 500 mg/mL, 50 mg per kg body weight, Serumwerk Bernburg AG, Bernburg, Germany) for 3 consecutive d and a single injection of 10 mg dinoprost (Dinolytic, 5 mg/mL; Zoetis Deutschland GmbH, Berlin, Germany) on the first day of treatment. Sows with purulent vaginal discharge for more than 1 day, but without other overt clinical signs, received only a single injection of 10 mg dinoprost.

A blood sample was taken of each sow by puncture of the jugular vein with a disposable needle, (2.00 x 100 mm, Supra®, Vivomed GmbH, Geislingen, Germany) attached to a serum – kabevette, 7.5 mL (Kabe Labortechnik GmbH, Nümbrecht – Elsenroth, Germany) for the measurement of Hp and CRP at d 7. The blood samples were centrifuged at 6000 rpm for 10 minutes after clotting and 2 aliquots of the serum were stored at -25 °C until analysis. Serum haptoglobin concentration was analyzed using an ELISA (Sunrise reader, Tecan, Maennedorf, Switzerland) in a commercial laboratory (Synlab Berlin, Berlin, Germany). The intra- and interassay coefficients of variance (CV) were 5.3% to 6.3% and 4.1% to 5.7%. C-reactive

protein was also analyzed in a commercial laboratory (BioCheck Leipzig, Leipzig, Germany) by an ELISA (Porcine CRP Assay Kit, Tridelta Development Limited., Maynooth, County Kildare, Ireland) in the same laboratory with an intraassay CV of 6.9% and interassay CV of 9.7% for a range of 0-1500 ng/mL.

2.1. Statistical analysis

Data were recorded with Excel (Office 2010, Microsoft Deutschland GmbH, Munich, Germany) and analysed using SPSS for Windows (Version 20.0, SPSS Inc., Munich, Germany). Vaginal temperatures measured by temperature loggers that were below 38.0°C were considered artefacts and excluded from analysis. Data from vaginal temperature loggers were averaged to 1-h periods for every sow for further analysis.

Serum haptoglobin concentration and CRP were not normally distributed and therefore nonparametric statistics were used. The association between Hp and CRP and their association to mean piglet weight gain was determined using Spearman correlation (ρ). Because there is a lack of scientific information on thresholds of Hp and CRP to distinguish between healthy and sick sows the 75 percentile of Hp (2.13 mg/mL) and CRP (216.5 µg/mL) were used to discriminate between sows with low and high Hp and CRP as described before [20]. The effects of low or high Hp and CRP on BT (RT and VT separately) were tested in a repeated measure ANOVA using measuring time as repeated factor (RT: two times for 6 d leading to 12 measurements; VT: 99 hours after insertion of the logger due to limitations of the SPSS software) and Hp and CRP as fixed factor (exceeding the 75 percentile: 1 = yes and 2 = no).

The difference in Hp and CRP considering parity (1 = gilt, 2 = parity 2 to 4, 3 = > parity 4) was tested with a Kruskal-Wallis-Test. Post hoc pairwise comparisons between the 3 classes were performed with Mann-Whitney-U-tests. Furthermore, the differences of Hp and CRP considering illness (1 = at least 3 of the following clinical signs during the trial: reduced

general condition, reduced feed intake, vaginal discharge and RT > 40.0 °C and 2 = less than 3 clinical signs during the trial), feed intake (1 = partly or no feed intake at least at two times during the trial, 2 = partly or no feed intake maximal once during the trial), general behaviour (1 = slightly reduced or apathic at least three times during the trial, 2 = slightly reduced or apathic maximal two times during the trial), vaginal discharge (1 = purulent vaginal discharge at least three times during the trial or 2 = purulent vaginal discharge maximal two times during the trial) and treatment (1 = antibiotic and anti-inflammatory treatment, 2 = no antibiotic and anti-inflammatory treatment) were tested separately with a Mann-Whitney-U-test. All sows that received antibiotic and anti-inflammatory treatment (n = 8) were excluded from analysis of the factors illness, general condition, feed intake and vaginal discharge to control the influence of medical treatment on Hp and CRP.

3. Results

3.1. General outcomes

A total of 199 sows were enrolled in the study. In 156 sows a VT logger was inserted after parturition. The remaining 43 sows did not receive a temperature logger and served as a negative control group. A total of 15 sows were excluded from VT analysis because of logger losses (n = 10, 6.4%) or technical problems of the loggers (n = 5, 3.2%). These sows, however, were included in the analysis of RT. In total 34 gilts and 165 pluriparous sows were used in the study. Of these 100 and 65 sows were parity 2 to 4 and 5 to 10, respectively (mean ± SD = 3.8 ± 2.3, including gilts). Temperature loggers recorded 118,127 10-min readings of VT from 141 sows. Out of these 468 (0.4%) were below 38.0°C and excluded from analysis. Thus 19,761 hourly means of VT were calculated. Measurements were taken until 126 hours considering all 141 sows. In 121 and 81 sows the observation period was 140 hours and 139 hours after insertion, respectively. In total 19,458 hourly means of VT could be used. For further statistical analyses of VT it were only used 18,509 readings from d 1 to 6 because RT

was measured and examinations performed during this period. A total of 1,192 and 1,189 RT values were measured in the morning and in the afternoon, respectively.

A total of 18 sows (9.0%) were treated with dinoprost (n = 10, 5.0%) within the first 6 d postpartum because of vaginal discharge or with anitibiotic and anti-inflammatory drugs (n = 8, 4.0%) for 3 consecutive d as described above.

3. 2. Haptoglobin and C-reactive protein

The median Hp concentration was 1.83 mg/mL with an interqartile range **(IQR)** from 1.42 to 2.13 mg/mL (n = 199). The median CRP concentration was 60.0 µg/mL with an IQR from 15.2 to 216.5 µg/mL (n = 199). Serum haptoglobin concentration and CRP were not correlated ($\rho = 0.11$, n = 199, P = 0.12, Figure 1).

3. 3. Body temperature and APP

Day postpartum had an effect on RT of sows in the repeated measure ANOVA ($P < 0.05$). Sows with Hp > 2.13 mg/mL (i.e. 75% percentile) had higher RT than sows with Hp ≤ 2.13 mg/mL (P = 0.04, Fig 2). Sows with CRP > 216.5 µg/mL (i.e. 75% percentile) had higher RT than sows with CRP ≤ 216.5µg/mL (P = 0.02, Fig 3).

The time of measurement also had an effect on VT in the repeated measure ANOVA ($P < 0.05$). Vaginal temperatures did not differ between sows with Hp > 2.13 mg/mL and sows with Hp ≤ 2.13 mg/mL (P = 0.24, Fig. 4). Sows with CRP > 216.5 µg/mL had higher VT than sows with CRP ≤ 216.5 µg/mL (P = 0.02, Fig. 5).

3. 4. Paritiy and APP

Serum haptoglobin concentration did not differ between gilts (median = 1.92 mg/mL, IQR: 0.94 to 2.13 mg/mL, n = 34), sows of parity 2 to 4 (median = 1.88 mg/mL, IQR: 1.58 to 2.18

mg/mL, n = 100) and sows of parity greater than 4 (median = 1.77 mg/mL, IQR: 1.24 to 2.03 mg/mL, n = 65, P = 0.23, Figure 6).

C-reactive protein was higher in gilts (median = 159.5 µg/mL, IQR: from 23.8 to 395.3 µg/mL, n = 34) in comparison to sows with more than 4 parities (median = 36.5 µg/mL, IQR: 10.8 to 120.4 µg/mL, n = 65, P < 0.05). There was no difference between gilts and parity 2 to 4 sows (median = 66.7 µg/mL, IQR: 19.2 to 203.8 µg/mL, n = 100, P = 0.21) and paritiy 2 to 4 and older sows (P = 0.06, Figure 7).

3. 5. Clinical parameters and APP

Concentrations of Hp and CRP did not differ between sows categorized as ill (at least 3 of the following clinical signs on a single d: reduced general condition, reduced feed intake, vaginal discharge and RT >40.0 °C, Hp: median = 1.92 mg/mL, IQR: 1.50 mg/mL to 2.22 mg/mL, n = 62 and CRP: median 70.9 µg/mL, IQR: 14.7 to 257.6 µg/mL, n = 62) in comparison to healthy sows (Hp: median = 1.80 mg/ mL, IQR: 1.37 to 2.07 mg/ mL, n = 129, P = 0.1, CRP: median = 53.3 µg/mL, IQR: 15.2 to 195.0 µg/mL, n = 129, P = 0.34).

A reduced feed intake during the trial was not associated with higher Hp (median = 2.06 mg/mL, IQR: 1.42 to 2.30 mg/mL, n = 42) and CRP (median = 59.6 µg/mL, IQR: 14.7 to 275.3 µg/mL, n = 42) in comparison to sows with normal feed intake (Hp: median = 1.80, IQR: 1.38 to 2.05 mg/mL, n = 149, P = 0.07, CRP: median = 56.5 µg/mL, IQR: 15.2 to 195.0 µg/mL, n = 149, P = 0.49).

Furthermore, we did not find any association between a reduced general behavior and Hp (P = 0.39) or CRP (P = 0.62). Study animals with reduced general behavior at least three times had a median Hp of 1.92 mg/mL (IQR: 1.37 to 2.14 mg/mL, n = 41) and a median CRP of 42.3 µg/mL (IQR: 13.3 to 257.6 µg/mL, n = 41). Sows with normal general condition had a

median Hp of 1.82 mg/mL (IQR: 1.42 to 2.11 mg/mL, n = 150) and a median CRP of 58.0 µg/mL (IQR: 15.4 to 195.0 µg/mL, n = 150).

There was no difference between sows with and without vaginal discharge in the first 6 d postpartum in Hp (P = 0.05) and CRP (P = 0.23) concentrations. Sows with purulent vaginal discharge for at least three times had a median Hp of 2.02 mg/mL (IQR: 1.61 to 2.31 mg/mL, n = 35) and a median CRP of 27.5 µg/mL (IQR: 12.0 to 163.1 µg/mL, n = 35) in comparison to sows that showed purulent vaginal discharge twice or less (Hp: median = 1.82 mg/mL, IQR: 1.36 to 2.08 mg/mL, n = 156, CRP: median = 59.7 µg/mL, IQR: 16.0 to 227.6 µg/mL, n = 156).

Sows that received antibiotic and anti-inflammatory treatment during the trial did not differ in Hp (median = 2.07 mg/mL, IQR: 1.85 to 2.44 mg/mL, n = 8) or CRP (median = 180.8 µg/mL, IQR: 65.3 to 270.8 µg/mL, n = 8) from untreated sows (Hp: median = 1.83 mg/mL, IQR: 1.38 to 2.11 mg/mL, n = 191; *P* = 0.09; CRP: median = 56.5 µg/mL, IQR: 14.7 to 206.7 µg/mL, n = 191; P = 0.21).

3. 6. Piglet weight gain and APP

The mean piglet weight at d 1 was 1.5 kg ± 0.25 kg and 7.7 kg ± 0.73 kg at d 28 leading to a mean weigt gain per piglet of 6.3 kg ± 0.7 kg. A correlation between the mean weight gain per piglet until weaning and Hp (ρ = 0.04, n= 185, P = 0.63) or CRP (ρ = 0.004, n= 185, P = 0.96) at d 7 postpartum did not exist.

4. Discussion

This is the first study which examined the association of Hp and CRP and RT, VT and clinical parameters (i.e. general condition, feed intake, and vaginal discharge) in postpartum sows. In contrast to my hypothesis Hp and CRP were not correlated (Figure 1). This aspect has not

been examinated in recent studies. C-reactive protein is considered as major APP in pigs whereas Hp is classified as moderate APP. Major APP have a low serum concentration (< 1 µ/L) in healthy animals, rise 100 to 1000–fold on stimulation and decline rapidly during recovery phase. Moderate APP increase 5 to 10-fold on activation and decrease more slowly than major APP [21]. Based on the results, it can be speculated that the production of CRP and Hp might be regulated differently depending on the causing inflammation, infection or trauma.

Furthermore the results of this study show that sows with a higher RT (Figure 3) and VT (Figure 5) had higher CRP concentrations. It remains unclear why there was a relationship between Hp and RT (Figure 2) but not with VT (Figure 4).

In one study first parity sows had higher Hp than sows in greater parities [9] while in another study increase of Hp with age of the sow was demonstrated [22]. We did not find differences of Hp between sows of different parities (P = 0.23, Figure 6). Only C-reactive protein differed between gilts and sows with more than 4 parities (P = 0.01, Figure 7). The type of animals used in the studies might help to explain these discrepancies. Verheyen et al. (2007) enrolled only clinically healthy sows on various stages of production and Petersen et al. (2002) used finishing pigs. In our study sows 1 to 6 d postpartum (i.e. sick and healthy) were utilized. We therefore hypothesize that the parity influences Hp and CRP less than other factors (e.g. specific infections such as influenca or PRRS).

The data of the present study do not provide evidence that a reduced general health status or a reduced feed intake lead to an increase in Hp or CRP in sows postpartum. Additionally, there was no difference between sows with and without vaginal discharge. This is in accordance to the study of Oravainen et al. [23] in which Hp and CRP in sows with and without vulvar discharge syndrom (**VDS**) was determined and did not differ (P = 0.6).

Kostro et al. [24] studied the concentration of CRP in sows after parturition. In their study the concentration of CRP steadily decreased in sows treated for PPDS in comparison to non-

treated sows. In contrast, Hp and CRP did not differ between treated and untreated sows in this study. However, only 8 sows were treated in this study which potentially limits the validity of this finding.

5. Conclusions

The concentrations of haptoglobin and C-reactive protein do not support the detection of early pospartum disorders in sows. Further research is warrantd to improve the diagnosis of postpartum dysglactia syndrom in sows.

References

[1] Kemper N and Gerjets I. Bacteria in milk from anterior and posterior mammary glands in sows affected and unaffected by postpartum dysgalactia syndrome (PPDS). Acta Vet Scand 2009;51.

[2] Hirsch AC, Philipp H and Kleemann R. Investigation on the effiacacy of meloxicam in sows with mastitis-metritis-agalactia syndrom. J Vet Pharmacol Ther 2003;26:355-60.

[3] Bostedt H, Maier G, Herfen K and Hospes R. Klinische Erhebungen bei Sauen mit puerperaler Septikämie und Toxämie. Tierärztl. Prax 1998;26:332-8.

[4] Furniss SJ. Measurement of rectal temperature to predict mastitis, metritis and agalactia (MMA) in sows after farrowing. Prev Vet Med 1987;5:133-9.

[5] Gooneratne AD, Hartmann PE and Nottage HM, The initiation of lactation in sows and the mastitis-metritis-agalactia syndrom. Anim Reprod Sci 1982;5:135-40.

[6] Murata H, Shimada N and Yoshioka M. Current research on acute phase proteins in veterinary diagnosis: an overview. Vet J 2004;168:28-40.

[7] Baumann H and Gauldie J. The acute phase response. Immunol Today 1994;15:74-80

[8] Eckersall PD, Saini PK and McComb C. The acute phase response of acid soluble glycoprotein, α1-acid glycoprotein, ceruloplasmin, haptoglobin and C-reactive protein in the pig. Vet Immunol Immunop 1996;51:377-85.

[9] Verheyen AJM, Maes DGD, Mateusen B, Deprez P, Janssens GPJ, Lange Ld et al. Serum biochemical reference values for gestating and lactating sows. Vet J 2007;174:92-8.

[10] Kovac G, Tothova CS, Nagy O and Seidel H. Acute phase proteins during the reproductive cycle of sows. Acta Vet-Beograd 2008;58:459-66.

[11] Pomorska-Mól M, Markowska-Daniel I and Pejsak Z. Acute phase protein response during subclinical infection of pig with H1N1 swine influenza virus. Vet Microbiol 2012;159:499-503.

[12] Barbé F, Atanasova K and Van Reeth K. Cytokines and acute phase proteins associated with acute swine influenza virus in pigs. Vet J 2011;187:48-53.

[13] Gómez-Laguna J, Gutiérrez A, Pallarés FJ, Salguero FJ, Céron JJ and Carrasco L. Haptoglobin and C-reactive protein as biomarkers in the serum, saliva and meat juice of pigs experimentally infected with porcine reproductive and respiratory syndrome virus. Vet J 2010;185:83-7.

[14] Grau-Roma L, Heegard PMH, Hjulsager CK, Sibila M, Kristensen CS, Allepuz A et al. Pig major acute phase protein and haptoglobin serum concentrations correlate with PCV2 viremia and the clinical course of postweaning multisystemic wasting syndrome. Vet Microbiol 2009;138:53-61

[15] Hellmann K and Radeloff I. International Cooperation on Harmonisation of Technical Requirements for registration of Veterinary Medical Products (VICH), Brussels/ Belgium: VICH, 2000.

[16] Vickers LA, Burfeind O, von Keyserlingk MAG, Veira DM, Weary DM and Heuwieser W. Technical note: Comparison of rectal and vaginal temperature in lactating dairy cows. J Dairy Sci 2010;93:5246-52.

[17] Suthar V, Burfeind O, Maeder B and Heuwieser W. Agreement between rectal and vaginal temperature measured with vaginal temperature loggers in dairy cows. Journal of Dairy Research 2013;80:240-5.

[18] Maeder B, Arlt S, Burfeind O and Heuwieser W. Continous vaginal temperature measurement in bitches before parturition. Reprod Biol 2013;13, Supplement 2:31-2.

[19] Stiehler T, Heuwieser W, Pfützner A, Voigtsberger R, Burfeind O, Repeatability of measures of the rectal temperautre and comparison of vaginal and rectal temperature in puerperal sows. Tierärztl Prax GN 2013;41:217-24.

[20] Altes A, Remacha AF, Sarda P, Baiget M, Sureda A, Martino R et al. Early clinical impact of iron overload in stem cell transpantation. A prospective study. Annals of Hematology 2007;86:443-7.

[21] Eckersall PD and Bell R. Acute phase proteins: Biomarkers of infection and inflammation in veterinary medicine. Vet J 2010;185:23-7.

[22] Petersen HH, Ersbøll AK, Jensen CS and Nielsen JP. Serum-haptoglobin concentration in Danish slaughter pigs of different health status. Prev Vet Med 2002;54:325-35.

[23] Oravainen J, Heinonen M, Seppä-Lassila L, Orro T, Tast A, Virolainen JV et al. Factors Affecting Fertility in Loosely Housed Sows and Gilts: Vulvar Discharge Syndrome, Environment and Acute-phase Proteins, Reprod Domest Anim 2006;41:549-54.

[24] Kostro K, Wawron W, Szczubial M, Luft-Deptula D and Glinski Z. C-reactive protein in monitoring and evaluation of effects of therapy of the MMA syndrome of sows. Pol J Vet. Sci 2003;6:235-8.

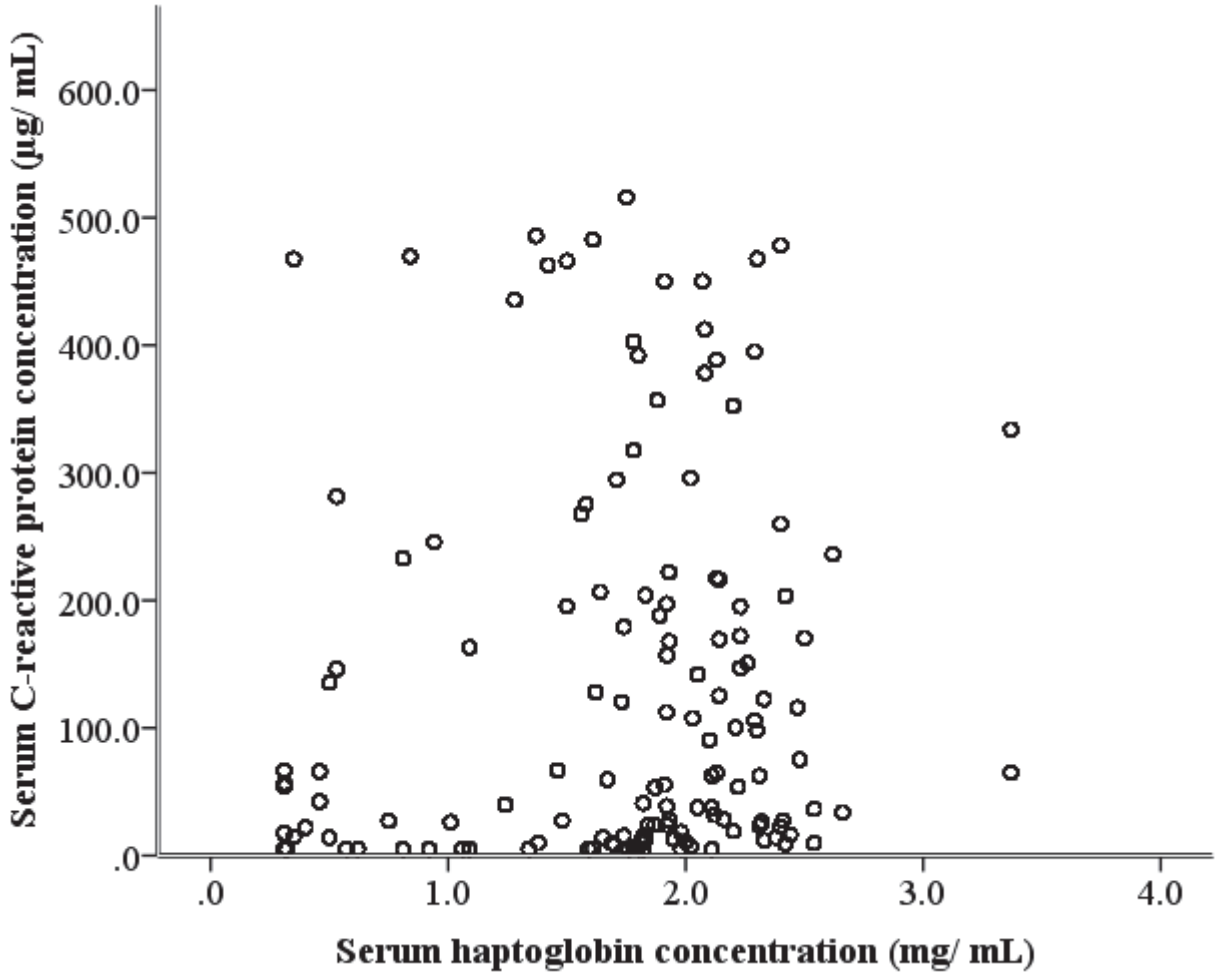

Figure 1. Scatter plot of serum haptoglobin concentration (mg/mL) and C-reactive protein concentration (µg/mL) in sows at d 7 postpartum (n = 199)

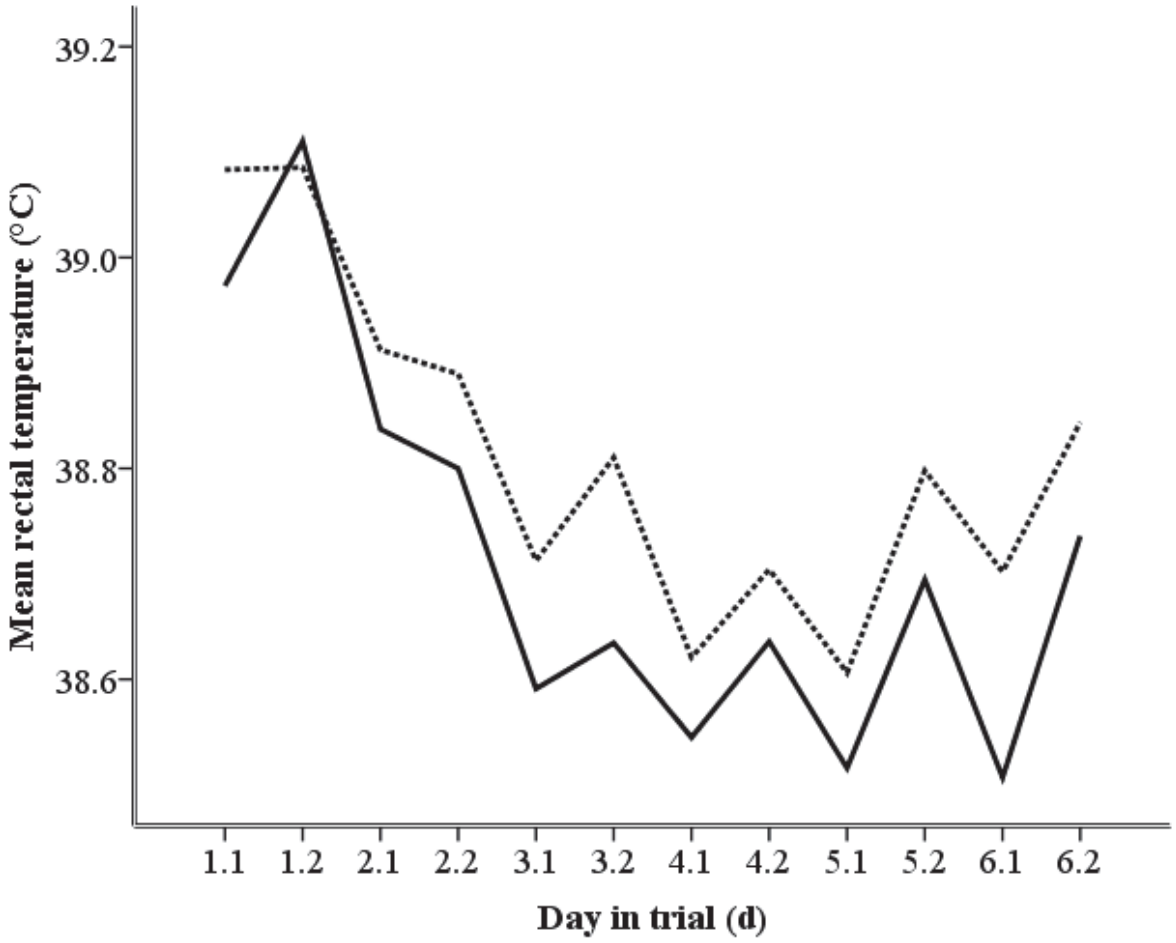

Figure 2. Mean rectal temperature (°C) in sows with serum haptoglobin concentration ≤ 2.13 mg/mL (——— continous line, n = 149) and > 2.13 mg/mL (····· dotted line, n = 50) from d 1 to 6 postpartum in the morning (.1) and in the afternoon (.2).

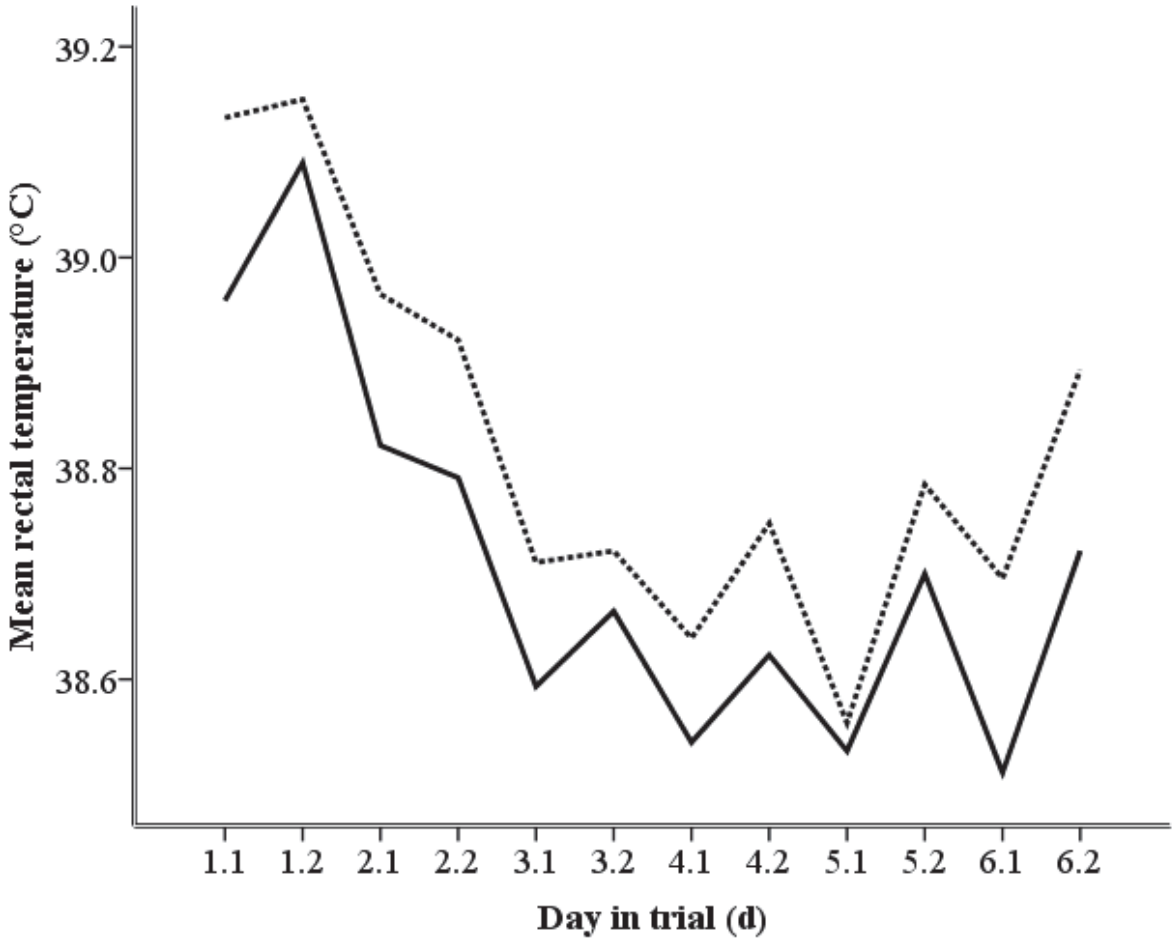

Figure 3. Mean rectal temperature (°C) in sows with serum C-reactive protein concentration ≤ 216.5 µg/mL (—— continous line, n = 151) and > 216.5 µg/mL (····· dotted line, n = 48) from d 1 to 6 postpartum in the morning (.1) and in the afternoon (.2)

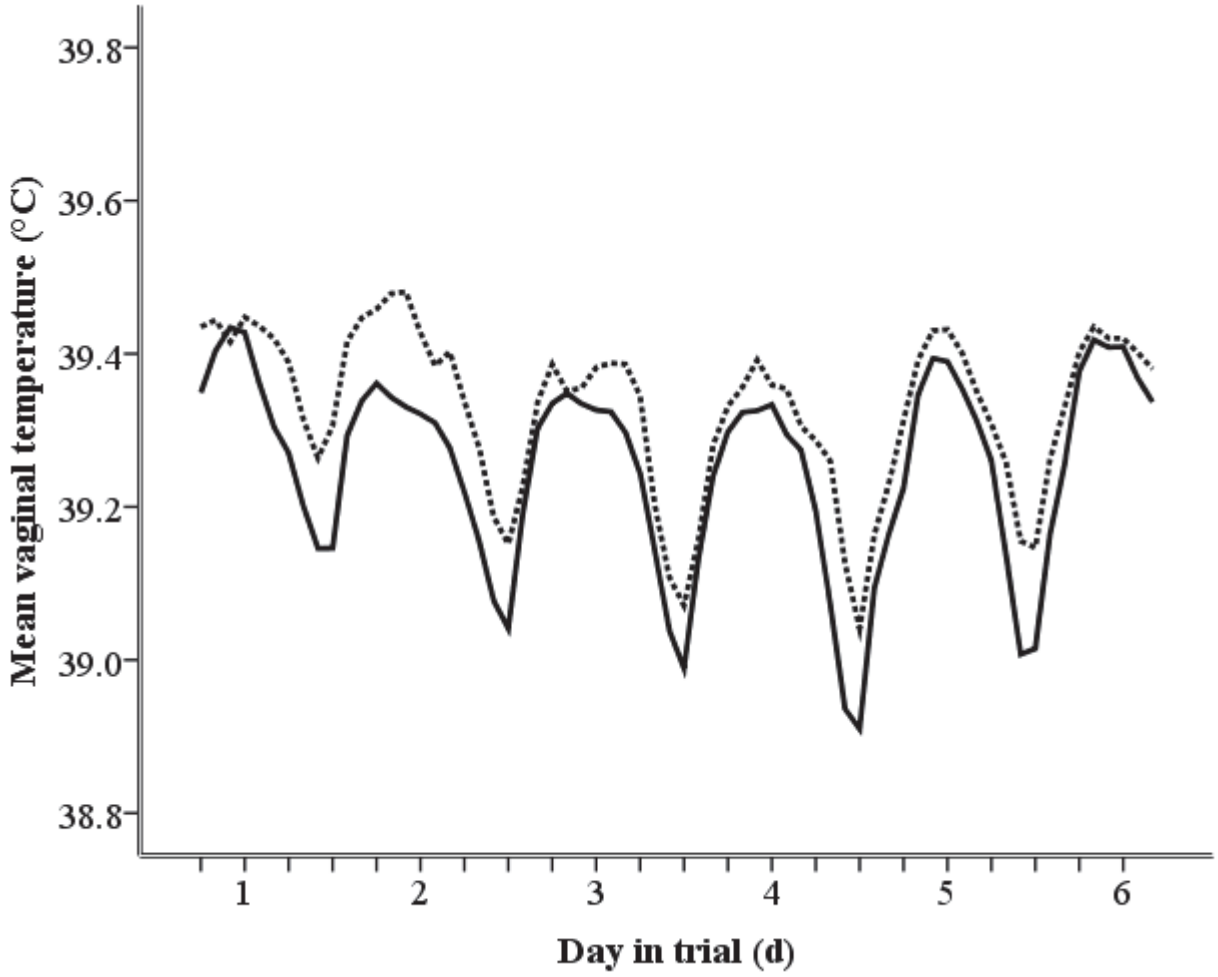

Figure 4. Mean vaginal temperature (°C) in sows with serum haptoglobin concentration ≤ 2.13 mg/mL (—— continous line, n = 99) and > 2.13 mg/mL (⋯⋯ dotted line, n = 42) from d 1 to 6 postpartum.

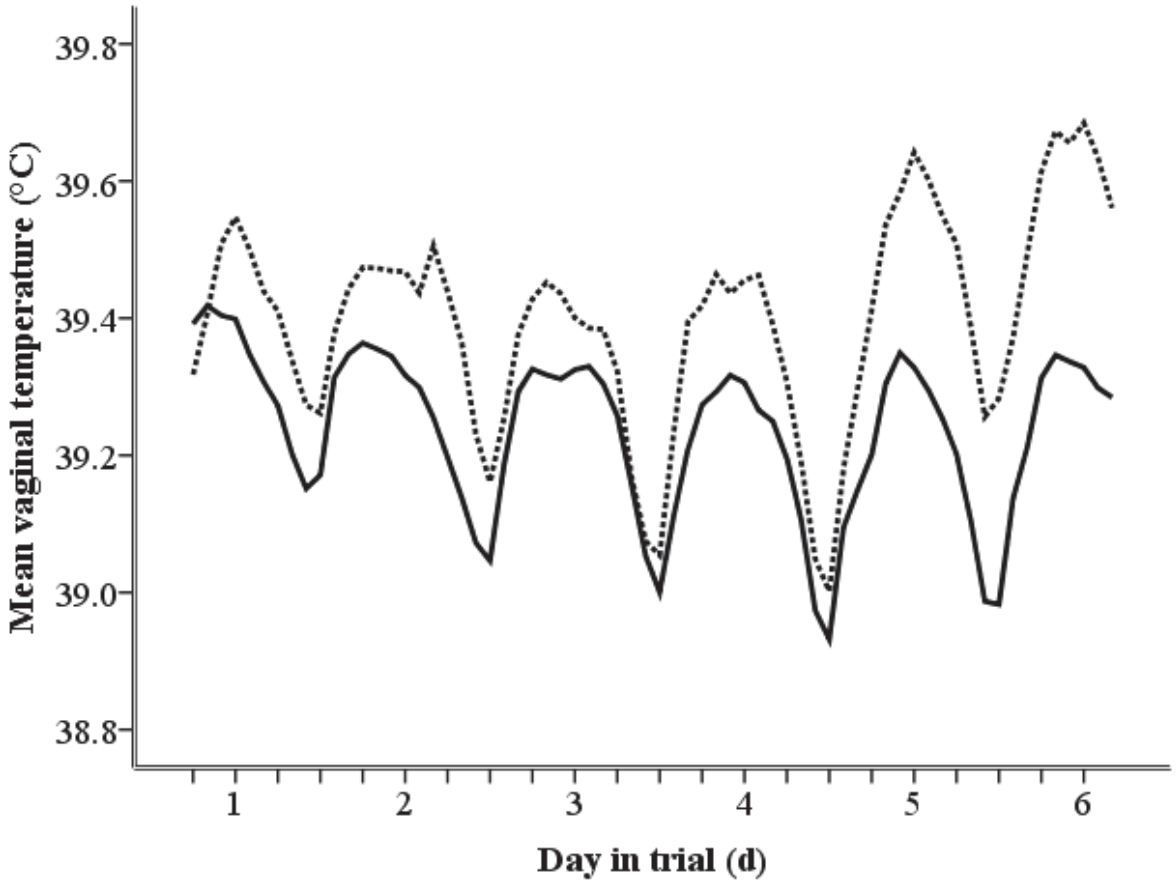

Figure 5. Mean vaginal temperature (°C) in sows with serum C-reactive protein concentration ≤ 216.5 µg/mL (—— continous line, n = 109) and > 216.5 µg/mL (⋯⋯ dottet line n = 32) from d 1 to 6 postpartum.

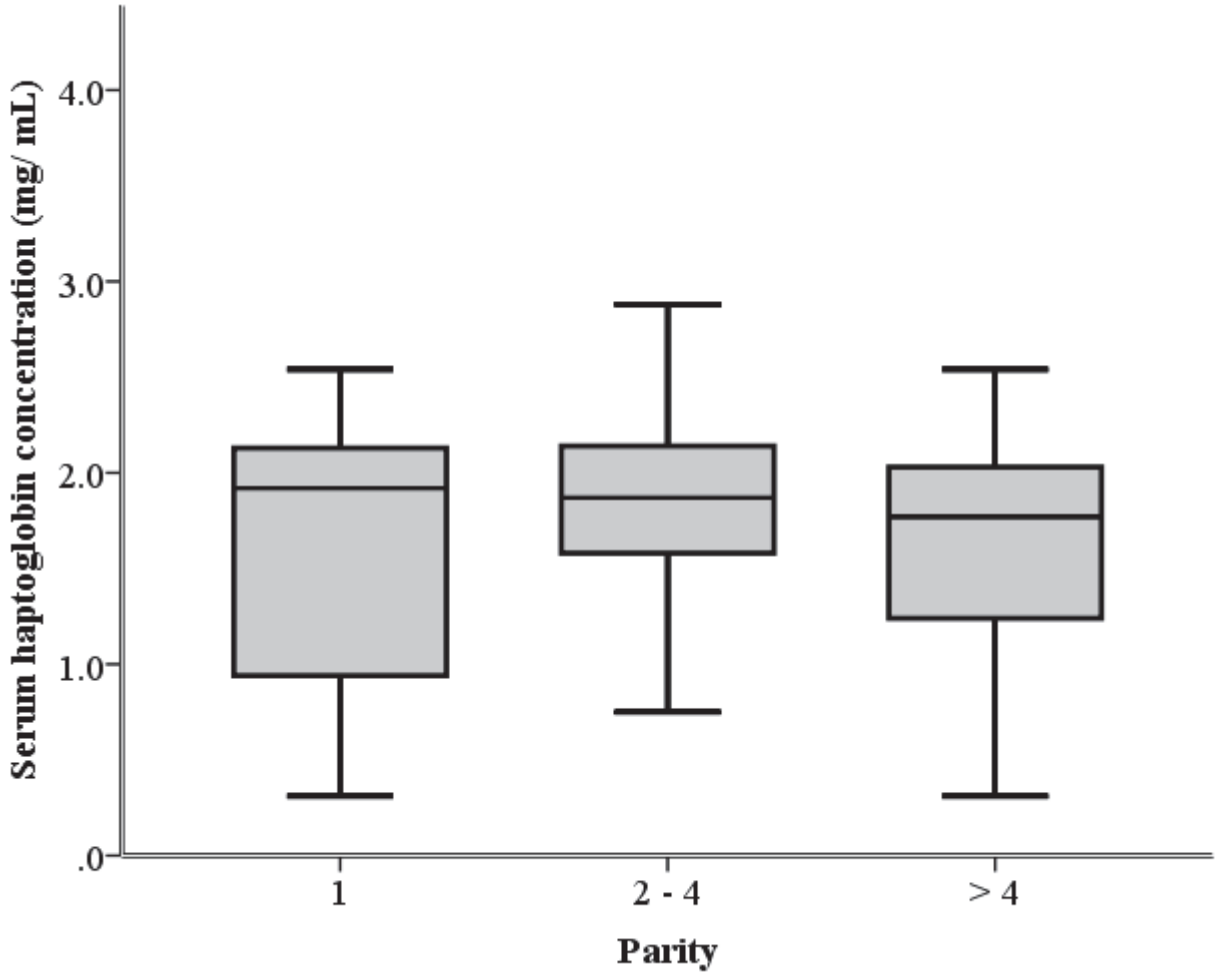

Figure 6. Serum haptoglobin concentration (mg/mL) on d 7 postpartum of sows at different parities (parity 1: n = 34, paritiy 2 to 4: n=100, > paritiy 4: n = 65)

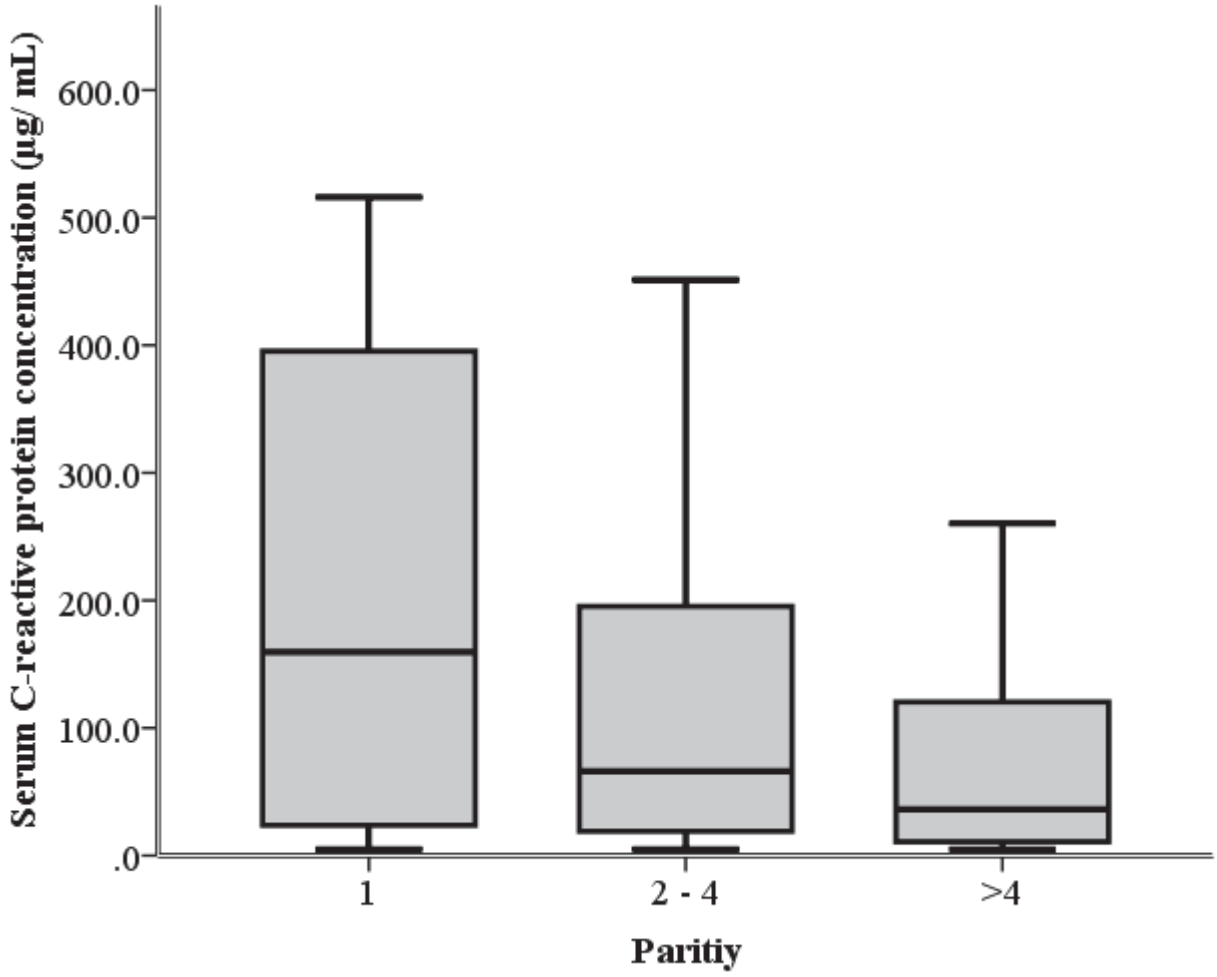

Figure 7. Serum C-reactive protein concentration (µg/mL) on d 7 postpartum of sows at different parities (parity 1: n = 34, paritiy 2 to 4: n=100, > paritiy 4: n = 65)

4 Discussion

Measuring rectal temperature is a common method for the diagnosis of sick sows postpartum and for the decision to implement medical treatment (Gerjets and Kemper, 2009; Hoy, 2002). The results of my first study demonstrate that measuring rectal temperature is a repeatable diagnostic method in sows. Differences between thermometers and examinators were minimal and negligible. The insertion depth of the thermomter did influence the measured results and should be standardized. There is a lack of studies about the diagnostic relevance of a single measurement and the frequency of false positive results (sow is diagnosed as sick but is actually healthy).

Furthermore the first trial illustrated that a vaginal temperature logger in early postpartum sows is a valid method for continously measuring of body temperature. In former studies temperature sensors for measuring body temperature were often inserted by invasive procedures under general anesthesia, e.g. in the near of the the carotid artery (Ingram and Mount, 1973), pulmonary artery, urinary bladder, rectal and femoral artery (Hanneman et al., 2004) and animals were kept under laboratory conditions (Hanneman et al., 2005; Schmidt et al., 2013). In my study I used temperature loggers inserted into the vagina which allowed to continuously record vaginal temperature under field conditions as recently validated for cows and dogs (Maeder et al., 2013; Vickers et al., 2010). The logger was attached to a modified vaginal controlled internal drug release device and could not slide out as described in other studies (Schmidt et al., 2013). The loggers were inserted without anaesthesia and the sows showed a good acceptance to the loggers.

It must be considered that vaginal temperature is 0.4 °C higher than rectal temperature. There were no difference between rectal and vaginal temperature in a previous study, but the measurement was not performed simultanously (Vickers et al., 2010). In another study the vaginal temperature was 0.2 °C ± 0.2 °C (Suthar et al., 2012) or 0.01 ± 0.1 °C (Suthar et al.,

2013) higher than rectal temperature in cows. A possible reason for higher vaginal temperature is that the logger is placed more cranial than the sensor of a rectal thermometer. Also faeces in the rectum or a poor contact to the wall of the rectum can cause lower temperatures. The second study proves that the loggers can be inserted for the duration of 6 days in sows. Insertion of a vaginal temperature logger affected rectal temperature ($P < 0.01$). This might be explained as a physiologic reaction of the organism to a foreign body. Assesing the fertility, from 151 sows with vaginal temperature logger 146 sows got pregnant after one insemination (96,7%) and 5 sows after a second insemination. From 40 sows without logger 39 sows (97,5%) were pregnant after one insemination and 1 sow after the second insemination. Therefore, the logger had no effect on fertility after weaning ($P = 1.0$).

Vaginal temperature showed a prominent circadian rhythm with the lowest temperature in the morning from 05:00 h to 06:00 h and the highest temperature in the afternoon from 13:00 h to 19:00 h. The vaginal temperature increased parallel to activities in the farrowing pen and reached highest values from 15:00 h to 19:00 h. At 15:00 h the work in the farrowing pen was finished and I hypothesize that the vaginal temperature decreased parallel to the activity of the sows. This corresponds to previous study which stated that the rhythm of body temperature appears to be masked by feeding or activity in pigs (Ingram and Dauncey, 1985). Bekkering and Hoy (2007) also found a circadian rhythm for the ear temperature with a minimum between 05:00 and 06:00 h and a maximum between 16:00 and 18:00 h in boars. When ambient temperature increased by 5 °C the skin temperature also increased by 3 to 5 °C. In our second study, 59 and 17 of 199 sows had a rectal temperature above 39.5°C and above 40.0°C, respectively and 57 sows had a vaginal temperature above 40.3°C. Only 8 of these sows received antibiotic and anti-inflammatory treatment. Recent studies have already shown that postfarrowing body temperature in sows is higher than prefarrowing body temperature (Elmore et al., 1979). In that study body temperature rose 1°C 12 to 15 hours prior to the birth of the first piglets and stayed high during the lactation period until the piglets were weaned.

King et al. (1972) also demonstrated a significant increase of body temperature coinciding with parturition. High body temperature in clinically normal sow should not be considered as evidence of disease (King et al., 1972). In my study general behavior, feed intake and vaginal discharge had a significant influence on rectal and vaginal temperature ($P < 0.01$). Furthermore, gilts had higher rectal and vaginal temperature from day 1 to 6 than older sows. This result is similar with previous findings in cows (Burfeind et al., 2014; Suthar et al., 2012), but has not been described for sows yet. The number of liveborn piglets, mean weight of piglet at day 1, the mean weight gain and the mean weight on day 28 did not influence rectal and vaginal temperature. These findings are similar to the results of other studies (van Gelder and Bilkei, 2005). Clinical signs such as general behaviour, feed intake and vaginal discharge did increase body temperature in sows. I therefore conclude that body temperature is only one symptom of the PPDS complex and the diagnostic value of additional clinical signs should be further evaluated considering their subjective nature.

In recent studies, cows with haptoglobin ≤ 1.1g/L were defined as healthy independently from body temperature (Burfeind et al., 2012). I hypothesised that it is also possible for sows. Therefore, haptoglobin and C-reactive protein were measured in a second part of the study. This was the first study which investigated the association of haptoglobin and C-reactive protein as well as the relationship to rectal temperature, vaginal temperature and clinical parameters like general condition, feed intake and vaginal discharge. In contrast to my hypothesis haptoglobin and C-reactive protein were not correlated ($\rho = 0.11$, $n = 199$, $P = 0.12$). C-reactive protein is necessary for protection against infection, degeneration of damaged tissue and regulation of inflammatory response (Mold et al., 2002) whereas haptoglobin binds free haemoglobin which is toxic and pro-inflammatory (Wagener et al., 2001) in plasma and reduces oxidative damage connected with haemolysis (Yang et al., 2003). I conclude that C-reactive protein and haptoglobin might react differently in various diseases. Furthermore, the results of this study show that sows with a higher rectal and

vaginal temperature had higher values of C-reactive protein. Regarding haptoglobin there was a relationship to rectal temperature but not to vaginal temperature. Therefore, I speculate that C-reactive protein is a more sensitive parameter than haptoglobin in postpartum sows. In this study there was no evidence that a reduced general health status or a reduced feed intake lead to an increase in Haptoglobin or C-reactive protein in sows postpartum. In contrast to these findings, other authors stated that measurements of serum concentrations of acute phase proteins might be useful for monitoring of postpartum diseases in sows (van Gelder and Bilkei, 2005). Serum haptoglobin concentration and C-reactive protein did not differ between sows with and without vaginal discharge syndrome ($P = 0.6$). This is in accordance to the findings of Oravainen et al. (2006) who showed that the vaginal discharge syndrome did not cause systemic acute phase response as indicated by stable concentrations of haptoglobin and C-reactive protein.

Kostro et al. (2003) suggested that elevated concentration of C-reactive protein in sows at the early stage of PPDS reflected the inflammation in the reproductive tract and in the mammary gland. They postulated that measuring C-reactive protein is a possibiltiy for early diagnosis and initiating therapy when clinically symptomes are still absent. In the treated sows the concentrations of C-reactive protein steadily decreased and by the end of the experiment had returned to initial values. In the non-treated sows C-reactive protein persisted at a high level. In contrast to this, haptoglobin and C-reactive protein did not differ between treated and untreated sows in my study. However, only 8 sows were treated which potentially limits the validity of this finding. As demonstrated in this study haptoglobin and C-reactive protein did not have any predictive value for the identification of early pospartum disorders. Summing up, further research is necessary to improve the diagnosis of PPDS in sows.

In coclusion it can be stated that the measurement of rectal temperature in sows is a repeatable and objective method. The measuring procedure should be standardized and conducted regularly at the same time of the day with a similar insertion depth to reduce bias. The use of

vaginal temperature loggers is a practicable method for studying body temperature in the first days postpartum in research settings. Furthermore, body temperature should not be used as single criterium for the decision of giving medical treatment to early postpartum sows. However, I emphasize that the validity and diagnostic values of other signs is unclear and needs to be determined. Simple statements that signs such as apathy, inappetence and mastitis should be part of the diagnostic procedure are not backed up by science-based evidence. The concentrations of haptoglobin and C-reactive protein do not support the detection of early pospartum disorders in sows.

5 Summary

Postpartum diseases belong to the economical most important diseases of sows. They affect animal health and welfare of sows and piglets. Fast diagnosis and effective medical treatment are necessary to prevent economical losses. Routine measurement of rectal temperature postpartum is an often advised and used diagnostic method for early detection of infectious diseases in sows. The first study was conducted on a commercial pig farm with 1,370 sows in Brandenburg in June 2011. The primary objective was to evaluate the influence of different factors on measures of rectal temperatures (e.g. investigator, thermometer, penetration depth of the thermometer). Thirty sows were used in this experiment. The data showed that rectal temperature can be measured repeatably (mean ± standard deviation = 38.7 ± 0.1°C, Coefficient of variation = 0.2%). Different investigators or thermometers measured low differences (0.0°C and 0.1°C). The penetration depth of the thermometer can influence the result (difference of 0.4°C at 5 and 10 cm). The secondary objective was to validate the application of a temperature logger to continuously measure vaginal temperature. Rectal and vaginal temperatures measured in 21 sows were highly correlated (r = 0.80, $P<0.01$) with a mean difference of 0.3°C. The data show that temperature loggers inserted in the vagina can provide a reasonable measure of body temperature in early puerperal sows. The objective of a subsequent study was to monitor vaginal temperature via loggers in sows for a longer duration to investigate the course of the body temperature in early postpartum sows and identify possible factors that may influence body temperature. The study was conducted on the same commercial pig farm from January to May 2013. A total of 156 sows received a vaginal temperature logger for 6 days postpartum and 43 sows remained without logger as negative control group. Vaginal temperature was measured continuously every 10 min. During the trial rectal temperature, feed intake, general condition and vaginal discharge were evaluated and noticed daily. The sows showed a clear circadian rhythm of vaginal temperature with minimal temperatures of 39.0 ± 0.5°C from 5:00 h to 6:00 h and maximum temperatures of 39.4 ±

0.5°C from 13:00 h to 19:00 h ($P < 0.05$). The day postpartum ($P < 0.01$), time of day ($P < 0.01$), age ($P < 0.01$), general condition ($P < 0.01$), vaginal discharge ($P < 0.01$) and medical treatment ($P < 0.01$) had an effect on rectal and vaginal temperature. The measurement of vaginal temperature with a temperature logger in early postpartum sows provides continuous and non-invasive monitoring of body temperature. A high percentage of sows (40.4%) had a vaginal temperature over 40.3°C in the first 6 days postpartum but only 12% of these sows were treated with antibiotics. The second part of the study was the investigation of two acute phase proteins in sows postpartum and the relationship to body temperature. Blood sample from 199 sows were collected at d 7 and the serum concentration of haptoglobin and C-reactive protein determined. The median of haptoglobin and C-reactive protein were 1.83 mg/mL (interqartile range: 1.42 to 2.13 mg/mL) and 60.0 µg/mL (interqartile range: 15.2 to 216.5 µg/mL). There was no correlation between Haptoglobin and C-reactive protein ($\rho = 0.11$, $P = 0.12$) nor a difference between sows categorized as ill and healthy sows in Haptoglobin ($P = 0.1$) and C-reactive protein concentration ($P = 0.34$). Sows with Haptoglobin > 2.13 mg/mL had higher rectal temperatures than sows with Haptoglobin ≤ 2.13 mg/mL ($P = 0.037$) but there was no difference in vaginal temperatures ($P = 0.24$). Sows with C-reactive protein > 216.5 µg/mL had higher rectal ($P = 0.017$) and vaginal temperature ($P = 0.02$) than sows with C-reactive protein ≤ 216.5 µg/mL. As demonstrated in this study haptoglobin and C-reactive protein do not support the detection of early postpartum disorders in sows. Summing up, further research is necessary to improve the diagnosis of PPDS in sows.

6 Zusammenfassung

Rektale und vaginale Körpertemperatur von Sauen im Frühpuerperium und deren Zusammenhang mit der Serumkonzentration von Akut Phase Proteinen

Postpartale Erkankungen bei Sauen haben in der Schweineproduktion eine große medizinische und wirtschaftliche Bedeutung. Beeinflusst werden nicht nur die Leistung und das Wohlbefinden des Muttertieres, sondern auch die Gesundheit und Entwicklung der Ferkel. Eine schnelle Diagnose und die sofortige Einleitung effektiver therapeutischer Maßnahmen sind notwendig, um wirtschaftliche Schäden zu minimieren. Die regelmäßige rektale Temperaturmessung post partum zur Früherkennung infektiöser Erkrankungen ist bei Sauen eine häufig empfohlenes und angewendetes diagnostisches Kriterium. Die erste Studie wurde in einer Sauenzuchtanlage in Brandenburg durchgeführt. Der Bestand umfasste 1.370 Sauen. Ziel dieser Studie war die Untersuchung der Wiederholbarkeit der rektalen Temperaturmessung sowie der Einfluss verschiedener Faktoren (z.B. Untersucher, Art des Thermometers oder Messtiefe) auf das Messergebnis. Für dieses Experiment wurden 30 Sauen verwendet. Die Daten zeigen, dass die Messung der rektalen Körpertemperatur wiederholbar ist (Mittelwert ± Standardabweichung = 38,7 ± 0,1°C, Variationskoeffizient = 0,2%). Zwischen verschiedenen Untersuchern und Thermometern wurden nur geringe Unterschiede gemessen (0,0 bzw. 0,1°C). Die Eindringtiefe des Messfühlers (5 versus 10cm) hatte einen Einfluss auf das Messergebnis (Differenz von 0,4°C). Ein zweites Ziel der Studie war die Validierung eines Temperaturloggers zur Messung der vaginalen Temperatur bei der Sau postpartum. Hierfür wurden 21 Sauen verwendet. Rektale und vaginale Temperatur zeigten eine hohe Korrelation ($r = 0,80$, $p<0,01$) bei einer mittleren Abweichung von 0,3°C. Die Messung der vaginalen Temperatur mit einem Temperaturlogger ist somit eine Möglichkeit zur kontinuierlichen und nicht-invasiven Überwachung der Körpertemperatur bei

Sauen im Frühpuerperium. Nach dieser ersten Validierungsstudie war es das nächste Ziel, den Temperaturlogger für mehrere Tage bei Sauen einzulegen, um den Verlauf der Körpertemperatur kontinuierlich zu erfassen und mögliche Einflussfaktoren zu untersuchen. Diese Studie wurde im gleichen Sauenbestand von Januar bis Mai 2013 durchgeführt. Insgesamt wurde 156 Sauen ein Temperaturlogger für eine Dauer von sechs Tagen vaginal eingelegt. Insgesamt bekamen 43 Sauen keinen Temperaturlogger und bildeten somit die negative Kontrollgruppe. Die Vaginaltemperatur wurde kontinuierlich alle 10 Minuten gemessen. Während der Versuchszeit wurde die Rektaltemperatur zweimal täglich gemessen. Zusätzlich wurden das Allgemeinbefinden, die Futteraufnahme und das mögliche Vorhandensein von pathogenem Vaginalausfluss täglich evaluiert und schriftlich dokumentiert. Die Sauen zeigten einen deutlichen circadianen Rhythmus der Körpertemperatur mit Minimalwerten von 39,0 ± 0,5°C zwischen 05:00 Uhr und 06:00 Uhr sowie Maximalwerten von 39,4 ± 0,5°C zwischen 13:00 Uhr und 19:00 Uhr ($P < 0,05$). Der Tag postpartum ($P < 0,01$), die Tageszeit ($P < 0,01$), die Parität ($P < 0,01$), das Allgemeinbefinden ($P < 0,01$), das Vorhandensein von pathogenem Vaginalausfluss ($P < 0,01$) und eine medikamentelle Therapie ($P < 0,01$) hatten einen Einfluss sowohl auf die rektale als auch auf die vaginale Temperatur. Die Messung der Vaginaltemperatur mit Hilfe eines vaginal eingelegten Temperaturloggers ermöglicht eine kontinuierliche und nicht-invasive Überwachung der Körpertemperatur bei Sauen im Frühpuerperium. Ein hoher Prozentsatz an Sauen (40,4%) zeigte in den ersten sechs Tagen nach der Geburt eine Vaginaltemperatur über 40,3°C, dennoch wurden nur 12% dieser Sauen antibiotisch behandelt.

Im zweiten Teil dieser Studie wurde die Konzentration von zwei Akut-Phase Proteinen bei den gleichen Sauen am 7. Studientag bestimmt. Hierfür wurde eine Serumprobe von allen 199 Sauen für die Messung von Haptoglobin und C-reaktivem Protein genommen. Der Medianwert von Haptoglobin war 1,83mg/ml (Interquartilsabstand: 1,42 bis 2,13 mg/mL) und

60,0 µg/mL (Interquartilsabstand: 15,2 bis 216,5 µg/mL). Es zeigte sich keine Korrelation zwischen Haptoglobin und C-reaktivem Protein (ρ = 0,11, *P* = 0,12) und kein Unterschied zwischen Sauen, die hinsichtlich der Konzentrationen von Haptoglobin (*P* = 0,1) oder C-reaktivem Protein im Serum (*P* = 0,34) als krank oder gesund kategorisiert wurden. Sauen mit einem Serumhaptoglobin über 2,13 mg/ml zeigten eine höhere Rektaltemperatur als Sauen mit Serumkonzentrationen unter diesem Wert (*P* = 0,037). Bei der Vaginaltemperatur wurde kein Unterschied zwischen diesen beiden Gruppen von Sauen gefunden (*P* = 0,24). Sauen mit einer Konzentration von C-reaktivem Protein im Serum > 216,5 µg/mL hatten eine höhere Rektaltemperatur (*P* = 0,017) und Vaginaltemperatur (*P* = 0,02) als Sauen mit einer Serumkonzentration ≤ 216,5 µg/mL. In dieser Studie wurde deutlich, dass die Messungen der Serumkonzentration von Haptoglobin und C-reaktivem Protein nicht zur Früherkennung von postpartalen Erkrankungen bei Sauen genutzt werden können. Zusammenfassend kann festgestellt werden, dass weitere Studien notwendig sind, um die Diagnostik von PPDS bei Sauen zu verbessern.

7 References for introduction and discussion

Barbé, F., K. Atanasova and K. Van Reeth. 2011. Cytokines and acute phase proteins associated with acute swine influenza infection in pigs. Vet J 187: 48-53.

Baumann, H. and J. Gauldie. 1994. The acute phase response. Immunol Today 15: 74-80.

Bekkering, J., and S. Hoy. 2007. Continuous monitoring of ear temperature in boars. Deut Tierarztl Woch 114: 16-19.

Burfeind, O., V. S. Suthar and W. Heuwieser. 2012. Effect of heat stress on body temperature in healthy early postpartum dairy cows. Theriogenology 78: 2031-2038.

Burfeind, O., V. S. Suthar, R. Voigtsberger, S. Bonk and W. Heuwieser. 2014. Body temperature in early postpartum dairy cows. Theriogenology.

Collier, R. J., J. P. McNamara, C. R. Wallace and M. H. Dehoff. 1984. A review of endocrine regulation of metabolism during lactation. Journal of Animal Science 59: 498-510.

De Winter, P. J. J., M. Verdonck, A. de Kruif, L. A. Devriese and F. Haesebrouck. 1992. Endometritis and vaginal discharge in the sow. Anim Reprod Sci 28: 51-58.

Dewulf, J., F. Koenen, H. Laevens and A. de Kruif. 2003. Infrared thermometry is not suitable for the detection of fever in pigs. Vlaams Diergen Tijds 72: 373-379.

Eckersall, P. D. and R. Bell. 2010. Acute phase proteins: Biomarkers of infection and inflammation in veterinary medicine. Vet J 185: 23-27.

Elmore, R. G., C. E. Martin, J. L. Riley and T. Littledike. 1979. Body temperatures of farrowing swine. J Am Vet Med Assoc 174: 620-622.

Furniss, S. J. 1987. Measurement of rectal temperature to predict mastitis, metritis and agalactia (MMA) in sows after farrowing. Prev Vet Med 5: 133-139.

Gerjets, I. and N. Kemper. 2009. Coliform mastitis in sows: A review. J Swine Health Prod 17: 97-105.

Gómez-Laguna, J. et al. 2010. Haptoglobin and C-reactive protein as biomarkers in the serum, saliva and meat juice of pigs experimentally infected with porcine reproductive and respiratory syndrome virus. Vet J 185: 83-87.

Gooneratne, A. D., P. E. Hartmann and H. M. Nottage. 1982. The initiation of lactation in sows and the mastitis-metritis-agalactia syndrome. Anim Reprod Sci 5: 135-140.

Hanneman, S. K., J. T. Jesurum-Urbaitis and D. R. Bickel. 2004. Comparison of methods of temperature measurement in swine. Lab Anim 38: 297-306.

Hanneman, S. K., K. McKay, G. Costas and D. Rosenstrauch. 2005. Circadian temperature rhythm of laboratory swine. Comparative Med. 55: 249-255.

Heinritzi, K. and J. Hagn. 1999. Untersuchungen zur Wirksamkeit und Verträglichkeit des neu entwickelten Cephalosprins Cephquinom bei an puerperaler Sepikämie und Toxämie erkrankten Sauen. Tierärztl Prax GN 27: 114-121.

Hirsch, A. C., H. Philipp and R. Kleemann. 2003. Investigation on the efficacy of meloxicam in sows with mastitis-metritis-agalactia syndrome. J Vet Pharmacol Ther 26: 355-360.

Hoy, S. 2002. Investigations on influence of different housing factors on frequency of puerperal diseases in sows. Prakt Tierarzt 83: 990-996.

Hoy, S. 2006. The impact of puerperal diseases in sows on their fertility and health up to next farrowing. Anim Sci 82: 701-704.

Ingram, D. L. and M. J. Dauncey. 1985. Circadian rhythms in the pig. Comparative Biochemistry and Physiology Part A: Physiology 82: 1-5.

Ingram, D. L. and L. E. Mount. 1973. Effects of food intake and fasting on 24-Hourly variations in body-temperature in young pig. Pflugers Arch 339: 299-304.

King, G. J., R. A. Willough and R. R. Hacker. 1972. Fluctuations in rectal temperature of swine at parturition. Can Vet J 13: 72-74.

Kluger, M. J. 1991. Fever - Role of pyrogens and cyrogens. Physiol Rev 71: 93-127.

Kostro, K., W. Wawron, M. Szczubial, D. Luft-Deptula and Z. Glinski. 2003. C-reactive protein in monitoring and evaluation of effects of therapy of the MMA syndrome of sows. Pol J Vet Sci 6: 235-238.

Maeder, B., S. Arlt, O. Burfeind and W. Heuwieser. 2013. Continuous vaginal temperature measurement in bitches before parturition. Reprod Biol 13, Supplement 2: 31-32.

Martineau, G. P., C. Farmer and O. Peltoniemi. 2012. Mammary System. In: J. J. Zimmerman, L. A. Karriker, A. Ramirez, K. J. Schwartz and G. W. Stevenson (eds.) Diseases of Swine No. 10th. p 270-293. Wiley Blackwell.

Martineau, G. P., T. Y. Le and D. Guillou. 2013. Postpartum dysgalactia syndrome: A simple change in homeorhesis? J Swine Health Prod 21: 85-93.

Mold, C., W. Rodriguez, B. Rodic-Polic and T. W. Du Clos. 2002. C-reactive protein mediates protection from lipopolysaccharide through interactions with Fc gamma R. J Immunol 169: 7019-7025.

Murata, H., N. Shimada and M. Yoshioka. 2004. Current research on acute phase proteins in veterinary diagnosis: an overview. Vet J 168: 28-40.

Oravainen, J. et al. 2006. Factors Affecting Fertility in Loosely Housed Sows and Gilts: Vulvar Discharge Syndrome, Environment and Acute-phase Proteins. Reprod Domest Anim 41: 549-554.

Preissler, R., H. Looft and N. Kemper. 2012. The postpartum dysgalactia syndrome: An overview of the genetic predisposition. Tieraerztliche Umschau 67: 520-527.

Reiner, G., B. Hertrampf and H. R. Richard. 2009. Postpartales Dysgalaktiesyndrom der Sau - eine Übersicht mit besonderer Berücksichtigung der Pathogenese. Tierärztl Prax 37: 305-318.

Ross, R. F. et al. 1981. Bacteriologic Study of sow agalactia. Am J Vet Res 42: 949-955.

Schmidt, M., C. Ammon, P. Schon, C. Manteuffel and G. Hoffmann. 2013. Assessment of continuous vaginal logger-based temperature monitoring in fever-induced guilts. Am J Anim Vet Sci 8: 55-65.

Suthar, V. et al. 2012. Factors associated with body temperature of healthy Holstein dairy cows during the first 10 days in milk. Journal of Dairy Research 79: 135-142.

Suthar, V., O. Burfeind, B. Maeder and W. Heuwieser. 2013. Agreement between rectal and vaginal temperature measured with temperature loggers in dairy cows. Journal of Dairy Research 80: 240-245.

Traulsen, I., K. Naunin, K. Müller and J. Krieter. 2010. Application of infrared thermography to measure body temperature of sows. Züchtungskunde 82: 437-446.

Van Gelder, K. N. and G. Bilkei. 2005. The course of acute-phase proteins and metritis agalactia (M MA) of the sow and serum cortisol in mastitis sow performance. Tijdschr Diergeneeskd 130: 38-41.

Vickers, L. A. et al. 2010. Technical note: Comparison of rectal and vaginal temperatures in lactating dairy cows. J Dairy Sci 93: 5246-5251.

Wagener, F. et al. 2001. Heme is a potent inducer of inflammation in mice and is counteracted by heme oxygenase. Blood 98: 1802-1811.

Yang, F. M. et al. 2003. Haptoglobin reduces lung injury associated with exposure to blood. Am J Physiol-Lung Cell Mol Physiol 284: L402-L409.

8 Publications

Research articles

- Stiehler, T, W. Heuwieser, A. Pfützner, R. Voigtsberger and O. Burfeind. 2013. Repeatability of measures of the rectal temperautre and comparison of vaginal and rectal temperature in puerperal sows. Tierärztl Prax GN 41:217-24.

- Stiehler T, W. Heuwieser, A. Pfützner and O. Burfeind. 2015. The course of rectal and vaginal temperature in early postpartum sows. J Swine Health Prod 23(2):72–83.

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10 Declaration of independence

Hiermit bestätige ich, Tina Stiehler, dass ich die vorliegende Arbeit selbständig angefertigt habe. Ich versichere, dass ich ausschließlich die angegebenen Quellen und Hilfen in Anspruch genommen habe.

Tabelle 1. Eigener Anteil an den Forschungsprojekten der vorliegenden Dissertation

Aktivität	Studie 1[a]	Studie 2[b]	Studie 3[c]
Studienplanung	+++	+++	+++
Datenerhebung	+++	+++	+++
Datenanalyse	+++	+++	+++
Verfassen des Manuskripts	+++	+++	+++
Editieren des Manuskripts	++	++	++

Legende: +++: > 70 %, ++: 50-70 %, +: < 50 %

[a] Repeatability of measurements of the rectal temperature and comparison of vaginal and rectal temperature in puerperal sows.

(Tierärztliche Praxis Großtiere. 2013;41:217–224)

[b] The course of rectal and vaginal temperature in early postpartum sows

(Journal of Swine Health and Production. 2015)

[c] Serum haptoglobin and C-reactive protein concentration in relation to rectal and vaginal temperature of early postpartum sows

(Additional unpublished data)

Berlin, den 16.02.2015 *Tina Stiehler*