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Genetic Parameters of Temperament in Beef Cattle

Cuvillier Verlag Göttingen
Internationaler wissenschaftlicher Fachverlag

GENETIC PARAMETERS OF TEMPERAMENT IN BEEF CATTLE

Dissertation
for the Doctoral Degree
at the Faculty of Agricultural Sciences,
Georg-August-University Göttingen

presented by
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born in Brakel/Westf.

Göttingen, December 2008

Bibliografische Information der Deutschen Nationalbibliothek
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.ddb.de abrufbar.
1. Aufl. - Göttingen : Cuvillier, 2009
Zugl.: Göttingen, Univ., Diss., 2008

978-3-86727-920-8

D 7

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Date of disputation: 23. January, 2009

Nonnenstieg 8, 37075 Göttingen
Telefon: 0551-54724-0
Telefax: 0551-54724-21
www.cuvillier.de

1. Auflage, 2009
Gedruckt auf säurefreiem Papier

978-3-86727-920-8

DANKSAGUNG

Herrn Prof. Dr. Dr. Matthias Gauly danke ich für die Überlassung des Themas sowie die Betreuung und Unterstützung während der Anfertigung dieser Arbeit. Ganz herzlich danke ich ihm für das entgegengebrachte Vertrauen bei der Umsetzung der Versuche auf dem Lehr- und Versuchsbetrieb Rudlos, besonders aber auf den landwirtschaftlichen Praxisbetrieben.

Herrn Prof. Dr. Georg Erhardt danke ich ebenso für die Überlassung des Themas und dafür, dass er diese Zusammenarbeit zwischen Göttingen, Gießen und Rudlos ermöglicht und unterstützt hat. Darüber hinaus danke ich ihm für die Übernahme der Funktion des zweiten Gutachters.

Herrn Prof. Dr. Wolfgang Holtz danke ich für die Übernahme der Funktion des Drittprüfers.

Der Deutschen Forschungsgemeinschaft gilt mein Dank für die finanzielle Unterstützung im Rahmen des Sonderforschungsbereichs 299.

Für die Hilfe bei der statistischen Auswertung der Daten möchte ich mich bei Herrn apl. Prof. Dr. Horst Brandt, Herrn PD Dr. Sven König sowie Herrn Burchhard Möllers bedanken.

Herrn Hubertus Frhr. von Schnurbein danke ich für die Unterstützung dieser Arbeit auf dem Lehr- und Versuchsbetrieb Rudlos und für die freie Hand, die er mir bei der Organisation und Umsetzung der Versuche vor Ort gelassen hat. Ebenso danke ich ihm für die Einplanung der Versuche in den alltäglichen Arbeitsablauf. Bei allen Mitarbeitern des Lehr- und Versuchsbetriebes Rudlos möchte ich mich bedanken. Ihre stete Unterstützung und freundliche Art wird dazu beitragen, dass ich die Zeit in Rudlos in guter Erinnerung behalten werde.

Bei allen landwirtschaftlichen Betrieben möchte ich mich für die Bereitstellung ihrer Tiere für die Durchführung des Praxisversuchs bedanken. Den Betriebsleitern und ihren Mitarbeitern danke ich für die tatkräftige Unterstützung bei der Datenaufnahme sowie für die freundliche Aufnahme auf den Betrieben.

Für die Hilfestellung bei der Auswahl der Betriebe und der praktischen Umsetzung des Versuchs danke ich dem Landesverband Thüringer Rinderzüchter e.G., insbesondere Herrn Ronald Bialek und Herrn Wolfram Knorr; der Masterrind GmbH, insbesondere Herrn

Friedrich Averbeck, Herrn Thorsten Ahlers und Herrn Torsten Kirstein; der Rinderproduktion Berlin-Brandenburg GmbH, insbesondere Frau Cornelia Buchholz, Frau Hannelore Kloß, Herrn Wilfried Hoffmann und Herrn Ingo Jackewitz sowie der Zucht- und Besamungsunion Hessen e.G., insbesondere Herrn Jost Grünhaupt.

Darüber hinaus bedanke ich mich bei allen Mitarbeitern des Instituts für Tierzucht und Haustiergenetik für die gute Zusammenarbeit in den letzten Jahren, besonders bei den Doktoranden und Doktorandinnen und meinen Kollegen in der AG Produktionssysteme für Nutztiere, sowie Walter Schmitz.

Mein ganz besonderer Dank gilt Herrn Jörg Bönsel. Letztlich sind die in Rudlos durchgeführten Versuche nur durch seine unermüdliche Einsatzbereitschaft weit über das normale Maß hinaus ermöglicht worden. Seine wertvollen Erfahrungen in der praktischen Mutterkuhhaltung haben mir entscheidend bei der Planung und Umsetzung dieser Arbeit, besonders auch bei dem Praxisversuch, geholfen. Des Weiteren möchte ich ihm für das freundschaftliche Verhältnis danken.

Bedanken möchte ich mich ganz herzlich bei meinen Kollegen und Freunden Christina Münch und Birthe Niemann sowie André Hahn. Ihre Unterstützung, Motivation und Hilfsbereitschaft hat außerordentlich zum Gelingen dieser Arbeit beigetragen.

Meiner Schwester danke ich ganz herzlich für ihre Unterstützung und Hilfe, die entscheidend zum Gelingen dieser Arbeit beigetragen hat.

Letztlich gebührt meinen Eltern der größte Dank. Ohne sie wäre mir diese Arbeit nicht möglich gewesen.

ACKNOWLEDGEMENT

Firstly, I would like to express my gratitude to Prof. Dr. Dr. Matthias Gauly for abandoning the topic of this thesis as well as for his confidence, assistance and support during the whole process of research and writing this dissertation.

Equally I would like to thank Prof. Dr. Georg Erhardt for abandoning the topic. I also express my thanks for providing and supporting the opportunity of cooperation between Göttingen, Giessen and Rudlos. Furthermore I thank Prof. Dr. Georg Erhard for accepting the position as the second supervisor.

I express my thanks to Prof. Dr. Wolfgang Holtz for taking the position of the third supervisor.

I would like to thank the German Research Foundation for its financial support.

For the helpful assistance in statistical analyses I would like to thank apl. Prof. Dr. Horst Brandt, PD Dr. Sven König as well as Mr. Burchhard Möllers.

Also I would like to thank Mr. Hubertus Frhr. von Schnurbein for his support during research at the experimental farm in Rudlos, especially I thank for giving me plenty of scope for the organization and implementation of the experiments in Rudlos. Equally I would like to thank for integrating the experiments in the daily work processes at the farm. Furthermore I am grateful to thank all employees at the experimental farm. Their continuous support, assistance and friendly manner makes me keep in good memory the time I spent in Rudlos.

This is a great opportunity to express my thanks to all farms for providing their animals for the experiments. I thank all managers and employees for their active support as well as for the friendly reception at each farm.

For their assistance with the selection of farms and the implementation of experiments I give my thanks to the Landesverband Thüringer Rinderzüchter e.G., particularly to Mr. Ronald Bialek and Mr. Wolfram Knorr, to the Masterrind GmbH, in particular to Mr. Friedrich Averbeck, Mr. Thorsten Ahlers and Mr. Torsten Kirstein. Equally I thank Rinderproduktion Berlin-Brandenburg GmbH, particularly Mrs. Cornelia Buchholz, Mrs. Hannelore Kloß, Mr. Wilfried Hoffmann und Mr. Ingo Jackewitz as well as to the Zucht- und Besamungsunion Hessen e.G., especially to Mr. Jost Grünhaupt.

Moreover I would like to sincerely thank all members of the Institute of Animal Breeding and Genetics for the excellent cooperation in the past years, in particular to all PhD students and my colleagues in the Livestock Production Systems Group, as well as Walter Schmitz.

My sincere thanks I would like to give to Mr. Jörg Bönsel. Finally, the experiments carried out in Rudlos were only possible with his indefatigable commitment beyond normal scope. His valuable experience in practical beef cattle production has supported me to a great extent, particularly concerning the implementation of the crush test on the commercial farms.

Moreover I express my cordial thanks to my colleagues and friends Christina Münch and Birthe Niemann as well as to André Hahn. Their continuous support, motivation and helpfulness have extraordinarily contributed to the success of this thesis.

I would like to sincerely thank my sister who has made a decisive contribution to the accomplishment and success of this dissertation.

Finally my sincerest thanks I give to my parents. There would not have been the chance for me to write this dissertation without their unrestricted support.

TABLE OF CONTENTS

Zusammenfassung		**1**
Summary		**4**
Chapter 1	**General introduction**	**7**
	Beef cattle production in Germany	9
	Beef cattle temperament	15
	Use of functional traits in beef cattle breeding	15
	Definition of temperament	15
	Evaluation of temperament	16
	Temperament and genetics	17
	Breeding goal “temperament” and estimation of breeding values	21
	Temperament and performance	21
	Scope of this thesis	22
	References	23
Chapter 2	**Temperamental traits of beef cattle calves measured under field conditions and their relationships to performance**	**27**
Chapter 3	**Maternal protective behaviour of German Angus and Simmental beef cattle after parturition and its relation to production traits**	**45**
Chapter 4	**Temperamental traits of German Angus and Simmental beef cattle measured at young age and their relationships to maternal protective behavior**	**61**
Chapter 5	**General discussion**	**79**
	Introduction	81
	Performance of beef cattle	81
	Beef cattle temperament	82
	Implications of temperament on the efficiency of beef cattle production	83
	Possibilities of genetic selection in beef cattle temperament	85
	Conclusions	91
	References	92

ZUSAMMENFASSUNG

In der vorliegenden Arbeit wurden Merkmale des Temperaments und der Umgänglichkeit verschiedener, in Deutschland bedeutender Fleischrinderrassen untersucht. Dies erfolgte auf Basis verschiedener Testverfahren, die aufgrund bisheriger Erfahrungen als geeignet erschienen, eine zuverlässige Erfassung und Bewertung des Verhaltens von Fleischrindern unterschiedlicher Altersstufen vornehmen zu können.

In einem ersten Schritt wurden in den Jahren 2006 und 2007 genetische und umweltbedingte Faktoren des Temperaments der Fleischrinderrassen Deutsch Angus, Deutsch Fleckvieh, Charolais, Hereford und Limousin untersucht. Ziel dieses Versuchs war es, den Wiegetest hinsichtlich seiner Praxistauglichkeit zu validieren und genetische Parameter der Merkmale „Wiegescore“ und „Fluchtgeschwindigkeit“ zu schätzen. Die Ergebnisse haben gezeigt, das signifikante Unterschiede zwischen den betrachteten Rassen bestehen, wobei Tiere der Rassen Deutsch Angus und Hereford günstigere Temperamenteigenschaften aufwiesen als Rinder der französischen Rassen Charolais und Limousin. Kälber der Rasse Deutsch Fleckvieh bewegten sich in einem mittleren Bereich zwischen den beiden vorgenannten Gruppen. Die geschätzten Heritabilitäten waren sowohl für den Wiegescore als auch für die Fluchtgeschwindigkeit moderat, mit Werten zwischen $h^2 = 0,11$ und $h^2 = 0,36$. Auf dieser Grundlage erscheint eine züchterische Bearbeitung des Temperaments in allen fünf Rassen Erfolg versprechend. Da die Wirtschaftlichkeit in der Mutterkuhhaltung zu einem wesentlichen Teil von den täglichen Zunahmen der Kälber bestimmt wird, wurden zusätzlich genetische Korrelationen zwischen den beiden Merkmalen des Temperaments und den täglichen Zunahmen geschätzt. Die ermittelten Werte sind moderat und liegen überwiegend im negativen Bereich, entsprechend einer gewünschten Beziehung zwischen Temperament und Produktionsleistung. Folglich ist keine Verschlechterung der Produktionsleistungen durch eine züchterische Bearbeitung des Temperaments von Fleischrindern zu erwarten.

Mutterkühe stellen die Basis der Fleischrinderproduktion dar. Es sind diejenigen Tiere, die am längsten in den Beständen verbleiben und züchterisch genutzt werden. Im zweiten Teil dieser Arbeit standen sie daher im Mittelpunkt. In der Literatur wurde wiederholt von aggressivem Verhalten von Mutterkühen im Anschluss an die Kalbung berichtet. Vor diesem Hintergrund wurde zwischen 2000 und 2008 das maternale Schutzverhalten von Mutterkühen der Rassen Deutsch Angus und Deutsch Fleckvieh innerhalb von 24 Stunden nach der Geburt ihrer Kälber beobachtet und bewertet. Kühe der Rasse Deutsch Angus

zeigten ein ausgeprägteres Schutzverhalten gegenüber ihrem Kalb als Deutsch Fleckvieh Kühe. Im Verlauf der Laktationen stiegen die Verhaltensnoten beider Rassen an, was darauf hindeutet, dass sich die Mutterkühe scheinbar nicht an das Handling ihres Kalbes direkt nach der Geburt gewöhnen. Vielmehr verstärkte dies die Verhaltensreaktion der Kühe. Das maternale Schutzverhalten erwies sich in beiden Rassen als ein moderat erbliches Merkmal, wobei der Wert mit $h^2 = 0,42$ für Deutsch Fleckvieh deutlich höher lag als bei der Rasse Deutsch Angus mit einem Wert von $h^2 = 0,14$. In beiden Rassen konnten keine Zusammenhänge zwischen dem Schutzverhalten der Kuh und den täglichen Zunahmen der Kälber nachgewiesen werden. Eine züchterische Bearbeitung des maternalen Temperaments ist daher grundsätzlich möglich, problematisch erscheint jedoch der späte Zeitpunkt der Datenerfassung, frühestens nach der ersten Kalbung im Alter von zwei Jahren oder älter.

Vor diesem Hintergrund war die zentrale Frage der abschließenden Untersuchung, inwieweit es Testverfahren gibt, die geeignet sind, das spätere Verhalten der Mutterkuh schon in frühen Altersabschnitten zuverlässig vorherzusagen. Hierzu wurden Daten ausgewertet, die zwischen 1998 und 2008 auf dem Lehr- und Versuchsbetrieb Rudlos der Universität Gießen aufgenommen wurden. Auf Basis der Eigenleistungen als Jungtier und wiederholter Beobachtungen als Mutterkuh wurden genetische Parameter geschätzt, um eine Grundlage für zukünftige Zuchtentscheidungen zu schaffen. Es konnte gezeigt werden, dass die im Kälber- oder Absetzeralter vergebenen Verhaltensnoten positiv mit dem späteren Schutzverhalten der Mutterkühe korreliert sind ($r_g = 0,13$ bis $r_g = 0,99$). Bei moderaten Erblichkeiten für die Temperamentmerkmale erscheint insbesondere die Bewertung des Verhaltens von Jungtieren im Wiegetest sowie im Separier- und Rückhaltetest für eine züchterische Selektion auf weiblicher Seite geeignet zu sein. Die Ergebnisse des Praxisversuchs deuten jedoch darauf hin, dass der Wiegetest aus arbeitswirtschaftlichen Gründen Vorteile mit sich bringt, da eine Einbindung in den routinemäßig durchgeführten Wiegevorgang auf den Betrieben möglich ist.

Erstmals wurden in dieser Arbeit Merkmale des Temperaments von Fleischrindern verschiedener Rassen auf Praxisbetrieben sowie Beziehungen zwischen dem Temperament von Jungtieren und dem späteren Schutzverhalten von Mutterkühen untersucht. Zusammenfassend kann abschließend Folgendes festgehalten werden:

- Die Evaluierung des Temperaments von Fleischrindern ist mit Hilfe des Wiegetests im Rahmen einer Feldprüfung möglich.
- Eine züchterische Bearbeitung des Temperaments von Jungtieren ist grundsätzlich möglich, teilweise verbunden mit einer Verbesserung der Produktionsleistungen.
- Verschiedene Testverfahren sind geeignet, dass spätere Schutzverhalten der Mutterkühe vorherzusagen,
- wobei die erfassten Parameter der Jungtiere überwiegend in gewünschter Weise mit dem späteren maternalen Temperament korreliert sind.
- Eine züchterische Verbesserung des Temperaments kann durch eine Verringerung des Arbeitsaufwandes und des Verletzungsrisikos sowie durch eine Steigerung der Produktionsleistungen zu einer Effizienzsteigerung der Fleischrinderhaltung beitragen.
- Eine Berücksichtigung des Temperaments als eigenständiges Zuchtziel sollte daher in den in dieser Arbeit betrachteten Rassen angestrebt werden.

SUMMARY

In this thesis, temperamental traits of the most common German beef cattle breeds were examined. For this purpose, different test procedures were used which seemed to be appropriate for reliable recording and evaluation of beef cattle temperament at different stages of life.

In a first step, genetic and environmental factors of beef cattle temperament were investigated in 2006 and 2007, using German Angus, German Simmental, Charolais, Hereford and Limousin calves. The aim of this field study was to validate the crush test concerning its applicability on commercial farms. Furthermore, estimation of genetic parameters was accomplished for measures of temperament, the crush score and flight-speed. Significant differences were observed between breeds, with German Angus and Hereford calves having a more favorable temperament than animals from the French breeds Charolais and Limousin. German Simmental calves ranked between the two groups mentioned before. Heritability estimates were moderate, both for the crush score and the visual flight-speed score, with values of $h^2 = 0.11$ to $h^2 = 0.36$. Based on these results, genetic selection in temperament seems to be promising in all of the five breeds. Since average daily weight gain of the calves is one of the main factors influencing efficiency of beef cattle production, genetic correlations were estimated between this trait and temperament. Estimates were moderate, and mostly negative, indicating a favorable relationship among temperament and performance. Accordingly, genetic improvement of beef cattle temperament is accompanied by an increase in performance.

Suckler cows are the base of beef cattle production, staying in the herd for several years. Therefore the cows took a center stage in the second part of this thesis. In the literature it was repeatedly reported that suckler cows often show aggressive behavior after parturition. For this reason, maternal protective behavior of German Angus and Simmental suckler cows was tested within 24 h postpartum. German Angus cows were scored higher than Simmentals as well as cows with higher lactation-numbers in comparison to younger cows. It seems that suckler cows tend to develop a greater disposition for protective behavior as a result of routine handling of their calves. Maternal protective behavior was a moderately heritable trait, with estimates of $h^2 = 0.42$ for German Simmentals and $h^2 = 0.14$ for German Angus. No relationships were found among maternal protective behavior and performance of their calves. Thus, allowing genetic selection in maternal temperament.

However, a main problem of this test procedure is that earliest information is available after first calving at an age of two years or even older.

The pivotal question of the final analysis was to determine test procedures which are appropriate to predict maternal protective behavior of mature cows at an early stage of life. For this reason, data recorded between 1998 and 2008 at the experimental farm "Rudlos" of the University of Giessen were analyzed. To generate a base for future selection strategies, genetic parameters were estimated using individual measures of young calves and repeated observations of maternal protective behavior scores of the cows. It was shown that behavior scores of the calves were positively correlated (r_g = 0.13 to r_g = 0.99) with maternal protective behavior. Due to moderate heritabilities of temperamental traits, the crush test and the docility test particularly seem to be qualified for use in selection of females with desirable temperament. Since the results of the field trial indicate that an implementation of the crush test in a routine weighing process is possible, one advantage of this test is that required workload for record keeping is reduced.

For the first time, temperamental traits of beef cattle of various breeds were examined on commercial farms, just as the relationships between temperament of young beef cattle and maternal protective behavior of suckler cows. In summary it can be concluded that:

- The crush test is reliable for evaluation of beef cattle temperament within a field check.
- Genetic improvement of temperament of young animals is feasible, partially associated with an increase in performance traits.
- Prediction of maternal protective behavior is possible using different behavior tests,
- whereas temperamental traits of young animals are favorably correlated with later maternal temperament.
- Genetic improvement of temperament is associated with reduced workload for cattle handling, a decrease in the risk of injuries and increased performance resulting in a higher efficiency of beef cattle production.
- Therefore temperament should be considered as an independent breeding goal in the breeds used within these experiments.

1st CHAPTER

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Beef cattle production in Germany

Beef cattle production in Germany became more important since the setting of quotas for milk production in 1984. Along with a continuous increase in milk yield per cow, this led to a decrease of the number of dairy cows. In consequence, grassland was available for alternative utilization like beef cattle production (Mathiak, 2002). Additionally, beef cattle farming represents an extensive production system with low requirements to barns, productivity of grassland and last but not least to labor input (Hampel, 2005), making it an interesting branch of agricultural production, especially for spare-time farmers.

In a worldwide comparison beef cattle farming is of inferior importance in Germany with only every 8th cow being a suckler cow. The share of suckler cows of total cows is higher in other European countries like Ireland, France or Spain with about fifty percent. In the USA, Brazil, Canada, Australia and Argentina the situation is completely different with about eighty percent being suckler cows (Deblitz, 2006). Within the last few years, the number of suckler cows in Germany ranges about 650,000 animals (Table 1). At last 669,500 suckler cows were counted in 2007. In relation to the number of farms, average herd sizes are low with only fourteen cows per farm in 2002, slightly increasing to fifteen cows per farm in 2007, respectively (Table 1).

Table 1. Number of farms and suckler cows, cows per farm and annual change in number of suckler cows for consecutive years, kept in Germany between 2002 and 2007[1]

Year	Farms (1000)	Suckler cows (1000)	Cows per farm	Change (%)
2002	48.5	679.0	14.0	n.a.
2003	45.6	651.4	14.3	-4.1
2004	n. a.[2]	n. a.	n. a.	n.a.
2005	45.8	648.4	14.2	n.a.
2006	45.4	654.7	14.5	+1.0
2007	44.7	669.5	15.0	+2.3

[1]Data adopted from the annual reports of the German Beef Cattle Breeders Association (2002 – 2007); [2]n.a. = not available.

Within Germany the structure of beef cattle production is extremely diverse, with rather small farms in western Germany and large farms with hundreds of cows in eastern Germany, especially in Brandenburg and Mecklenburg-Western Pomerania (Deblitz et al., 2004). Furthermore, there is a great variety of beef cattle breeds in Germany, but only a few are important for agricultural production. The actual distribution of breeds registered in herd books is presented in figure 1. It is quite evident that German Simmentals, Limousin, Charolais and German Angus are the most popular breeds, followed by Herefords which are far less common. These five breeds unite about 70% of all registered breeding animals in Germany, emphasizing the particular status of these breeds for German beef cattle production and justifying their integration in this research project. Galloway and Highland Cattle, with approximately eight and six percent of all registered animals respectively, are of particular importance in landscape management or hobby farming (Golze, 1997).

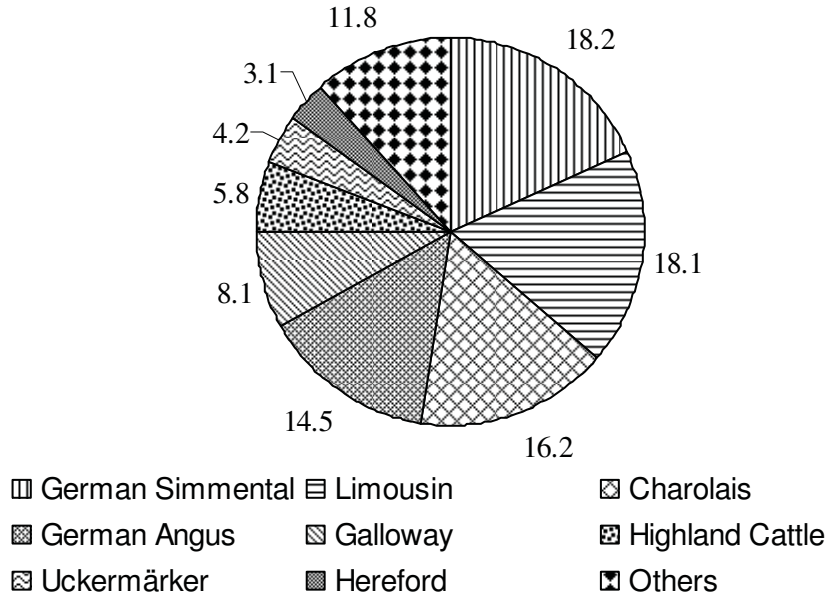

Figure 1. Relative distribution of registered breeding animals by breed (German Beef Cattle Breeders Association, 2007)

German Angus, Charolais, Hereford, Limousin and German Simmental are breeds characterized by differences in constitution, performance and functional traits like fertility, maternal care and temperament. For this reason the main breeding goals of each breed, constituted by the German Beef Cattle Breeders Association (2008) are presented below:

- German Angus cattle were developed in Germany in the 1950s by breeding Aberdeen Angus bulls to German dual-purpose breeds. The moderate framed beef cattle are characterized by a long and slight constitution and early maturity associated with good maternal traits such as milk production or persistency. Thus leading to moderate growth rates. German Angus cows are productive with an average age of two years at first calving and few calving difficulties. In order to temperament, calm and docile animals are preferred.
- Charolais are intensive, large framed beef cattle with heavy muscling of shoulder, back and haunch, resulting in high growth rates but also in higher birth weights than in other beef breeds. Charolais cows should have good maternal traits with sufficient milk production. German Charolais breeders want their cattle to be calm and docile.
- Herefords are moderate framed beef cattle with acceptable muscling and growth rates. Breeders emphasize good fundaments and feed conversion to suit extensive pasture systems. Hereford cattle are described as very docile and fertile with calving difficulties being unusual. Females should have pronounced maternal care traits and an average age of 24 month at first calving.
- Limousin cattle distinguish themselves from most other beef breeds through a very slender constitution with extraordinary muscling, especially of the haunch. A favorable gradient of the pelvis, associated with moderate birth weights, results in easy calving cows. According to temperament no specifications are defined by the Limousin breeders.
- German Simmental should be well muscled with an adequate constitution. They are large framed beef cattle with high growth rates, due to an outstanding milk production of the cows. Females are fertile with an average age at first calving of approximately 28 month. German Simmental should be docile and adaptable to different rearing conditions.

Table 2. Main characteristics of the most important beef cattle breeds in Germany

Breed	Trait	Male	Female
German Angus	Hip height (cm)	cir. 145	cir. 136
	Body weight (kg)	950 – 1200	600 – 700
	Birth weight (kg)	35	32
Charolais	Hip height (cm)	cir. 154	cir. 144
	Body weight (kg)	1200 – 1300	800 – 900
	Birth weight (kg)	44	40
Hereford	Hip height (cm)	cir. 141	cir. 136
	Body weight (kg)	900 – 1300	600 – 700
	Birth weight (kg)	36	33
Limousin	Hip height (cm)	cir. 150	cir. 140
	Body weight (kg)	1100	700
	Birth weight (kg)	39	36
German Simmental	Hip height (cm)	150 – 165	140 – 150
	Body weight (kg)	1100 – 1300	700 – 850
	Birth weight (kg)	41	39

A survey of basic measures of birth weights of the calves or body size, and body weights of mature animals is shown in table 2. Based on these attributes, Charolais, Limousin and German Simmental cattle could be characterized as the large framed, intensive beef cattle breeds, whereas German Angus and Herefords are moderate framed and more extensive breeds (Golze, 1997). As average daily weight gain is one of the most important performance traits in beef cattle production (Hampel, 2005; Nkrumah et al., 2007), corresponding data were calculated for male and female calves at weaning and as yearlings, using information from the annual reports of the German Beef Cattle Breeders Association (2007). A summary of these figures is presented in tables 3 and 4, emphasizing differences in performance of growth rates of the beef cattle breeds used in these experiments.

Between 2005 and 2007 average daily weight gains at 200 and 365 days of life were at the same level in German Angus and Hereford cattle, ranging about 1100 g/d for males, and 1000 g/d (200-d) and 900 g/d (365-d) for females, respectively. On the other side, values were explicitly higher in Charolais and German Simmentals bulls, with values about 1300 g/d. Heifers of both breeds reached average daily weight gains of over 1100 g/d at weaning and 1000 g/d as yearlings. Limousin cattle ranked between the two groups mentioned before.

Table 3. Body weights (BW)[1] and average daily weight gains (ADG)[1] of male beef cattle at weaning (200-d) and as yearlings (365-d) recorded between 2005 and 2007

Breed	Year	200-d		365-d	
		BW (kg)	ADG (g/d)	BW (kg)	ADG (g/d)
German Angus	2005	215.7	1079	386.7	1059
	2006	217.1	1086	392.1	1074
	2007	218.0	1090	387.0	1060
Charolais	2005	253.3	1267	466.3	1278
	2006	258.3	1292	465.3	1275
	2007	254.9	1275	454.9	1246
Hereford	2005	206.3	1032	397.3	1088
	2006	222.3	1112	404.3	1108
	2007	226.2	1131	406.2	1113
Limousin	2005	233.9	1170	409.9	1123
	2006	235.4	1177	416.4	1141
	2007	232.0	1160	415.0	1137
German Simmental	2005	244.2	1221	482.2	1321
	2006	245.4	1227	484.4	1327
	2007	252.3	1262	489.3	1341

[1]Birth weight corrected values.

Table 4. Body weights (BW)[1] and average daily weight gains (ADG)[1] of female beef cattle at weaning (200-d) and as yearlings (365-d) recorded between 2005 and 2007

Breed	Year	200-d		365-d	
		BW (kg)	ADG (g/d)	BW (kg)	ADG (g/d)
German Angus	2005	197.1	986	322.1	882
	2006	199.6	998	324.6	889
	2007	200.1	1001	323.1	885
Charolais	2005	223.1	1116	361.1	989
	2006	231.5	1158	368.5	1010
	2007	231.4	1157	368.4	1009
Hereford	2005	190.8	954	311.8	854
	2006	196.6	983	322.6	884
	2007	206.2	1031	323.2	885
Limousin	2005	207.1	1036	332.1	910
	2006	211.7	1059	333.7	914
	2007	207.5	1038	335.5	919
German Simmental	2005	220.3	1102	357.3	979
	2006	226.6	1133	359.6	985
	2007	231.4	1157	367.4	1007

[1]Birth weight corrected values.

Another important aspect to consider is that the beef cattle breeds mentioned above differ in order to their breeding history. Most of the breeds were developed during the 19th century (Jarrige and Auriol, 1992). Herefords in England and Aberdeen Angus in Scotland were selected for early maturity to suit extensive pasture systems with relatively poor feeding conditions, resulting in smaller body size and lower growth rates. Out of Aberdeen Angus, German Angus cattle were developed in the 1950s by breeding Aberdeen Angus bulls to German dual-purpose breeds (Hampel, 2005). The repeated use of Aberdeen Angus bulls through artificial insemination and the purchase of purebred breeding animals have a large impact on German Angus cattle until today. In contrast to the British beef cattle breeds, European continental breeds like the French Charolais and Limousin or likewise the German Simmentals were retained for dual-purpose until the middle of the 20th century, e.g. for meat production and as draught animals or, in the case of German Simmentals, for meat- and milk production. These dual-purpose breeds were large framed and heavy muscled with late maturity (Jarrige and Auriol, 1992). The described differences in former breeding goals and rearing conditions between European continental and British or British-derived beef cattle breeds may have long lasting effects on these breeds.

Beef cattle temperament

Use of functional traits in beef cattle breeding

In beef cattle breeding not only production traits like growth rates and muscling are substantial but also other, so called functional traits (Swalve, 2008). Reproductive performance, ease of calving, maternal behavior and suckling ability are functional traits of suckler cows with great influence on productivity of beef cattle production (Phocas et al., 2006). Furthermore, attributes like temperament and docility are nowadays of growing importance since beef cattle are usually kept under extensive rearing conditions, partially on pasture throughout the year and with a decreased labor input per animal (Le Neindre et al., 1998). Close human-animal interactions are rare and mostly restricted to veterinary care or routine management procedures (identification, herding, weighing or vaccinations). Rushen et al. (1999) stated that consequently, negative behavioral responses of beef cattle are likely to happen more often during human handling. Thus strengthening the risk of injuries or increasing the workload for cattle handling with detrimental effects on efficiency of beef cattle production (Le Neindre et al., 2002).

Definition of temperament

Temperament is usually described as the behavioral response of animals to human contact or handling (Fordyce et al., 1985, 1988; Grandin, 1993). Since behavioral agitation was chosen as an indicator for temperament, it seems to be strongly related to the degree of fearfulness shown by the animals during handling because individuals with low fear response will remain calm and docile (Petherick et al., 2002) or will have lower flight-speeds when released from fixation (Burrow et al., 1988). In the same way it is possible to predict cattle temperament by the ease with which routine management procedures can be carried out (Morris et al., 1994). The behavioral response of an animal can vary from docility to excitement and, at last, aggression (Burrow and Dillon, 1997), with docility being preferred for farming conditions (Gauly et al., 2001). Based on this, an animal is considered to have a “good” temperament either if it remains calm and docile during handling (Grandin, 1993) or if the flight distance towards humans is small (Morris et al., 1994). In contrast, a “poor” temperament is assumed if cattle are highly agitated during handling, show high flight-speeds or a large flight-distance.

Evaluation of temperament

In the past, several tests were developed to assess cattle temperament, but to date no general criteria have been established. The different test procedures can be divided into two classes, as suggested by Burrow (1997). At first, non-restraint tests enable the animal to move freely within the test area. Secondly, restraint tests are used and the animals are restrained on various occasions. An advantage of a restraint test is that the test situation is related to routine husbandry tasks like tethering or weighing of an animal and that it could be implemented in this regular work (Willecke, 2006).

Non-restraint tests

An example for non-restraint tests is the docility test developed by Le Neindre et al. (1995) and enhanced by Gauly et al. (2001). Behavioral agitation of beef cattle after separation from their herdmates was observed in a yard, and time spent moving, the amount of aggression of the animal towards humans and at last the time a heifer could be restraint in a defined corner within a 30 s period was measured. On this base, a docility score is assigned to the animal. Another example for a non-restraint test is measuring of flight-speed which is defined as the time an animal needs to cover a fixed distance after being released from fixation, e.g. in a weighing crush (Burrow et al., 1988; Burrow and Dillon, 1997). Individual differences among the fear response of cattle to physical fixation and close human contact are the basic principle of the flight-speed test. It is an objective measurement, in which lower flight-speeds indicate a more favorable temperament (Burrow and Dillon, 1997). Based on this, Burrow and Corbet (2000) as well as Lanier and Grandin (2002) generated a visual flight-speed test, subjectively assessing the gait of an animal while leaving the weighing crush.

In regard to mature cows, a test procedure was developed by Buddenberg et al. (1986), and later on modified by Morris et al. (1994). Scoring of maternal protective behavior after parturition is performed during routine handling of the calves like weighing or earmarking. During the test, the cow's responsiveness to her calf is observed, and a subjective score is assigned ranging from very docile for cows which nearly show no interest up to animals with pronounced protective behavior which are highly agitated associated with aggression against humans.

Restraint tests

This group encompasses test situations in which free movement of the animals is constrained in some way. The behavioral response of cattle to physical restraint is recorded in form of defense reactions or vocalizations. One example is the crush test, developed by Tulloh (1961). The animals are restraint in the head gate of a weighing crush. During restraint, two main factors impact on the animals. At first they are isolated from the group and secondly, they are exposed to close human contact, both potentially fearful situations (Grignard et al., 2001). Another test of this category is the fixation test (Boissy and Bouissou, 1988), which is usually used on younger calves. The calf is separated from the herd and tethered with a rope for a fixed time period. Temperament is then classified at the base of behavioral agitation during the fixation.

Temperament and genetics

In the past, a lot of research was conducted to identify genetic differences in beef cattle. In an early study, Tulloh (1961) reported that Hereford cattle were most docile during fixation in a crush compared to Angus and Shorthorns which were nervous and excitable. However, Fordyce et al. (1988) have shown that Shorthorns themselves had better temperamental traits than *Bos indicus*-cattle. A nervous and excitable temperament of *Bos indicus*-cattle compared to *Bos taurus*-cattle was observed in several other studies using various test situations (Hearnshaw and Morris, 1984; Fordyce et al., 1985; Voisinet et al., 1997a). Shrode and Hammack (1971) did not find temperamental differences between Aberdeen Angus and Hereford cattle, but later on in a trial by Morris et al. (1994) Aberdeen Angus were scored significantly higher for behavioral agitation in a crush than Herefords, with higher scores indicating a more excitable temperament. Vanderwert et al. (1985) reported that Angus cattle were easier to handle than Limousins. In a preceding study, Mathiak (2002) compared German Angus and Simmental beef cattle in different test situations, and determined a more favorable temperament in German Angus calves than in German Simmentals. Similar results were obtained by subsequent trials of the same research group by Willecke (2006) and Urban (2007).

Le Neindre et al. (1995) studied individual differences in 904 Limousin heifers from 34 AI bulls based on the docility test. In order to behavioral agitation of an animal during human handling, sire was a significant source of variation. Similar results were obtained by Mathiak (2002) comparing progeny groups of five German Angus and five German

Simmental bulls, either in a fixation test, a crush test or a docility test. Grignard et al. (2001) observed temperament of 245 Limousin heifers from 10 bulls, both in a docility test and in a crush test. They determined a significant effect of the sire on docility scores of their daughters, as well as on their behavioral agitation during restraint in the crush.

Based on different breeds or test procedures, heritability of temperamental traits was estimated in numerous studies. A survey of heritability estimates with importance for the experiments conducted within this thesis is presented in table 5 for non-restraint tests and in table 6 for restraint tests, respectively. Unless otherwise noted the values correspond to behavior scores.

Since most studies have reported small to moderate heritabilities, genetic selection seems to be promising to improve temperamental traits of beef cattle. With increased age of the animals estimates were lower, due to a greater habituation of these animals to test procedures or generally more experience with human contact or handling, increasing the environmental influence on a special trait (Burrow, 1997). In addition, standard errors of heritability estimates are usually high since most of the studies were conducted with only a relative small number of animals.

Table 5. Heritability estimates (h^2 ± SE) of temperamental traits of beef cattle measured in different non-restraint test situations (mod. from Burrow, 1997)

Non-restraint tests							
Trait	Breed	n	Sires (n)	Sex	Age	h^2 ± SE	Reference
Docility test (Score)	Limousin	904	34	female	10 – 11 month	0.22	Le Neindre et al. (1995)
	Limousin	558	21	female	9 month	0.29 ± 0.13	Le Neindre et al. (2002)
Score before Handling	German Angus	518	5	both	7 – 8 month	0.13 ± 0.11	Mathiak (2002)
Score Handling	German Simmental	400	5	both	7 – 8 month	0.17 ± 0.12	Mathiak (2002)
Score before Handling	German Angus	518	5	both	7 – 8 month	0.61 ± 0.17	Mathiak (2002)
Score Handling	German Simmental	400	5	both	7 – 8 month	0.55 ± 0.15	Mathiak (2002)
	Limousin	2781	102	female	heifers	0.18	Phocas et al. (2006)
	Angus, Simmental	471	13	both	7 month	0.38 ± 0.01	Urban (2007)
	Angus, Simmental	471	13	both	7 – 8 month	0.33 ± 0.03	Urban (2007)
Flight-speed (Time)	Zebu-derived cattle	561	42	both	6 month	0.54 ± 0.16	Burrow et al. (1988)
		558	38	both	18 month	0.26 ± 0.13	Burrow et al. (1988)
	Bos indicus x *Bos taurus*	1659	92	both	6 month	0.39	Burrow and Corbet (2000)
		1659	92	both	12 month	0.33	Burrow and Corbet (2000)
		1659	92	both	18 month	0.29	Burrow and Corbet (2000)
	Angus, Simmental	454	13	both	7 month	0.60 ± 0.02	Urban (2007)
	Angus, Simmental	454	13	both	1 – 7 month	0.25 ± 0.01	Urban (2007)
	Bos taurus[1]	302	n.a.[2]	steers	n.a.	0.49 ± 0.18	Nkrumah et al. (2007)
Maternal behavior (Score)	Hereford	162	n.a.	female	mature	0.32	Brown (1974)
	Angus	266	n.a.	female	mature	0.17	Brown (1974)
	Bos taurus[3]	889	n.a.	female	mature	0.06 ± 0.01	Buddenberg et al. (1986)
	Bos taurus[4]	2121	486	female	mature	0.09 ± 0.03	Morris et al. (1994)

[1]Angus, Charolais and Hybrid bulls; [2]n.a. = not available; [3]Angus, Hereford, Charolais and Red Poll; [4]Angus, Hereford and different crosses out of these breeds.

Table 6. Heritability estimates (h^2 ± SE) of temperamental traits of beef cattle measured in different restraint test situations (mod. from Burrow, 1997)

Restraint tests							
Trait	Breed	n	Sires (n)	Sex	Age	h^2 ± SE	Reference
Crush test (Score)	*Bos taurus*[1]	n.a.[2]	176	Both	Calf	0.10 ± 0.09	Morris et al. (1994)
	Bos taurus[1]	n.a.	47	female	12 month	0.24 ± 0.23	Morris et al. (1994)
	Bos taurus[1]	n.a.	53	female	mature	0.02 ± 0.11	Morris et al. (1994)
	German Angus	259	5	both	7 month	0.18 ± 0.09	Mathiak (2002)
	German Simmental	206	5	both	7 month	0.25	Mathiak (2002)
	Angus, Simmental	454	13	both	7 month	0.30 ± 0.03	Urban (2007)
	Angus, Simmental	454	13	both	1 – 7 month	0.23 ± 0.02	Urban (2007)
Fixation test (Score)	German Angus	258	5	both	3 weeks	0.10 ± 0.06	Mathiak (2002)
	German Simmental	204	5	both	3 weeks	0.29 ± 0.12	Mathiak (2002)
	Angus, Simmental	482	13	both	3 weeks	0.17 ± 0.03	Urban (2007)
	Angus, Simmental	482	13	both	1 and 7 month	0.01 ± 0.00	Urban (2007)

[1]Angus, Hereford and different crosses out of these breeds; [2]n.a. = not available.

Breeding goal "temperament" and estimation of breeding values

In the past, handling problems increased in purebred Limousin cattle reared in Australia, New-Zealand or North America. The negative effects of this development were most obvious in large commercial crossbred herds using Limousin sires. Limousin breeders worried about a drop in demand of their breeding animals since this lack of docility may keep potential commercial buyers from using Limousin bulls in their herds.

Consequently, by the end of the last century temperament was considered as a new and one of the main breeding goals in the Limousin breed in these countries (Phocas et al., 2006). Therefore, the North American Limousin Foundation started the first genetic evaluation of temperament in beef cattle in 1998 and later on in 2002 also the Canadian Limousin Association participated (McGrath, 2008). The docility EBV (Expected Progeny Value) is an estimate of genetic differences between animals in temperament, which is expressed as the difference in the percentage of progeny that will show a favorable temperament, either in the crush test or the docility test (Breedplan, 2008).

Temperament and performance

Importance of temperament in order to economic valuable performance traits of beef cattle was highlighted repeatedly in the literature. Cattle with "poor" temperament have been shown to have lower weight gains than those with a desirable temperament (Burrow and Dillon, 1997; Voisinet et al., 1997a; Gauly et al., 2001; Mathiak, 2002; Urban, 2007). Higher flight-speeds, indicating a poorer temperament of the animals, were correlated with lower average daily weight gains due to lower feed conversion rates (Petherick et al., 2002) or decreased dry matter intake (Fox et al., 2004). Nkrumah et al. (2007) studied temperament and performance traits in beef cattle. Higher flight-speeds were attended by a degradation of average daily weight gain, final body weight and carcass marbling. Colditz et al. (1999) studied feedlot performance of beef cattle selected for temperament. Calves from a calm group had higher average daily weight gains and lower morbidity than those from a nervous group. Fordyce et al. (1988) observed that in beef cattle carcass bruises occur more often in cattle with poorer temperament. Such cattle are likely to produce tougher meat (Voisinet et al., 1997b).

Scope of this thesis

As presented before, the main beef cattle breeds in Germany are German Simmental, Limousin, Charolais, German Angus, and with smaller interest, Hereford cattle. Le Neindre et al. (1996) stated that a major problem of the change to extensive management systems is the use of breeds not selected for such conditions, as experiments have shown an interaction between genetic and environmental factors. Since temperament has been shown to be a moderately heritable trait in beef cattle they suggest to select animals from different genetic lines within a breed, featured with desirable behavioral traits (Le Neindre et al., 1995; Grignard et al., 2001). Until today, experiments focused either on young or mature animals, but no information is available concerning genetic links among temperamental traits of beef cattle at different stages of life. Furthermore most of the studies were performed on research stations or experimental farms with usually small numbers of animals.

Consequently, the first part of this research was to transfer the crush test (mod. from Tulloh, 1961) to commercial beef cattle farms to validate its routine on-farm applicability, since previous studies have shown that the implementation in a routine weighing process is possible and evaluations of temperament are reliable (Mathiak, 2002; Willecke, 2006; Urban, 2007). Determination of relevant environmental factors affecting temperament of the most common beef cattle breeds in Germany was another request, both using the crush test and a modified flight-speed test. In a second step, maternal protective behavior of German Angus and Simmental cattle was observed, analyzing genetic and environmental sources of variation in this behavioral trait of mature beef cattle. In regard to economic efficiency of beef cattle production, correlated changes in performance traits of beef cattle were studied depending on temperament.

At last, the global purpose of this study was to determine if suckler cows likely to be aggressive towards humans after parturition can be predicted from measures recorded at young age to facilitate early selection of females with desirable temperamental traits. Therefore, to generate a base for future selection strategies, genetic (co)variance components among different temperamental traits and maternal protective behavior after parturition were estimated.

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2nd CHAPTER

TEMPERAMENTAL TRAITS OF BEEF CATTLE CALVES MEASURED UNDER FIELD CONDITIONS AND THEIR RELATIONSHIPS TO PERFORMANCE

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Submitted to

Journal of Animal Science (October 13th, 2008)

TEMPERAMENTAL TRAITS OF BEEF CATTLE CALVES MEASURED UNDER FIELD CONDITIONS AND THEIR RELATIONSHIPS TO PERFORMANCE

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ABSTRACT

A total of 3050 German Angus (Aberdeen Angus x German dual-purpose breeds), Charolais, Hereford, Limousin and German Simmental calves were used to examine temperamental traits of beef cattle using two different test procedures. Both, the crush test and the flight-speed test have been validated in terms of routine on-farm applicability. Behavior tests were performed in 2006 and 2007 on 24 commercial beef cattle farms located in the northern and eastern part of Germany. A single, trained observer assigned subjective scores to characterize the behavior of each animal during restraint in the head bail (calm, restless shifting, squirming, vigorous movement, violent struggling) and when leaving the crush (walk, trot, run, jumping out of the crush). Breed was a significant source of variation in crush scores and flight-speed scores ($P < 0.001$). Charolais and Limousin cattle had the highest scores in both traits, whereas Herefords had the lowest crush scores. German Angus and Hereford calves had the lowest flight-speeds, indicating that these breeds have a more favorable temperament. Temperament scores differed significantly between male and female calves ($P < 0.01$), with females scored higher for both traits. Average daily weight gains of the calves were significantly influenced by effects of breed ($P < 0.001$) and sex ($P < 0.001$) of the calves. Heritabilities were estimated for crush- and flight-speed scores of beef cattle. They were lowest for crush score and flight-speed score of Limousin cattle with values of 0.11. In contrast, highest heritabilities were 0.33 for crush score, and 0.36 for flight-speed score of Hereford cattle. Genetic correlations were estimated among both temperamental traits, with values between 0.57 and 0.98. Crush scores and visual flight-speed scores were negatively correlated with daily weight gain of

the calves in most breeds. The results presented in this paper point out that on-farm evaluation of beef cattle temperament is possible, either using the crush test or the flight-speed test. Genetic selection seems to be promising to improve temperamental traits of beef cattle without decreasing production traits like average daily weight gain of the calves.

Key Words:

beef cattle, behavior test, flight-speed, production traits, temperament

INTRODUCTION

Beef cattle are usually kept under extensive rearing conditions, partially on pasture throughout the year and with a decreased labor input per animal (Le Neindre et al., 1998). Close human-animal interactions are restricted to veterinary care or routine management procedures, associated with stress for the animals (Rushen et al., 1999). Due to the limited habituation to men, negative behavioral responses of beef cattle are likely to happen more often during handling, strengthening the risk of injuries or increasing the workload for cattle handling (Le Neindre et al., 2002).

The behavioral response of beef cattle to human handling was chosen as an indicator for an animal's temperament (Grandin, 1993; Burrow, 1997). It can vary from docility to aggression, with docility being preferred for farming conditions. Temperament can be quantified by scoring behavior in a standardized test situation (Tulloh, 1961; Burrow et al., 1988; Le Neindre et al., 1995; Hoppe et al., 2008).

Temperament differs among beef cattle breeds and gender (Stricklin et al., 1980; Vanderwert et al., 1985; Gauly et al., 2001a, b). It has been shown to be related to various aspects of animal production, such as daily weight gain, feed conversion and beef quality (Fordyce et al., 1988; Voisinet et al., 1997; Colditz et al., 1999; Petherick et al., 2002; Nkrumah et al., 2007).

Heritabilities of temperament are low to moderate (Morris et al., 1994; Burrow and Corbet, 2000; Mathiak, 2002), indicating the possibility to include temperament in an overall breeding goal.

The purpose of this study was to determine most relevant environmental factors affecting temperament of the most common beef cattle breeds in Germany. For the first time, both the crush test and the flight-speed test have been validated in terms of routine on-farm applicability. Estimation of genetic (co)variance components among temperament and production traits was accomplished to generate a base for future selection strategies.

MATERIALS AND METHODS

Experimental location

The present study was conducted in 2006 and 2007 on 24 commercial beef cattle farms located in the northern and eastern part of Germany. Completeness of performance and pedigree data was ensured by selecting beef cattle herds in cooperation with the responsible breeding associations.

Animals

Beef cattle used in this study originated from the following five beef cattle breeds: German Angus (Aberdeen Angus x German dual-purpose breeds), Charolais, Hereford, Limousin and German Simmental. In total, 3050 calves were tested at an average age of 233d ± 68d (Table 1). An overview of the genetic structure within each breed is given in Table 2.

Table 1. Number of calves by breed and sex tested for temperament in 2006 and 2007, and average age (± SD) of calves at testing

Item	German Angus	Charolais	Hereford	Limousin	German Simmental
2006					
Male	219	124	188	138	209
Female	207	130	185	125	130
2007					
Male	149	158	165	72	156
Female	131	144	159	89	172
Total	706	556	697	424	667
Age (d)	278 ± 63	263 ± 72	194 ± 42	233 ± 69	202 ± 49

Table 2. Number of sires and offspring per sire within breeds

Breed	Number of sires	Offspring per sire	
	n	Mean (± SD)	Range
German Angus	40	17.6 ± 19.1	1 – 73
Charolais	32	17.4 ± 16.7	1 – 64
Hereford	40	17.4 ± 20.4	1 – 80
Limousin	56	7.6 ± 8.6	1 – 45
German Simmental	45	14.8 ± 18.2	1 – 89

Test procedures

Temperament of calves was scored using the crush-test (mod. from Tulloh, 1961). Crush scores reflect the animal's behavior while restraint in the head bail, and were assigned immediately after fixation. Crush scores for all animals were given by the same observer, according to a five-point system suggested by Grandin (1993): 1 = calm, no movement; 2 = restless, shifting; 3 = squirming, occasionally shaking of the crush; 4 = continuous vigorous movement, and shaking of the crush; 5 = rearing, twisting of the body, or violent struggling. Additionally, the same observer recorded the gait of the calves while leaving the crush and a visual flight-speed score was assigned to each calf. According to Lanier and Grandin (2002), the flight-speed scores were: 1 = walk; 2 = trot; 3 = run, and 4 = jumping out of the crush.

For each animal, the rank order of entrance into the crush was recorded. Due to different group sizes, the absolute rank order was transformed to a relative rank order using the following formula:

$$\text{Relative rank order} = \frac{\text{absolute rank order}}{\text{absolute group size}} \times 100\%$$

According to their relative rank order, animals were distributed in five different groups for rank order as follows: 1 = 1% - 20%; 2 = 21% - 40%; 3 = 41% - 60%; 4 = 61% - 80%; 5 = 81% -100%.

During fixation in the crush, the body-weight of each animal was measured. Average daily weight gain of the calves was calculated for the time interval from birth to testing date.

Statistical analysis

Analysis of variance to reveal the impact of environmental effects on traits was carried out with the software package SAS 9.1.3 (2001) using the Mixed procedure. Genetic (co)variance components were estimated within a multivariate approach using VCE4, Version 4.2.5 (Neumeier and Groeneveld, 1998) by applying an animal model. Pedigrees were traced back for three generations.

The temperamental traits crush score and flight-speed score were analyzed using the following model 1:

$$y_{ijklmn} = \mu + B_i + S_j + Y_k + F_l(B_i) + G_m + bA + e_{ijklmn} \quad [1]$$

with y_{ijklmn} = observed trait, μ = overall mean, B_i = fixed effect of breed, S_j = fixed effect of sex, Y_k = fixed effect of year, $F_l(B_i)$ = fixed effect of farm within breed, G_m = fixed effect of

rank order group, bA = age of animal as linear regression, and e_{ijklmn} = random residual effect.

The following model 2 was used to analyze body-weight and average daily weight gain (ADG):

$$y_{ijklm} = \mu + B_i + S_j + Y_k + F_l(B_i) + bA + e_{ijklm} \quad [2]$$

with y_{ijklm} = observed trait, μ = overall mean, B_i = fixed effect of breed, S_j = fixed effect of sex, Y_k = fixed effect of year, $F_l(B_i)$ = fixed effect of farm within breed, bA = age of animal as linear regression, and e_{ijklm} = random residual effect.

For genetic analysis, models 1 and 2 were extended by including the random additive genetic effect of each animal.

RESULTS

Breed differences were highly significant ($P < 0.001$) for crush scores and flight-speed scores. Charolais and Limousin calves had the highest crush scores with values of 2.78 ± 0.06 and 2.95 ± 0.07, respectively. Intermediate crush scores were observed in German Angus and German Simmental cattle (Figure 1). Herefords had the lowest crush scores (2.05 ± 0.07). German Angus and Hereford calves had the lowest flight-speeds, with values of 1.49 ± 0.05 and 1.46 ± 0.06, respectively. A continuous and significant increase in flight-speed scores were observed for German Simmental, Charolais and Limousin cattle (Figure 2).

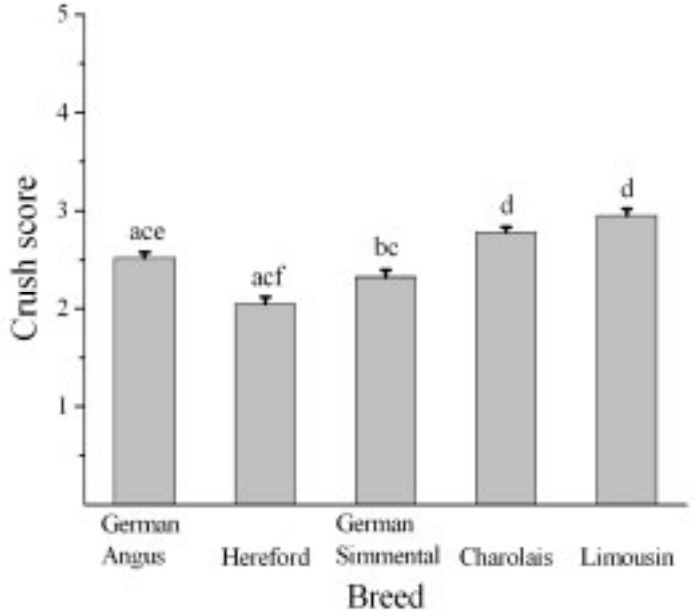

Figure 1. Least-square means (± SE) for crush score by the effect of the breed
a,b; c,d; e,f: $P < 0.05$

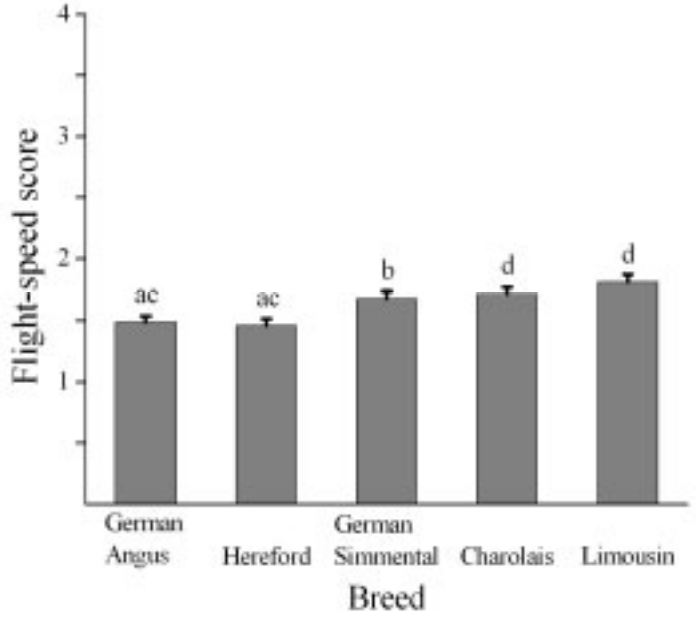

Figure 2. Least-square means (± SE) for flight-speed score by the effect of the breed
a,b; c,d: $P < 0.05$

Temperament scores differed significantly between male and female calves ($P < 0.01$). Females had a crush score of 2.57 ± 0.03, and a flight-speed score of 1.69 ± 0.03. In contrast, male calves were scored 2.49 ± 0.03 and 1.58 ± 0.03 for both traits. Corresponding values within each breed are presented in Table 3. In 2006, the animals' behavior was more agitated during handling compared to lower scores in 2007 (Table 3).

Table 3. Least-square means (± SE) for crush score and flight-speed score stratified by the effects of sex of calf and year

Test	Item	German Angus	Charolais	Hereford	Limousin	German Simmental
	Sex					
Crush score	male	2.48±0.07	2.79±0.07	1.98±0.08	2.92±0.08	2.27±0.08
	female	2.57±0.07	2.77±0.07	2.13±0.08	2.99±0.08	2.40±0.08
		n.s.	n.s.	*	n.s.	n.s.
Flight-speed	male	1.46±0.06	1.67±0.06	1.40±0.06	1.69±0.07	1.73±0.07
	female	1.51±0.06	1.78±0.06	1.52±0.06	1.87±0.07	1.89±0.07
		n.s.	*	*	**	**
	Year					
Crush score	2006	2.38±0.05	2.54±0.07	1.97±0.08	2.84±0.07	2.22±0.09
	2007	2.57±0.06	2.92±0.07	2.17±0.08	3.06±0.10	2.55±0.10
		**	***	**	*	***
Flight-speed	2006	1.40±0.04	1.50±0.06	1.53±0.06	1.84±0.06	1.68±0.08
	2007	1.45±0.04	1.81±0.06	1.48±0.07	1.73±0.08	1.80±0.08
		n.s.	***	n.s.	n.s.	n.s.

n.s., not significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

Only Hereford and Limousin cattle had lower flight-speed scores in the second year of this trial. Both measurements of temperament were significantly influenced by the effect of farm within breed ($P < 0.001$).The behavior of the animals during fixation in the head gate, and while leaving the crush was significantly influenced by the class of relative rank order ($P < 0.001$). Calves having low scores for the relative rank order had lower crush scores compared to animals of rank order groups 2 - 5 (Figure 3). Later entering of an animal in the weighing crush was associated with higher flight-speed scores. Calves in group 5 for relative rank order had the highest scores, indicating that they were more likely to run fast out of the crush if the front door was opened (Figure 4).

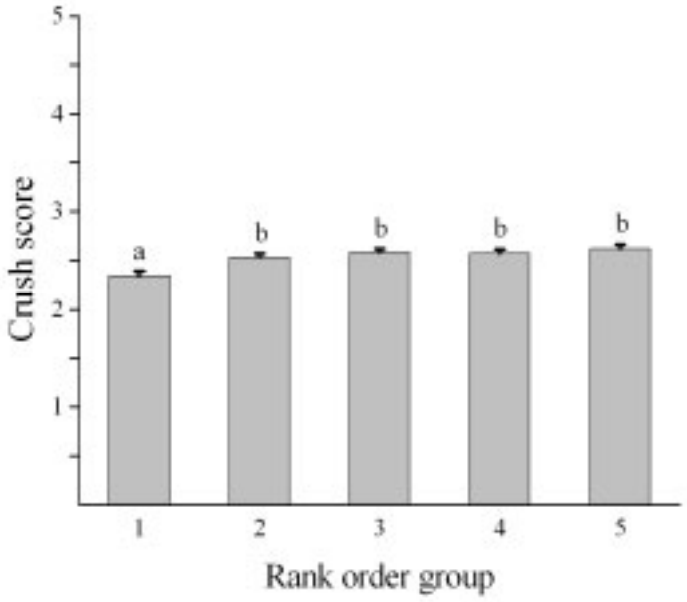

Figure 3. Least-square means (± SE) for crush score by groups for relative rank order a,b: $P < 0.001$

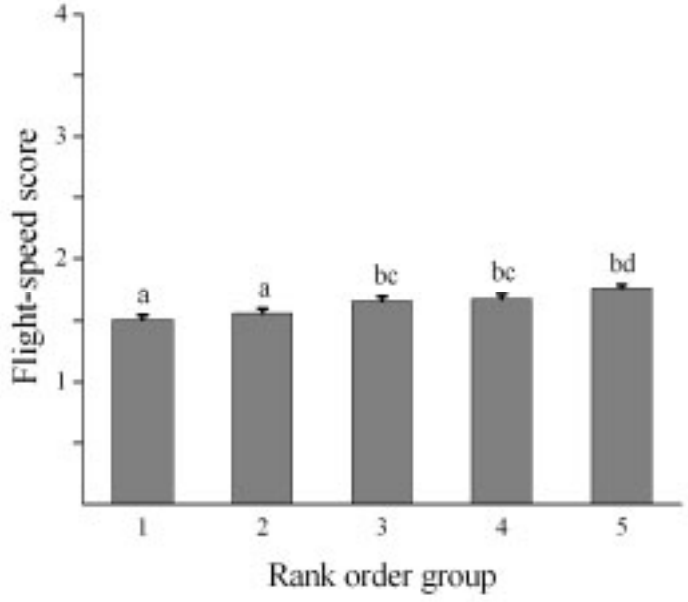

Figure 4. Least-square means (± SE) for flight-speed score by groups for relative rank order
a,b; c,d: $P < 0.05$

Average daily weight gains of the calves were significantly influenced by effects of breed ($P < 0.001$) and sex ($P < 0.001$) of the calves (Table 4). Male calves had higher average daily weight gains within each breed compared to female calves. Highest average daily weight gains were recorded for German Simmental cattle, with values of 1231 g/d and 1092 g/d for male and female calves, respectively, followed by Charolais and Hereford cattle. Average daily weight gain was lowest for German Angus calves.

Table 4. Least-square means (± SE) for weight and average daily weight gain (ADG) at testing date stratified by the effects of breed and sex of the calves

Breed	Sex	Weight (kg)	ADG (g/d)
German Angus	male	337 ± 2.2	1099 ± 8
	female	297 ± 2.3	963 ± 9
Charolais	male	363 ± 2.7	1216 ± 10
	female	326 ± 2.7	1089 ± 10
Hereford	male	272 ± 2.2	1210 ± 12
	female	244 ± 2.2	1081 ± 12
Limousin	male	292 ± 2.9	1130 ± 12
	female	258 ± 2.7	1004 ± 11
German Simmental	male	284 ± 2.6	1231 ± 13
	female	255 ± 2.7	1092 ± 14

Heritabilities were estimated for crush- and flight-speed scores of beef cattle. Estimates differed between 0.11 and 0.36 (Table 5). Heritabilities of crush score and flight-speed score were lowest for Limousin cattle having values of 0.11. In contrast, highest heritabilities were 0.33 for crush score, and 0.36 for flight-speed score of Hereford cattle. Genetic correlations were estimated between both traits of temperament, with values between 0.57 and 0.98 (Table 6). Both crush score and visual flight-speed score were negatively correlated with daily weight gain of the calves in most breeds (Table 6).

Table 5. Heritability estimates (± SE) of crush score and flight-speed score of the calves

Breed	Crush score	Flight-speed score
German Angus	0.15 ± 0.06	0.20 ± 0.08
Charolais	0.17 ± 0.07	0.25 ± 0.10
Hereford	0.33 ± 0.10	0.36 ± 0.06
Limousin	0.11 ± 0.08	0.11 ± 0.07
German Simmental	0.18 ± 0.07	0.28 ± 0.07

Table 6. Genetic correlations (± SE) among crush score (CS), flight-speed score (FS) and average daily weight gain (ADG) of the calves

Breed	CS – FS	CS – ADG	FS – ADG
German Angus	0.57 ± 0.17	0.13 ± 0.22	-0.04 ± 0.12
Charolais	0.63 ± 0.12	-0.16 ± 0.12	0.29 ± 0.17
Hereford	0.69 ± 0.08	-0.58 ± 0.11	-0.37 ± 0.11
Limousin	0.98 ± 0.08	-0.27 ± 0.27	-0.41 ± 0.27
German Simmental	0.98 ± 0.05	-0.34 ± 0.18	-0.27 ± 0.14

DISCUSSION

In this study, German Angus and Hereford cattle received lowest behavior scores in both temperament tests, indicating a calmer temperament of animals of these breeds compared to Charolais, Limousin, or German Simmental. Beneficial behavioral traits of British breeds were already observed in former studies (Vanderwert et al., 1985; Burrow and Corbet, 2000; Baszczak et al., 2006). Gauly et al. (2001a) found that German Angus cattle were easier to handle during a docility test than German Simmentals. Charolais and Limousin cattle seem to be more susceptible for stress during social isolation and close human-animal interaction, resulting in higher behavioral agitation during restraint, and higher flight-speeds when leaving the crush. The breeding history of Charolais and Limousin cattle may be an explanation for their excitable temperament. The traditional

French rearing system with a strong habituation of cattle to men could have masked underlying temperament traits preventing indirect selection processes (Grandin, 1994; Grandin et al., 1995). In contrast, Angus and Hereford cattle are traditionally reared under extensive pasture conditions with a minimum of human-animal-interactions. This may have promoted an indirect selection of calm and docile animals, whereas very nervous and aggressive animals were culled. This is also true for German Angus cattle, developed in the 1950s by breeding Aberdeen Angus bulls to German dual-purpose breeds. Repeated mating of Aberdeen Angus bulls to the initial population of German Angus cows may have forwarded docility of today's German Angus cattle.

Apart from the crush scores of Charolais cattle, female calves were scored higher in both test situations compared to male calves from the same breed, although not all differences were significant ($P > 0.05$). Based on these results, it could be assumed that at this age, male cattle have a more favorable temperament and are easier to handle than their female counterparts. This is in accordance with former studies observing higher behavioral agitation of female cattle during human handling (Stricklin et al., 1980; Voisinet et al., 1997; Gauly et al., 2001b). Temperament scores were higher in the second year of this trial. It is possible that different environmental influences like weather and resultant modifications of herd- and pasture management, e.g. frequent change of pasture and supplementary feeding, associated with habituation to human handling may have altered behavior of the animals. In addition, cattle used in this study were sired by different bulls (Table 2), with some bulls having progeny only in 2006 or 2007. Le Neindre et al. (1995) studied docility of Limousin heifers sired by 34 bulls, with significant differences between progeny groups. Similar results were reported by Mathiak (2002) for temperamental traits of German Angus and German Simmental cattle sired by different bulls. Relating to these results, paternal effects may partially explain the effect of year in this study.

As expected, the influence of farm within each breed effect on temperament traits was highly significant ($P < 0.001$), indicating that factors like prior experiences with human contact or handling, herd- and pasture management may have altered behavior patterns of the calves. Lanier et al. (2000) observed behavioral agitation of beef cattle during commercial auctions. They stated that it was not possible to control all the variables contributing to temperamental differences. This may be the same for the impact of different management effects in this study, described in the model by the general farm effect.

The behavioral agitation of the animals during fixation in the crush and the flight-speed were significantly influenced by the group of relative rank order, with calves of the first group having the lowest crush- and flight-speed scores. Calves which were easy to drive into the handling facility, or even passed it voluntarily, were more likely to remain calm and docile during restraint in the head gate. This finding confirms a former study by Tulloh (1961). Using *Bos indicus* crossbreds, Orihuela and Solano (1994) observed the relationship between order of entry and time spent to cover a distance of 20m in a slaughterhouse. They found that animals at the beginning of each group of five to seven cattle traversed the runway more quickly, indicating that they were easier to handle. In sheep, Syme and Elphick (1982) observed that vocal and stubborn animals moved at the back of the group during handling. Selecting calm and docile animals could therefore facilitate cattle handling, associated with reduced workload for routine management procedures. However, other factors may have contributed to the higher behavioral agitation of animals which were tested at the end of the whole group, e.g. they were longer separated from the herd (Grandin, 1980).

Body weight at testing date and average daily weight gain were significantly influenced by effects of breed ($P < 0.001$) and sex ($P < 0.001$) of the calves. This is in accordance with results of a former study using German Angus and Simmental cattle (Hoppe et al., 2008). Performance traits of the tested animals are representative for each breeds population in Germany (BDF, 2007).

Heritabilities estimated for both behavioral traits are low to moderate with significant differences between breeds. These estimates correspond with those reported earlier by Burrow and Corbet (2000). For repeated handling in a crush, Mathiak (2002) estimated heritabilities between 0.18 and 0.43 for German Angus and between 0.05 and 0.30 for German Simmental, respectively. Genetic correlations between both measurements of temperament differ between 0.57 in German Angus cattle and 0.98 in Limousin and German Simmental cattle. According to these results, it seems that either crush test or observation of flight-speed measure the same aspects of cattle temperament. In this experiment, beef cattle calves were exposed to social isolation from their herdmates, and close human contact during restraint in the crush, which have generated individual reactions of the calves to the test procedure. Both higher behavioral agitation during restraint and higher flight-speed scores indicate an attempt to escape in this restricted test situation. Therefore it is possible to use both tests to evaluate cattle temperament. Heritability is generally higher for visual flight-speed scores in contrast to crush scores.

Consequently, recording the gait of cattle exiting the crush may be a less subjective and more accurate measurement of temperament than the crush test. When applying the crush test, the observer assigns a score to the degree of agitation during restraint (Baker et al., 2003) associated with a highly subjective component. The negative genetic correlations between average daily weight gain and temperament scores suggest that less docile animals are less productive. Selection of beef cattle with desirable temperaments may lead to increased performance, resulting in both economic improvement of beef cattle production as well as labor efficiency due to improvements in behavior.

The results of this study show that both the crush-test and flight-speed scoring are adequate tools to detect individual differences in beef cattle temperament under field conditions. In terms of the requirements for a good test procedure devised by Grignard et al. (2001) and Boivin and Trillat (2006), these tests are easy to perform on farm. In addition, moderate heritabilities of both traits indicate sufficient repeatability. Furthermore, the crush test used in this study corresponds to routine handling situations representing current beef cattle husbandry conditions, because many routine management tasks are performed in a crush. The integration of both tests in the routine weighing process at weaning prevents additional workload for cattle handling and further stress for the animals. Another advantage of visual flight-speed scores is that no further equipment is required. Other procedures, e.g. electronic measurement of the time interval for a fixed distance after leaving the weighing crush (Burrow et al., 1988), are more labor intensive.

The results presented in this paper clearly point out that on-farm evaluation of beef cattle temperament is possible, either using the crush test or the flight-speed test. Genetic selection seems to be promising to improve temperamental traits of beef cattle without decreasing production traits like average daily weight gain of the calves. Within Hereford, Limousin and German Simmental cattle, a simultaneous improvement of temperament and performance can be expected.

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3rd CHAPTER

MATERNAL PROTECTIVE BEHAVIOUR OF GERMAN ANGUS AND SIMMENTAL BEEF CATTLE AFTER PARTURITION AND ITS RELATION TO PRODUCTION TRAITS

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Published in

Applied Animal Behaviour Science (2008) 114: 297-306

MATERNAL PROTECTIVE BEHAVIOUR OF GERMAN ANGUS AND SIMMENTAL BEEF CATTLE AFTER PARTURITION AND ITS RELATION TO PRODUCTION TRAITS

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ABSTRACT

A total of 390 German Angus (Aberdeen Angus x German dual-purpose breeds) and Simmental cows were tested in seven consecutive years (2000-2006) for maternal protective behaviour which was assessed by categorising behavioural response of the dams during earmarking their calves. The test was conducted within 24 h after parturition by the same person. Analysis of variance of maternal protective behaviour scores (MBS) was performed using a model including breed, lactation-number and calving month as fixed effects as well as the interaction between breed and lactation-number. The cow was included as a random effect. Breed, lactation-number and the interaction breed x lactation-number highly affected MBS. German Angus was scored higher than Simmental as well as cows with higher lactation-numbers in comparison to younger cows. Heritability was estimated under consideration of the whole relationship matrix and differed between 0.14 ± 0.08 for German Angus and 0.42 ± 0.05 for Simmental. Repeatabilities for MBS were 0.24 ± 0.04 for German Angus and 0.42 ± 0.05 for Simmental, respectively. Weaning weights and average daily weight gains of the calves were not correlated with maternal protective behaviour scores.

Key Words:

maternal protective behaviour, beef cattle, German Angus, Simmental, temperament

INTRODUCTION

In beef cattle, the maternal behaviour of the cow is essential for a proper development of the newborn calf. Features of the maternal behaviour are the establishment of a solid cow-calf relationship, the support of the calf's suckling behaviour and the cow's attentiveness to the calf, including its active protection (Grandinson, 2005). Handling the calf is necessary for routine management procedures immediately after birth (Turner and Lawrence, 2007). If the stockman is considered to be a threat for the calf, the mother cow may attack. This results in a higher risk of injury for both, animals and stockman during routine handling like weighing and earmarking the calves (Buddenberg et al., 1986; Le Neindre et al., 1998, 2002). Aggressive behaviour after parturition occurs regularly in a large number of suckler cows, especially when reared on pasture (Le Neindre et al., 1999).

Since average sizes of beef cattle herds are increasing in Europe (ADR, 2007) and the human contact per animal is reduced, cattle handling may become even more dangerous. At the same time, handling procedures such as veterinary care, identification of calves and weighing are required (Le Neindre et al., 1998; Turner and Lawrence, 2007). In consequence, negative behavioural responses of extensively kept cattle are likely to happen more often during these routine management procedures, strengthening the risk of injuries or increasing the workload for cattle handling.

In general, temperament is defined as an animal's reaction to human contact or handling (Fordyce et al., 1985, 1988). It is determined by both, genetics and environmental factors (Grandin and Deesing, 1998). Temperament can be quantified by scoring behaviour in a standardised test situation (Tulloh, 1961; Burrow et al., 1988; Le Neindre et al., 1995). To assess maternal protective behaviour of suckler cows, their reaction to human contact whilst earmarking their calves was observed in different studies (Buddenberg et al., 1986; Morris et al., 1994). Although quite low, the heritability of maternal protective behaviour was shown in these studies.

Avoidance behaviour in ewes during earmarking their lambs was examined by O'Connor et al. (1985). A higher fear response in ewes was associated with an increased preweaning mortality of lambs and a tendency to lower weaning weights of surviving lambs. Ewes selected for calm temperament due to lower fearfulness and reactivity in response to humans and a novel environment showed a better maternal behaviour (Murphy et al., 1998). They showed less avoidance behaviour towards humans at lambing, spent more time at the birth site and grooming their lambs and vocalised more to their

lambs. The mortality in lambs of calm ewes was significantly lower until weaning. In lactating sows, Grandinson et al. (2003) estimated a genetic correlation of 0.37 ± 0.34 between fear of humans and mortality of piglets, indicating that a lower fear response of sows is associated with a lower mortality rate. In cattle, Le Neindre et al. (2002) reported that Limousin heifers which reacted more docile to human handling had a better maternal behaviour if they later become a dam. The genetic correlation between docility and licking time was 0.34, with heritabilities of 0.29 for docility and 0.32 for licking time, respectively. Licking is therefore considered to be an important element of maternal behaviour in beef cattle (Le Neindre et al., 2002). Phocas et al. (2006) obtained similar results for Limousin heifers. Breed differences in maternal behaviour were recorded by Le Neindre (1989) for Salers and Friesian cows.

This highlights the importance of general maternal behaviour, especially of maternal protective behaviour after parturition. Up to date no studies were conducted using German Angus and Simmental cattle and no breed-specific heritabilities were published for this trait. Moreover, there is no information about the relation between maternal protective behaviour after parturition and performance traits of the calves. Therefore, the objective was to estimate genetic parameters of maternal protective behaviour and to determine factors affecting it. In addition, the influence of maternal protective behaviour after parturition on production traits like weaning weight and average daily weight gain of the calves was analysed.

MATERIALS AND METHODS

Experimental location

Data were collected between 2000 and 2006 at the Experimental Farm of the Department of Animal Breeding and Genetics of the University of Giessen in Rudlos, Germany. It is located in the low mountain range region Vogelsberg with an average height of 400 m above sea level. Average daily temperature and annual rainfall were 7.5°C and 500 mm, respectively. Nearly half of the farmland of 420 ha is used as pasture for the cattle.

Animals

The herd includes about 240 suckler cows. Half of the herd are German Angus and half are Simmental cows, kept on pasture from May to October. During winter (November to April) the animals were housed in barns on straw with an average group size of 30 cows.

Parturitions usually run from January to May each year within the herd with approximately two-thirds of the parturitions in February and March. The herd was established in 1997 by purchasing heifers from different beef cattle breeders throughout Germany. Simmental heifers originated partially from dairy farms. Since that time replacement heifers were exclusively selected from progeny born at Rudlos. Breeding bulls were only purchased from beef cattle breeders or selected from the own progeny. At Rudlos, all animals were managed under the same rearing conditions over the complete trial period.

Test procedure

The test was conducted within 24 h postpartum during the routine handling procedures of weighing and earmarking of the newborn calves. For this purpose the calves were caught in the barns and brought to the feed alley, so that intervisibility between mother and young was always ensured. The test procedure was modified from those described by Buddenberg et al. (1986) and Morris et al. (1994). Over the complete trial period, the behavioural response of the cow during catching, removing and earmarking her calf was scored by the same person, using a scoring system from 1 to 5: 1, the cow stands very quietly or rather shows indifference in the procedure; 2, the cow stands quietly and observes her calf, slightly excited; 3, the cow is excited, occasionally pawing the ground; 4, the cow is nervous and attempts to interfere with the handling procedure, the handler only feels safe if the cow is watched all the time; 5, the cow is dangerous and tries to push the handler away from her calf. The scoring system used in this study allocates five different classes to the observed behaviour of the cow, which basically represents a continuous variate.

Calves were weighed within 24 h after birth and at weaning with an average age of seven months. Average daily weight gain was calculated from birth to weaning.

Statistical analysis

The analysis of variance was carried out with the mixed procedure of the software package SAS 9.1.3 (2001) using a linear model. Breed, lactation-number and calving month were considered as fixed effects on the cow's score for protective behaviour after parturition as well as the interaction between breed and lactation-number. The cow was considered as a random effect. Heritability (h^2) was estimated using the programme ASReml version 1.10 (Gilmour et al., 2002) with an animal model under consideration of the whole relationship matrix with the following model:

$$y_{ijklm} = \mu + B_i + LNR_j + CM_k + (B \times LNR)_{ij} + pe_l + a_m + e_{ijklm}$$

with y_{ijklm} = maternal behaviour score, B_i = fixed effect of breed, LNR_j = fixed effect of lactation-number, CM_k = fixed effect of calving month, $(B \times LNR)_{ij}$ = fixed interaction between breed and lactation-number, pe_l = random permanent environmental effect of cow, a_m = random additive-genetic effect of cow, and e_{ijklm} = random residual effect.

Repeatabilities were calculated using the programme ASReml version 1.10 (Gilmour et al., 2002).

To analyse the effect of the cows maternal protective behaviour score on the performance of the calves for weaning weight and average daily weight gain a linear model was implemented using the GLM procedure. Breed, sex and birth year of calf, calving month, lactation-number and maternal protective behaviour score were considered as fixed effects in this model. For weaning weight, the age of the calves was considered as a covariate in the model.

RESULTS

A total of 1305 observations of maternal protective behaviour after parturition were recorded, including 727 observations from 197 German Angus cows and 578 observations from 193 Simmental cows. About 77 % of the observations were recorded after parturitions until March (Figure 1).

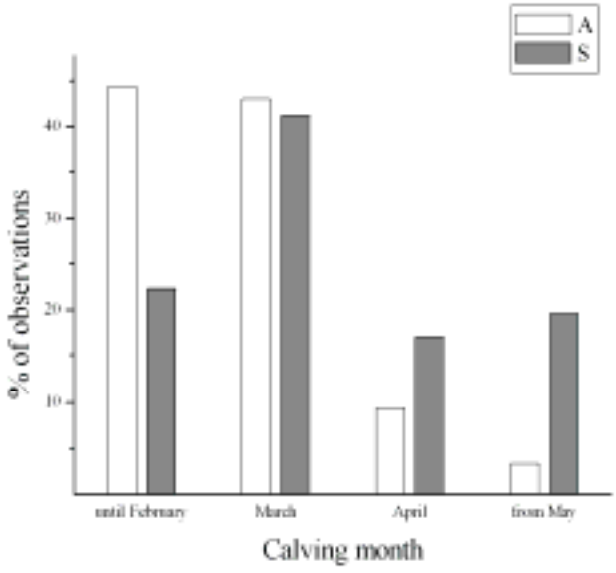

Figure 1. Relative distribution of observations depending on calving month within German Angus (A) and Simmental (S) cattle

The mean number of calvings was 6.0 ± 2.5 for German Angus cows and 4.9 ± 2.4 for Simmental cows, respectively. The behaviour of nearly 4 % of the German Angus cows and about 15 % of the Simmental cows was scored 1, indicating that these animals were very calm with nearly no behavioural agitation during handling of their calves. On the other hand, nearly 16 % of the cows were scored 4 or 5 for German Angus in contrast to only 7 % of the Simmental cows, indicating that German Angus cows paid more attention to their calves and had a greater disposition to interfere with the handling procedure (Figure 2). So German Angus cows had significantly higher temperament scores than Simmental cows ($P < 0.001$), with values of 2.78 ± 0.05 and 2.29 ± 0.05, respectively.

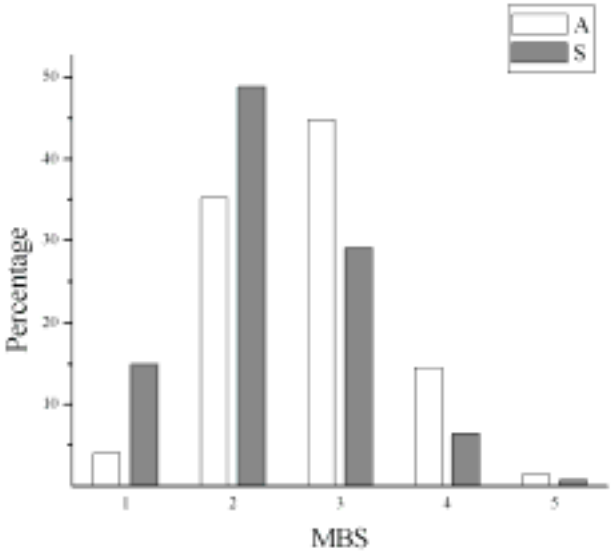

Figure 2. Relative distribution of maternal protective behaviour scores of German Angus (A) and Simmental (S) cattle

The lactation-number had a significant influence ($P < 0.001$) on the behavioural response of the cows, just as the interaction between breed and lactation-number ($P < 0.001$). Cows after first calving showed the lowest behavioural response to human handling of their calves, indicating that they were more docile than older cows (Figure 3).

The statistical analysis revealed significant differences between calving months for this behavioural trait ($P < 0.01$). For calvings until February the average score was 2.40 ± 0.04. Higher scores were observed in March and April (Figure 4). Cows showed the greatest behavioural response after calvings from May on, with an average score of 2.74 ± 0.08.

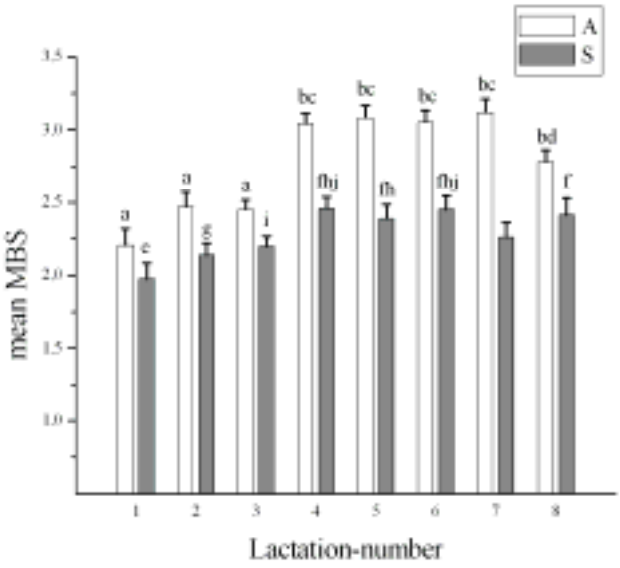

Figure 3. Influence of breed and lactation-number on maternal protective behaviour scores (LSQ-means ± SE)
[a,b; c,d; e,f; g,h; i,j] $P < 0.05$

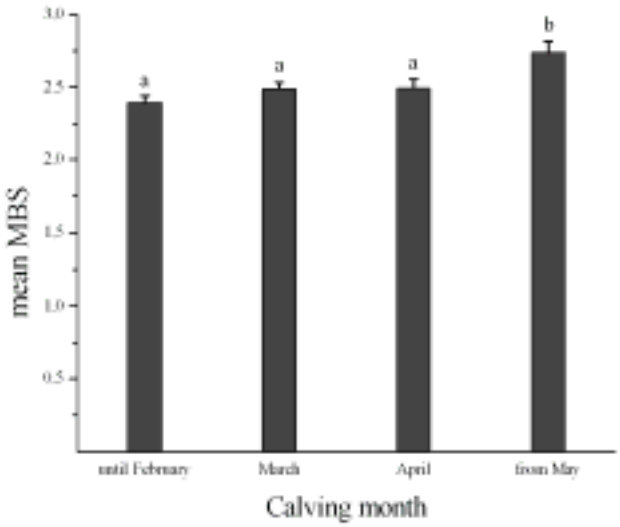

Figure 4. Influence of calving month on maternal protective behaviour scores (LSQ-means ± SE)
[a,b] $P < 0.01$

The repeatability of maternal protective behaviour scorings was 0.33 ± 0.03 over both breeds and all lactations. Separated by breed, the repeatability over all lactations was 0.24 ± 0.04 for German Angus and 0.42 ± 0.05 for Simmental. Repeatabilities for consecutive lactations differed between 0.26 and 0.50 for German Angus and 0.23 and 0.63 for Simmental (Table 1). The estimated heritabilities for maternal protective behaviour were 0.14 ± 0.08 for German Angus and 0.42 ± 0.05 for Simmental, respectively (Table 2). Over both breeds a heritability of 0.33 ± 0.03 was estimated.

Table 1. Repeatabilities (± SE) of maternal protective behaviour scores for consecutive lactation-numbers of German Angus and Simmental cows

	Repeatabilities (± SE)	
Lactation-number	German Angus	Simmental
1 – 2	0.50 ± 0.16	0.23 ± 0.19
2 – 3	0.46 ± 0.15	0.48 ± 0.11
3 – 4	0.26 ± 0.08	0.34 ± 0.10
4 – 5	0.32 ± 0.11	0.63 ± 0.09
5 – 6	0.47 ± 0.11	0.52 ± 0.11
6 – 7	0.27 ± 0.12	0.63 ± 0.09
7 – 8	0.29 ± 0.10	0.47 ± 0.13
1 – 8	0.24 ± 0.04	0.42 ± 0.05

Table 2. Estimated variance components for maternal protective behaviour scores of German Angus and Simmental cows

	German Angus	Simmental
$\sigma^2_{\text{additive-genetic}}$	0.0769	0.2729
$\sigma^2_{\text{permanent environment}}$	0.0462	0.3×10^{-6}
$\sigma^2_{\text{residual}}$	0.4288	0.3816
$\sigma^2_{\text{phenotypic}}$	0.5519	0.6545
h^2 (± SE)	0.14 ± 0.08	0.42 ± 0.05

Table 3. Phenotypic correlations of maternal protective behaviour scores and production traits of the calves

	Maternal behaviour score		
	German Angus	Simmental	All
Weaning weight	0.03	-0.08	-0.12
Average daily weight gain	0.05	-0.02	-0.09

Weaning weights and average daily weight gains of the calves were not significantly correlated with maternal protective behaviour (Table 3). Over all scores, mean values for weaning weights differed between 266 kg and 270 kg, for average daily weight gains between 1053 g/d and 1064 g/d, respectively (Table 4). Weaning weights and average daily weight gains were significantly influenced by breed and sex of calf ($P < 0.001$), calving month ($P < 0.01$) and lactation-number ($P < 0.001$).

Table 4. LSQ-means (± SE) for weaning weights (kg) and average daily weight gain (g/d) of the calves depending on maternal protective behaviour scores

	LSQ-means (± SE)	
MBS	Weaning weight	Average daily weight gain
1	270.2 ± 3.8	1064 ± 17.0
2	267.7 ± 2.1	1059 ± 9.1
3	266.1 ± 2.1	1053 ± 9.3
≥4	268.2 ± 3.5	1062 ± 15.5

DISCUSSION

The maternal protective behaviour of suckler cows at parturition differs significantly between German Angus and Simmental cows. This suggests that German Angus cows pay more attention to their calves during handling and have a greater disposition to actively defend their calves, for example by trying to push the handler away from the calf. Dairy cattle have been selected for less intense maternal behaviour compared to beef breeds in which a strong maternal behaviour is favoured (Edwards and Broom, 1982; Le Neindre, 1989). Selman et al. (1970) noticed that maternal behaviours after parturition were more vigorously shown in beef cattle than in dairy cattle. In reference to Simmental, traditionally reared as a dual-purpose breed for milk and beef production, this may explain the high percentage of Simmental cows scored 1, indicating that these mothers had a calmer temperament during handling of their calves. So the lower mean scores could be evidence for an overall weaker development of protective behaviour in Simmental cattle. The higher mean scores for German Angus are in agreement with the results of Buddenberg et al. (1986) who observed post calving behaviour of four different *Bos taurus*-beef breeds, including Angus, Charolais, Hereford and Red Poll cattle. In their study Angus cows received the highest scores, followed by Red Poll, Charolais and Hereford cows, indicating that Angus cows have the greatest disposition for aggressive behaviour against stockman whilst handling their calves. Morris et al. (1994) compared

Angus and Hereford purebred cows with different crosses out of these breeds. Differences between breed groups were highly significant, with Angus purebreds being the most and Hereford half- and purebreds being the least aggressive cows.

Beside the breed, the observed behaviour was highly affected by lactation-number and the interaction between breed and lactation-number. Lowest scores were given for cows after first calving. A reason for this could be that a young cow has no experience in rearing a calf so that important maternal behaviour traits are less pronounced than in older cows. In dairy cattle, it was observed that heifers which have failed to lick their first calf showed an adequate licking behaviour after their second parturition (Donaldson et al., 1971; Edwards and Broom, 1982). This indicates a stronger development of maternal behaviour in multiparous cows since licking is considered to be an important maternal care trait (Le Neindre et al., 2002). Price et al. (1986) tested maternal-filial relationships in Hereford cattle. A higher behavioural response of cows to a separation from their calves in comparison to heifers was observed. They emphasised that the effect of a former pregnancy was especially evident during the return of the calves from separation, when cows were more likely to approach and to follow their calves than heifers. Price et al. (1986) added that it is possible that maternal responses to the separation may be more easily triggered in cows than in heifers because of prior mothering experiences. In this study, behaviour scores were slightly higher for both breeds after second and third calvings, whereas behaviour scores of German Angus cows had a greater increase between 4^{th} and 7^{th} calf compared to Simmental. After the 8^{th} calving the maternal protective behaviour of German Angus cows was scored lower. Such an increase in maternal ratings for consecutive lactations was also shown by Buddenberg et al. (1986). They observed that scores were higher for 2^{nd} and 3^{rd} to 6^{th} calving in contrast to cows after first calving. Unlike this study, Buddenberg et al. (1986) had shown a further increase in maternal protective behaviour scores for older cows after 7^{th} calving. Because of the differences between breeds and lactation-numbers, it seems that suckler cows tend to develop a greater disposition for protective behaviour as a result of this routine management procedure involving their calves. The decrease in maternal protective behaviour scores of German Angus cows after 8^{th} calving may be due to the fact that highly aggressive cows were culled. In general, there is no habituation of cows to this particular handling procedure. Catching and earmarking their calves rather seems to be an aversive stimulus for suckler cows leading to higher behavioural responses in consecutive lactations. Such detrimental

effects of aversive handling were also shown in dairy cattle by De Passillé et al. (1996) for Holstein calves and by Rushen et al. (1998) for Danish Friesian cows.

Higher values of maternal protective behaviour scores after parturitions in May could be due to the fact that parturitions occurred partially on pasture. Because of the natural environment, the cow may show greater maternal care for her calf and therefore a greater protective behaviour. Le Neindre et al. (1999) observed that suckler cows reared in free range conditions all year round tend to exhibit aggressive behaviour after parturition more often than those which are housed in barns during winter. For Limousin cattle, Le Neindre et al. (1995) noticed that heifers reared indoors were more docile than those reared outdoors. Furthermore it is possible that the maternal protective behaviour scores are higher in May due to an overall smaller number of parturitions in this month.

Unlike the former estimations of heritability for maternal protective behaviour by Buddenberg et al. (1986) and Morris et al. (1994) with values of 0.06 and 0.09 respectively, the estimated heritability of 0.33 is moderate, so that the genetic component of this particular trait seems to be higher. The great differences between heritabilities of German Angus (0.14) and Simmental (0.42) are the result of divergent additive-genetic variances for both breeds (Table 2). A reason for these differences could be that Simmental cattle were purchased from beef cattle farms as well as from dairy farms. Therefore the genetic variability between the Simmental cows may be higher than those of the German Angus cows. Differences between breeds or breed-crosses and number of genotypes used in these studies could also contribute to divergent estimations of heritability, as well as small methodical differences in scoring systems or number of persons assigning the scores.

The scoring systems used in all these studies do not contain the full range of maternal behaviour, but are limited to the cow's reaction to this special handling situation in the form of close human-animal interactions. Major traits of maternal behaviour like the establishment of a solid cow-calf relationship, the support of the calf's suckling behaviour and the avoidance of suckling from alien calves are not considered. Nevertheless, this post-calving temperament score could be an indicator for the cow's maternal ability towards the calf (Morris et al., 1994).

No differences in weaning weights and average daily weight gains between maternal behaviour ratings were observed. Detrimental effects on the productivity of the cows depending on her protective behaviour after parturition should not be expected.

Based on the results of this experiment, scoring of maternal protective behaviour after parturition makes it possible to identify individuals which become highly agitated during handling of their calves. These cows could lead to an increased workload for required management tasks and they may endanger animal and handler safety. The estimated heritabilities make it possible to select in this behavioural trait of beef cattle without decreasing the examined production traits of the calves. However, subsequent research is required to quantify the relationship between maternal protective behaviour after parturition on the one hand and increased docility of individuals during routine management procedures on the other hand. Finally it is essential to understand how selection for maternal protective behaviour could impact on other important maternal care traits.

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4th CHAPTER

TEMPERAMENTAL TRAITS OF GERMAN ANGUS AND SIMMENTAL BEEF CATTLE MEASURED AT YOUNG AGE AND THEIR RELATIONSHIPS TO MATERNAL PROTECTIVE BEHAVIOR

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Submitted to

Journal of Animal Science (December 6th, 2008)

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ABSTRACT

Over a period of eleven years (1998 – 2008) temperamental traits of German Angus (Aberdeen Angus x German dual-purpose breeds) and German Simmental calves were measured at young age. Altogether, 4,435 calves were examined using three different test procedures. Additionally, maternal protective behavior of suckler cows was assessed within the first 24h after parturition by categorizing behavioral response of the dams during earmarking their calves. A total of 1,693 observations were made on 424 cows. Estimations of genetic (co)variance parameters were accomplished 1.) among the different temperamental traits of the calves and 2.) between these temperamental traits of the calves and maternal protective behavior of the dams after parturition. Heritability estimates for temperamental traits measured at young age ranged from 0.07 ± 0.03 to 0.35 ± 0.05, with values being generally higher for behavior scores than for running or times moving. Genetic correlations between behavior scores were in the range from 0.28 ± 0.16 to 0.65 ± 0.16. Heritability estimates of maternal protective behavior differed between 0.25 ± 0.05 for German Angus and 0.42 ± 0.03 for German Simmental cows, respectively. Finally, it was examined if maternal protective behavior of suckler cows after parturition can be predicted from temperament measures recorded at young age. Genetic correlations between temperament measures of calves and mature cows differed between 0.18 ± 0.18 and 0.99 ± 0.32 in the German Angus breed. Corresponding values were observed in German Simmental cattle ranging from 0.13 ± 0.11 to 0.53 ± 0.16. The results of this study

suggest the possibility for setting up selection strategies on temperamental traits in beef cattle, either at young or mature age. Favorable genetic correlations were found between behavioral traits from calf and cow measurements. Hence, additional genetic gain per year for cow temperament is possible through a substantial reduction in generation intervals and optimization of selection strategies, i.e. selection on temperament at an early stage of life.

Key Words:

beef cattle, genetic parameters, German Angus, maternal protective behavior, Simmental, temperament

INTRODUCTION

Suckler cows are the base of beef cattle production, staying in the herd for several years. Pronounced maternal behavior is preferred to suit low-labor input farming systems (Turner and Lawrence, 2007). The establishment of a solid cow-calf relationship, the support of the calf's suckling behavior and the cow's attentiveness to the calf, including its active protection are required for a proper development of the calf (Grandinson, 2005). At the same time, Le Neindre et al. (1999) observed that cows often show aggressive behavior against humans after calving, especially when reared on pasture with rare human-animal interactions.

Maternal protective behavior of suckler cows is moderately heritable, affected by breed, lactation-number or calving season (Buddenberg et al., 1986; Morris et al., 1994; Hoppe et al., 2008). Le Neindre et al. (2002) have shown that Limousin heifers which remained calm and docile during handling had a better maternal behavior. These animals licked their calves significantly longer than heifers which were highly agitated during a docility test. The situation seems to be the same in sheep (Murphy et al., 1998) and in pigs (Marchant Forde, 2002).

Individual temperament of beef cattle can vary from docility to aggression with docility being favored for farming conditions. It is a moderately heritable trait which differs among and within beef cattle breeds (Le Neindre et al., 1995; Gauly et al., 2001; Grignard et al., 2001), but up to date no information is available whether selection for calm and docile beef cattle has an impact on later maternal behavior of suckler cows.

The aim of this study was to determine if aggressiveness of suckler cows towards humans after parturition can be predicted from temperament measures recorded at a young age. To generate a substantial base for future selection strategies, genetic (co)variance components among different temperament traits in calves and maternal protective behavior of suckler cows were estimated.

MATERIALS AND METHODS

Experimental location

The present study was conducted at the Experimental Farm "Rudlos" of the Department of Animal Breeding and Genetics of the University of Giessen, Germany. Rudlos is located in the low mountain range region Vogelsberg with an average height of 400 m above sea level, an average daily temperature of 7.5°C, and an average annual rainfall of 500 mm.

Animals

The herd consists of 240 suckler cows, one half each German Angus and Simmentals. Cows and calves were kept on pasture from May to October in groups of 25 to 40 cows plus calves. During winter months (November to April) the animals were housed in barns on straw with an average group size of 30 cows. Parturitions were usually executed within the herd and from January to May each year with approximately two-thirds of the parturitions in February and March. Over the complete trial period animals were managed under the same rearing conditions.

Behavior tests

At Rudlos, different behavior tests were performed between 1998 and 2008: At first, a restraint test approximately 5 weeks after birth of the calves and secondly, a crush test and docility test at time of weaning at an age of 6 to 8 month. Table 1 gives an overview of numbers of observations for each test procedure.

Table 1. Number of observations for each test recorded between 1998 and 2008

	Test procedure			
Year	Fixation test	Crush test	Docility test	Maternal behavior test
1998	220	241	235	-
1999	216	242	230	-
2000	241	223	230	225
2001	241	231	240	244
2002	167	238	-	106
2003	227	-	207	212
2004	230	-	200	192
2005	-	-	-	124
2006	190	186	-	191
2007	-	-	-	186
2008	-	-	-	213
Total	1,732	1,361	1,342	1,693

Data were collected over the years by five different persons, but within a year the same observer recorded relevant temperamental traits and assigned the scores, except the years between 1999 and 2004. In these years three independent observers rated the animal's temperament during the docility test. Maternal behavior of suckler cows after calving

(maternal protective behavior test) was recorded by the same technician over the whole trial period.

The restraint test was modified from Boissy and Bouissou (1988). Calves were consecutively separated from the herd in a yard with visible contact to the other animals. Each calf was tethered with a rope around the head for 120 s. Time spent moving was recorded and behavioral agitation was classified using a four-point scale: 1 = relaxed, almost no body movement, with a loose tether rope; 2 = slightly nervous, regular body movement, tether rope often taut; 3 = nervous, some strong body movement, tether rope taut, calf struggling; and 4 = wild, fighting against tether rope. Two persons were involved in the test: one person caught the calf out of the herd and tethered it while a second person recorded the time spent moving and assigned the behavior score.

At weaning, temperament of calves was scored using the crush-test (mod. from Tulloh, 1961). For each animal the behavior while entering the crush was observed using four scores: 1 = animal enters the crush voluntarily; 2 = hesitantly, verbal driving required; 3 = animal enters only when urged with a cane, and 4 = difficult to get the animal into the crush. Crush scores reflect cattle behavior while restraint in the head bail, and were assigned immediately after fixation, according to a five-point system suggested by Grandin (1993): 1 = calm, no movement; 2 = restless, shifting; 3 = squirming, occasionally shaking of the crush; 4 = continuous vigorous movement, and shaking of the crush; and 5 = rearing, twisting of the body, or violent struggling.

Additionally, animals were tested in a docility test according to Le Neindre et al. (1995) and Gauly et al. (2001), with a combination of a non restraint (separation test) and a restraint test. At first, a group of ten animals were directed into a separation yard (100 m^2) with open walls on all sides. Then a handler attempted to separate one animal from the group into the restraint yard (25 m^2) for a maximum time of 180 s. The restraint yard was separated from the separation yard by a gate, which was opened by a second person. If the animal showed any aggression, such as lowering the head, threatening or attacking the handler, the separation procedure failed and maximum time was recorded. Total separation times were observed and recorded for all tested animals. In the second part of the docility test, the separated animal was left alone for 30 s in the restraint yard. The handler entered the restraint yard and stood still for another 30 s. This 60 s period was defined as the "before handling period". The handler then tried to move the animal into the far corner of the restraint yard (2 m x 2 m) for a maximum duration of 120 s. An attempt was made to

restrain the animal there for 30 s. This 180 s period was defined as the "handling period". Test duration of 120 s was recorded if the animal could not be moved into the corner or if it showed any sign of aggression. The recorded variables are shown in table 2.

Table 2. Recorded variables (max. time period) during both parts of the docility test

Variable	Abbreviation
Separation test (120 s)	
Time needed to separate an animal out of a group of ten	ST
Restraint test (60 s)	
Before handling period (60 s)	
Time spent running before handling in the restraint yard	RT1
Time spent running during handling in the restraint yard	RT2
Handling period (180 s)	
Time spent running in the restraint yard	RT3
Time until animal reached the corner	TUC
Time spent in corner	TIC
Behavior score of Handler A	DSA
Overall behavior score	DSM

The maternal protective behavior test, similarly described by Hoppe et al. (2008), was conducted within 24 h postpartum during the routine handling procedures of weighing and earmarking of the newborn calves. For this purpose the calves were caught in the barns and brought to the feed alley, with visible contact between cow and calf. The behavioral response of the cow during catching, removing and earmarking her calf was scored using a five-point system: 1 = the cow stands very quietly or rather shows indifference in the procedure; 2 = the cow stands quietly and observes her calf, slightly excited; 3 = the cow is excited, occasionally pawing the ground; 4 = the cow is nervous and attempts to interfere with the handling procedure, the handler only feels safe if the cow is watched all the time; and 5 = the cow is dangerous and tries to push the handler away from her calf. Over the years, repeated records of maternal behavior scores (MBS) were collected for a single cow in consecutive lactations.

Statistical analysis

Variance components and heritabilities for all calf measurements (i.e. fixation test, crush test, and docility test) as well as for the behavior scores of the cows were used from univariate animal models. REML methodology as incorporated in the software package VCE4, Version 4.2.5 (Neumeier and Groeneveld, 1998) was applied for all runs analyzing different breeds separately.

For the calf traits measured once at young age, the model 1 in matrix notation was:

$y_i = X_i b_i + Z_i a_i + e_i$, [1]

where y_i = vector of observations for the *i*th trait, b_i = vector of the fixed effects for the *i*th trait, a_i = vector of random genetic animal effects of the calf for the *i*th trait, and e_i = vector of random residual effects for the *i*th trait, and **X, Z** are the incidence matrices relating records to fixed and random effects. The fixed effects in model [1] were the effects of sex, and year. Age of the animal was considered in design matrix **X** as a linear regression. Genetic correlations among temperamental traits of young calves were estimated together for both breeds, and breed was then considered as a fixed effect in model [1].

Covariance components among different calf measurements were from all combinations of bivariate analyses. For these analyses, the (co)variance matrix of random effects considering two calf traits, e.g. trait 1 and trait 2, was:

$$\text{var}\begin{bmatrix} a_1 \\ a_2 \\ e_1 \\ e_2 \end{bmatrix} = \begin{bmatrix} g_{11}A & g_{12}A & 0 & 0 \\ g_{21}A & g_{22}A & 0 & 0 \\ 0 & 0 & r_{11} & r_{12} \\ 0 & 0 & r_{21} & r_{22} \end{bmatrix}$$

where g_{11} = additive genetic variance for the direct effect for calf trait 1, $g_{12} = g_{21}$ = additive genetic covariance between both calf traits, g_{22} = additive genetic variance for the direct effect for calf trait *2*, A = additive genetic relationship matrix, and r_{11}, r_{12}, r_{21}, r_{22} are the elements of **R** being the variance and covariance matrix for residual effects.

For the behavior scores *j* of cows, the model 2 in matrix notation was:

$y_j = X_j b_j + Z_j a_j + W_j pe_j + e_j$, [2]

where pe_j = vector of permanent environmental effects of the cow, and **W** = the belonging incidence matrix. The fixed effects in model [2] were the effects of parity, year, and calving month.

When correlating calf and cow traits, both traits are not necessarily recorded on the same animal, i.e. some calves had only calf measurements, and some cows had only maternal behavior scores. In such situations, there is no environmental covariance between traits and the residual covariance matrix **R** is diagonal, such as in the current case for two traits:

$R = diag(\sigma^2_{e1}, \sigma^2_{e2})$

However, the estimation of genetic covariances between cow and calf traits is possible through the incorporation of the relationship matrix *A* in the mixed model equations (MME).

Covariance components among different calf measurements and the behavior scores of cows were estimated from all combinations of bivariate analyses. For these analyses, the (co)variance matrix of random effects considering the calf trait *i* and the cow trait *j* was:

$$\text{var}\begin{bmatrix} a_i \\ a_j \\ pe_j \\ e_i \\ e_j \end{bmatrix} = \begin{bmatrix} g_{ii}A & g_{ij}A & 0 & 0 & 0 \\ g_{ji}A & g_{jj}A & 0 & 0 & 0 \\ 0 & 0 & I\sigma^2_{pe} & 0 & 0 \\ 0 & 0 & 0 & r_{ii} & 0 \\ 0 & 0 & 0 & 0 & r_{jj} \end{bmatrix}$$

The variance due to permanent environmental effects of the cow is σ^2_{pe}, and I is an identity matrix.

RESULTS

Genetic parameters were estimated for different temperamental traits of German Angus and Simmental beef cattle measured at young age. Heritability estimates ranged from 0.07 for three measures of the docility test (separation time, running time during handling and time until separation in corner) to 0.35 for the docility score in the same test procedure (Table 3). For the behavior tests used in this study, heritability estimates tended to be higher for behavior scores in comparison to those values estimated for times spent running or moving during handling. Additionally, heritabilities were calculated for both breeds separately with generally higher values for German Simmental beef cattle, except the estimate for time spent moving during the fixation test (Table 4).

For all the variables recorded at young age in different behavior tests genetic correlations were estimated over both breeds (Table 3). The two measures of temperament observed in the fixation test were highly correlated (r_g = 0.93). Furthermore, the genetic correlations between the score assigned to the calves for behavioral agitation during the fixation test and the crush score (r_g = 0.65) as well as the total time needed to separate an animal out of a group of ten (r_g = 0.59) were high.

Table 3. Genetic parameters across different temperamental traits at young age[1]

Trait[2]	Fixation test		Crush test		Docility test							
	TSM	BS	ES	CS	ST	RT1	RT2	RT3	TUC	TIC	DSA	DSM
TSM	**0.18**±0.04	0.93±0.04	-0.10±0.17	0.38±0.12	0.11±0.21	0.22±0.14	-0.27±0.16	0.03±0.21	0.02±0.20	0.02±0.19	0.13±0.09	0.14±0.13
BS		**0.10**±0.02	-0.11±0.19	0.65±0.16	0.59±0.23	0.30±0.18	-0.16±0.18	0.14±0.25	0.24±0.25	-0.13±0.20	0.28±0.16	0.28±0.16
ES			**0.12**±0.03	-0.50±0.12	0.08±0.22	-0.14±0.18	-0.27±0.18	-0.43±0.20	-0.45±0.19	0.37±0.18	-0.18±0.14	-0.30±0.14
CS				**0.28**±0.04	0.55±0.24	0.51±0.14	0.46±0.14	0.59±0.19	0.36±0.20	-0.33±0.17	0.51±0.11	0.39±0.13
ST					**0.07**±0.03	0.45±0.24	0.24±0.30	0.57±0.32	0.15±0.29	-0.71±0.35	0.77±0.25	0.63±0.24
RT1						**0.20**±0.04	1.00±0.00	n. conv.[3]	0.61±0.18	-0.87±0.14	0.89±0.07	0.86±0.08
RT2							**0.16**±0.04	0.92±0.16	0.99±0.08	n. conv.	0.84±0.13	0.82±0.11
RT3								**0.07**±0.03	n. conv.	-0.56±0.25	0.82±0.09	0.68±0.13
TUC									**0.07**±0.03	-0.70±0.20	0.81±0.10	0.70±0.12
TIC										**0.10**±0.03	n. conv.	n. conv.
DSA											**0.29**±0.04	0.99±0.01
DSM												**0.35**±0.05

[1]Heritabilities (± SE) on the diagonal, genetic correlations (± SE) above the diagonal. [2]TSM: Time spent moving, BS: Behavior score, ES: Entering score, CS: Crush score, ST: Separation time, RT1: Running time alone, RT2: Running time with man, RT3: Running time during handling, TUC: Time until separation in corner, TIC: Time restraint in corner, DSA: Docility score Handler A, DSM: Docility score. [3]n. conv. = not converged.

Table 4. Heritability estimates (± SE) of different temperamental traits of German Angus and German Simmental beef cattle

Test Trait	German Angus	German Simmental
Fixation test		
Time spent moving	0.29 ± 0.06	0.17 ± 0.05
Behavior score	0.00 ± 0.01	0.10 ± 0.03
Crush test		
Entering score	0.12 ± 0.04	0.15 ± 0.06
Crush score	0.22 ± 0.05	0.38 ± 0.08
Docility test		
Separation time	0.00 ± 0.00	0.04 ± 0.03
Running time alone	0.13 ± 0.08	0.17 ± 0.06
Running time with man	0.04 ± 0.03	0.15 ± 0.06
Running time during handling	0.08 ± 0.06	0.13 ± 0.06
Time until separation in corner	0.03 ± 0.04	0.09 ± 0.04
Time restraint in corner	0.03 ± 0.03	0.16 ± 0.07
Docility score Handler A	0.19 ± 0.07	0.39 ± 0.08
Docility score	0.23 ± 0.08	0.46 ± 0.10

Focusing on the crush test conducted at weaning age, the score for entering into the crush was negatively linked with the behavioral agitation during restraint in the head gate (r_g = -0.50). An animal scored higher while entering the crush showed lower running times during the docility test (r_g = -0.14 to r_g = -0.43), it was easier to drive into the corner (r_g = -0.45), easier to restrain in the corner (r_g = 0.37), and received lower temperament scores in the docility test (DSA: r_g = -0.18, and DSM: r_g = -0.30). Accordingly, a higher crush score was associated with increased running times in the docility test. It was harder to separate an animal out of a group of ten (r_g = 0.55), the animal spent more time running, both if it was alone in the restraint yard as well as if the handler was present (r_g = 0.46 to r_g = 0.59), and it was harder to restrain the animal in the defined corner of the restraint yard (r_g = -0.33). The crush score and both behavior scores recorded in the docility test were genetically related (DSA: r_g = 0.51, and DSM: r_g = 0.39).

Within the docility test, different measures of running times (ST, RT1, RT2, RT3 and TUC) were correlated with values ranging from 0.15 to 1. Higher behavioral agitation during handling (running time) in the docility test was negatively associated with the time an animal could be restraint in the corner. High genetic correlations (r_g = 0.63 to r_g = 0.89) were estimated between both behavior scores assigned in the docility test, and running times recorded within this test.

Maternal protective behavior of suckler cows was recorded between 2000 and 2008. A total of 1,693 observations were made on 213 German Angus cows (942 observations) and 211 German Simmental cows (751 observations). The estimated variance components for maternal protective behavior are presented in table 5. Heritabilities were 0.25 for German Angus, and 0.42 for German Simmental cows.

Table 5. Estimated variance components for maternal protective behavior scores of German Angus and German Simmental cows

	German Angus	German Simmental
$\sigma^2_{\text{additive-genetic}}$	0.145	0.257
$\sigma^2_{\text{permanent environment}}$	0.029	0.000
$\sigma^2_{\text{residual}}$	0.413	0.359
$\sigma^2_{\text{phenotypic}}$	0.587	0.616
h^2 (± SE)	0.25 ± 0.05	0.42 ± 0.03

Table 6. Genetic correlations (± SE) between different temperamental traits at young age and maternal protective behavior of German Angus and German Simmental cows

Test	Maternal protective behavior	
Trait	German Angus	German Simmental
Fixation test		
Time spent moving	0.01 ± 0.12	-0.20 ± 0.14
Behavior score	0.99 ± 0.32	0.53 ± 0.16
Crush test		
Entering score	-0.14 ± 0.18	0.14 ± 0.17
Crush score	0.21 ± 0.14	0.17 ± 0.11
Docility test		
Separation time	0.31 ± 0.05	0.95 ± 0.46
Running time alone	0.79 ± 0.32	-0.25 ± 0.05
Running time with man	not converged	-0.30 ± 0.17
Running time during handling	0.21 ± 0.25	0.23 ± 0.17
Time until separation in corner	0.08 ± 0.37	0.26 ± 0.20
Time restraint in corner	-0.63 ± 0.65	0.29 ± 0.17
Docility score Handler A	0.21 ± 0.20	0.13 ± 0.11
Docility score	0.18 ± 0.18	0.32 ± 0.11

In the final analyses, genetic correlations between temperamental traits at young age and later maternal protective behavior of suckler cows were estimated. The behavior score in the fixation test, the crush score, and both scores recorded in the docility test were favorably correlated with maternal behavior after parturition in both breeds (Table 6).

In German Angus cattle, estimates differed between 0.18 and 0.99. However, standard errors were relatively high. Corresponding values in German Simmental cattle ranged from 0.13 to 0.53, and standard errors were slightly lower. The different measurements of running or movement times were not consistently associated with maternal protective behavior of the cows (Table 6). For both breeds, the time needed to separate a calf out of a group of ten animals in the docility test was positively correlated with maternal protective behavior. Values were 0.31 for German Angus, and 0.95 for German Simmentals. Furthermore, the time an animal spent running during handling in the docility test was moderately related to maternal protective behavior (German Angus: $r_g = 0.21$, and German Simmental: $r_g = 0.23$).

DISCUSSION

Genetic parameters were estimated for different temperamental traits of young beef cattle. Behavior scores were moderately heritable, but estimates for most of the variables of running or movement times were low, indicating that behavior scoring based on clearly defined scales is more accurate than defined time records. This is in accordance to earlier estimates reported by Gauly et al. (2002) for behavioral agitation of calves in the fixation test and Mathiak (2002) for different test situations. In cattle and sheep it was observed that individuals are relatively consistent in their behavioral responses during different handling situations, e.g. reactions that express a high level of fear were positively correlated through various tests (Vandenheede and Bouissou, 1993; Boissy and Bouissou, 1995). Genetic correlations across different temperamental traits at young age calculated in this study ranged from -0.50 to 0.99 confirming previous studies (Gauly et al., 2001; Phocas et al., 2006). Genetic correlations within a test were generally higher than across the different behavior tests.

The scoring system used in this study to evaluate maternal protective behavior of suckler cows after parturition is a valuable tool to identify individuals being highly agitated during handling of their calves, or showing aggressive behavior towards man (Hoppe et al., 2008). Maternal protective behavior was found to be a moderately heritable trait with estimates of 0.25 for German Angus, and 0.42 for German Simmentals, enabling further selection strategies. Similar results have been observed in previous studies (Buddenberg et al., 1986; Morris et al., 1994). According to the definition of maternal behavior scores, the preferred rating for a suckler cow should be two or three because these cows are excited when their calves are handled, but they remain mostly calm without any aggression against

stockpersons. Turner and Lawrence (2007) suggested that selection in maternal protective behavior should not be culling the most aggressive individuals from the population. They recommended an adjustment of the whole population to an intermediate expression of this maternal temperament trait. Maternal protective behavior and average daily weight gain of the calves were not correlated in a previous study (Hoppe et al., 2008). Hence, selection of suckler cows with desirable temperamental traits does not have detrimental effects on the profitability of beef cattle production. However, a disadvantage of this evaluation system of maternal temperament is that earliest information on individuals are available after first calving of the cows at an age of two years or even older. For this reason, an early selection of suckler cows is impossible so far. Up to date it is discussed whether selection of calm and docile animals could have an impact on maternal behavior traits of suckler cows (Turner and Lawrence, 2007). Grandinson (2005) adverted that improvement of general maternal behavior could also intensify aggressiveness of suckler cows after calving.

According to the main objective of this study, genetic correlations were estimated between temperamental traits of young calves and later maternal protective behavior of suckler cows (Table 6). Behavior scores in all of the three test procedures were genetically correlated with later maternal protective behavior. Therefore calm and docile calves will also perform conveniently as a cow in both breeds. Thus, confirming Le Neindre et al. (2002) and Phocas et al. (2006) who have shown that maternal licking time after parturition was genetically favorably correlated with the docility score of Limousin heifers ($r_g = 0.34$ and $r_g = 0.17$). Since heritability estimates of behavior scores were moderate and they were correlated to maternal protective behavior, scoring behavior at young age seems to be an appropriate tool to predict this temperamental trait of suckler cows.

Behavior score during the fixation test was highly correlated with maternal behavior scores (MBS), but associated with high standard errors. In addition, heritability of this temperamental trait was low ($h^2 = 0.10$) and performing the test was relatively time consuming because each calf had to be caught, tethered and tested for two minutes and regularly no other routine management procedures can be combined.

Higher crush scores recorded at weaning were linked with MBS of suckler cows with values about $r_g = 0.20$. At the same time heritability of crush scores was high enough ($h^2 = 0.28$) for genetic selection. Furthermore the crush test is easy to perform during routine handling procedures which are performed in a weighing crush, without additional workload for record keeping (Grignard et al., 2001).

Genetic correlations between MBS and behavior scores obtained during the docility test were approximately at the same level than those values reported for crush scores and MBS, and heritabilities for both scores (DSA and DSM) are even higher. The time needed to separate an individual out of a group of ten animals was highly related to MBS, especially in German Simmental cattle (r_g = 0.95). A lower separation time indicates that the animal was easy to handle and remained calm during separation from its herdmates. It seems that this temperamental trait suits as an indicator for later maternal protective behavior, but significance of this trait is doubtful because of a low heritability (h^2 = 0.07). This is the same for the relationship between running time during handling and MBS. Urban (2007) obtained similar results and she noticed that most traits of the docility test are not useful for genetic selection moreover the implementation of this test procedure is very time-consuming.

The results of this study clearly point out that genetic selection in beef cattle temperament is possible, either at young or mature age as well as in different beef cattle breeds. Favorable genetic correlations between behavioral traits of young animals and later maternal protective behavior of suckler cows after parturition open the way for an early selection. Consequently, it seems to be possible to select individuals which remain calm and docile during human contact or handling at an early stage of life with an associated improvement of maternal temperament. Aggressiveness of suckler cows after parturition will be reduced simultaneously with positive impacts on safety of animals and stockman during routine management procedures. Genetic parameters estimated in this study for German Angus and Simmental beef cattle provide a basis for future selection strategies, although corresponding analyses should be conducted for other important beef cattle breeds.

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5th CHAPTER

GENERAL DISCUSSION

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Introduction

This thesis focused on genetic parameters of temperament in beef cattle. Individual differences in temperamental traits of young animals were investigated under field conditions for the most common beef cattle breeds in Germany. Two test procedures were validated concerning their routine implementation on commercial beef cattle farms. Alongside, maternal protective behavior after parturition was examined in German Angus and Simmental cows. In both studies, correlated changes in performance traits of the animals were analyzed. The main objective was finally to determine whether evaluation of beef cattle temperament at young age could be an appropriate and reliable tool to predict later maternal protective behavior of suckler cows. In the following chapter these results are discussed with regard to future selection strategies in German beef cattle production and recommendations are derived for the implementation of appropriate test procedures in a performance test for beef cattle temperament.

Performance of beef cattle

In 2006 and 2007, temperament of German Angus, Charolais, Hereford, Limousin, and German Simmental calves was investigated on commercial beef cattle farms in the Northern and Eastern parts of Germany. During restraint in the weighing crush, body weight of the animals was recorded and average daily weight gain of the animals was calculated from birth to testing date. For each breed, corresponding values for male and female calves are presented in chapter 2. In comparison to those values reported by the German Beef Cattle Breeders Association (2007), summarized in chapter 1, these figures were approximately at the same level. Separated by breed and in relation to the analogous time period, average daily weight gains of German Angus, Charolais, and Limousin cattle recorded during the field trial were slightly lower, in case of Charolais heifer calves around 70 g/d lower. This is possibly due to the geographical position of the participating farms in northeast Germany, where beef cattle production is carried out on extensive grassland, usually without supplementary feeding, and in herds with several hundred animals (Hampel, 2005). In contrast, data published annually by the German Beef Cattle Breeders association contain also those performance information recorded in southern and western Germany, both regions characterized by crop farming with only a small amount of extensive grassland, associated with mostly small herds of about ten suckler cows

(Faulhaber, 2008). Values for German Simmental cattle were at the same level for male calves and slightly lower for heifer calves. At last, higher performance was only observed in Hereford cattle, with an increased weight gain in the field trial of about 100 g/d. This can be explained by the fact that Hereford breeders involved in this experiment unite about forty percent of the German purebred Hereford population (German Beef Cattle Breeders Association, 2007). Therefore a potentially higher performance level on these farms may have contributed to a bias of performance data recorded within the field study in comparison to the whole population's average. The superior average daily weight gains of Charolais and German Simmentals in order to the other three breeds are in agreement with the breeding goals of these breeds and confirm earlier information by Golze (1997) and Hampel (2005).

Beef cattle temperament

Beef cattle breeds used in these experiments differ not only in constitution or performance but also in their evolution, i.e. breeding history. Significant differences between breeds were detected in crush scores and flight-speed scores of young animals as well as in maternal behavior scores of mature suckler cows. In both studies it seems that the afore mentioned breeding history influenced behavioral agitation of the animals during human handling, which itself was chosen as an indicator for temperament (Grandin, 1993; Burrow, 1997).

In young beef cattle, Charolais and Limousin calves had significantly higher crush scores and flight-speeds than German Angus and Herefords, indicating poorer temperamental traits of this French breeds. Grandin (1994) observed that undesirable temperamental traits are more common in cattle reared in intensive systems. Traditionally, this was the case in Charolais and Limousin cattle, retained for the dual-purpose of draught and meat production until the middle of the 20th century. Thus, resulting in a strong habituation to human handling and an associated overlap of genetically based poor temperament, preventing selection in behavioral traits. On the other hand, Hereford and Aberdeen Angus were bred to suit extensive British pasture systems (Jarrige and Auriol, 1992), likewise the German Angus cattle developed in the 1950s with great influence of Aberdeen Angus genetics until today. Referring to German Angus, Gauly et al. (2002) stated that against this background such breeds have been indirectly selected for docility.

As presented in chapter 3, German Simmental, traditionally reared as a dual-purpose breed for milk and beef production, had lower maternal protective behavior scores (MBS) during handling of their calves in comparison to their German Angus counterparts. Since dairy cattle have been selected for less intense maternal behavior in the past (Le Neindre, 1989), this may partially explain the breed differences in the cow's attentiveness towards her calf. An American study by Sandelin et al. (2005) has shown that maternal protective behavior after parturition was most vigorously shown in Angus cattle compared to cows of other beef cattle breeds like Charolais or Red Poll. Grandin and Johnson (2005) reported that Salers cows, developed in the harsh environment of French mountain regions, are very protective towards their calves. In contrast, they stated that Holstein dairy cattle have been selectively bred to be calm and produce milk, associated with a loss of almost any form of protective behavior. Consequently, it seems that former breeding goals; in particular meat, milk and/or draught; may have long lasting effects on temperamental traits of beef cattle, which become more important under current, extensive rearing conditions with reduced habituation of cattle to man (Turner and Lawrence, 2007).

Implications of temperament on the efficiency of beef cattle production

Different temperamental traits of beef cattle were investigated either at young age or in mature suckler cows, both with a simultaneous examination of correlated changes in performance traits. As presented in chapter 2, individual temperament of beef cattle calves is genetically linked with average daily weight gain in most breeds, with estimates up to r_g = -0.58 for the relationship between crush scores and average daily weight gain in Hereford cattle. Genetic correlations are particularly favorable in Hereford, Limousin, and German Simmental cattle. Thus indicating that a concurrent improvement of temperament and performance can be expected, but also in German Angus and Charolais, upgrading of temperamental traits seems to be possible without decreasing performance of the animals.

The positive relationships between individual temperament and performance observed in young beef cattle confirm several further studies, irrespective of breed or the applied test procedures (Gauly et al., 2001; Mathiak, 2002; Petherick et al., 2002; Nkrumah et al., 2007; Urban, 2007). Advantages in feed conversion rates of calm and docile animals are a potential explanation for this relation (Mathiak, 2002; Nkrumah et al., 2007), as well as an increased feed intake of such individuals (Fox et al., 2004).

With regard to maternal temperament, protective behavior of suckler cows after parturition was studied in chapter 3. Phenotypic correlations between MBS and performance traits of their calves were all close to zero. MBS was not a significant source of variation in both, weaning weight or average daily weight gain of the calves. As a result, economic efficiency of beef cattle production would not be negatively altered by selection of calm and docile suckler cows.

In dairy cattle, research of Steine et al. (2008) has revealed that a modification of the breeding goal in Norwegian Reds, with an increase of the economic weight for temperament during milking and some other traits, is associated with an increase of farm profit. Additionally, cattle with favorable temperamental traits facilitate routine handling, reduce required workload for routine management procedures, and drop the risk of injuries (Le Neindre et al., 2002). In young beef cattle of varying breeds, similar relationships were observed (chapter 2). Calves which were easy to separate from their herdmates and to drive into the handling facilities received significantly lower behavior scores and had lower flight-speeds than their counterparts of higher rank order groups. Animals which did not enter voluntarily and were in the last rank order group exhibited significantly higher flight-speeds when they were released from fixation in the weighing crush. Running or jumping out of the crush is associated with an increased risk of injury for the animals themselves but also for persons standing nearby.

Maternal protective behavior was investigated in German Angus and Simmental cows, with higher scores denoting agitated cows which are aggressive against humans during handling of their calves (chapter 3). Such cows are a major risk of injuries for both, their young calves and humans during handling (Le Neindre et al., 1998, 2002). Cows with calves at foot were the main source of fatal injuries in the UK between 1993 and 2003, mostly as a result of aggressive behavior of the cows, as reported by Turner and Lawrence (2007).

Table 1. Genetic correlations (± SE) among behavior scores of the restraint- and the crush test and some relevant measures of the docility test (chapter 4)

Test	Genetic correlations (± SE)
Restraint test	
Score – Total separation time	0.59 ± 0.23
Score – Time until animal reached the corner	0.24 ± 0.25
Crush test	
Score – Total separation time	0.55 ± 0.24
Score – Time until animal reached the corner	0.36 ± 0.20

Within the tests performed at the experimental farm "Rudlos" of the University of Giessen it was observed that behavior scores assigned in the restraint- and the crush test were either correlated to the total time needed to separate an animal out of a group of ten, as well as to the time needed to lead this individual into the defined corner of the yard during the docility test (chapter 4). According to Mathiak (2002), selecting animals based on their behavior scores seems to simultaneously improve direct behavioral responses of cattle to man. Relevant estimates are summarized in table 1, indicating that a higher behavioral response to fixation is related to increased efforts to handle an animal. Thus, confirming statements by Le Neindre et al. (2002). In summary, it seems that beneficial implications of improved beef cattle temperament are widespread, justifying a further examination of the potential of genetic improvement of behavioral traits and applicable test procedures.

Possibilities of genetic selection in beef cattle temperament

A reliable record keeping is unavoidable to develop a base for genetic selection. Therefore it is essential to determine whether the different test procedures examined within this thesis are comparable in some way. In the following, informational values of the temperamental traits measured within the experiments are discussed, as well as the main external impacts which may have altered individual behavioral responses of the animals during handling.

Temperament of young beef cattle was evaluated in two different test situations, the crush test and the flight-speed test. Behavioral agitation of beef cattle calves during restraint in the head gate of the weighing crush and visual flight-speed after released from the fixation were the particular indicators for cattle temperament (chapter 2). Specifications in an animal's behavior were influenced by social isolation from their herdmates and unfamiliar close human contact in both situations (Grignard et al., 2001). Based on individual differences in fearfulness, the behavioral response of an animal can vary from docility to excitement or even aggression (Boissy, 1998). In order to the crush test and the flight-speed test, a higher fear response of an individual is expressed in increased behavioral agitation and faster flight-speeds. Both scores obtained in this first experiment were highly correlated, with values ranging from $r_g = 0.57$ in German Angus up to $r_g = 0.98$ in Limousin and German Simmental cattle (Table 2), indicating that at last, both tests measure the same genetically determined temperamental trait of beef cattle.

Table 2. Genetic correlations (± SE) among crush score and flight-speed score of beef cattle calves of different breeds (chapter 2)

Breed	Genetic correlations (± SE)
German Angus	0.57 ± 0.17
Charolais	0.63 ± 0.12
Hereford	0.69 ± 0.08
Limousin	0.98 ± 0.08
German Simmental	0.98 ± 0.05

In chapter 4, genetic correlations were estimated among temperamental traits measured in various test situations. Genetic relationships between behavior scores were moderate to high (Table 3), supporting the results presented in chapter 2. In addition, they show that the test procedures used within these experiments are related to each other, since the animals are confronted to close human contact and social isolation in each situation. Influences on the animals in the crush test are described above. For the fixation test the calf is caught by a human handler and then tethered with a rope, and within the docility test the handler separates an individual out of its group, leads it into a defined corner where he tries to restrain it for some time. The variations in individual behavioral responses are based on differences in the fear response of an animal, as mentioned before in terms of the crush- and flight-speed test.

Table 3. Genetic correlations (± SE) among behavior scores of beef cattle calves obtained in different test situations (chapter 4)

Tests	Genetic correlations (± SE)
Restraint test – Crush test	0.65 ± 0.16
Restraint test – Docility test (Score DSA)	0.28 ± 0.16
Restraint test – Docility test (Score DSM)	0.28 ± 0.16
Crush test - Docility test (Score DSA)	0.51 ± 0.11
Crush test - Docility test (Score DSM)	0.39 ± 0.13

Therefore a comparable evaluation of beef cattle temperament seems to be possible within each of the tests applied and equally in different beef cattle breeds, confirming previous studies by Grignard et al. (2001) and Boivin and Trillat (2006). Grignard et al. (1999) compared a crush test with close human contact and a docility test. They stated that both methods are related despite differences in the procedures, allowing an evaluation of cattle reactivity to humans.

In mature female beef cattle, a maternal protective behavior test was performed within 24 h after parturition during handling of the calves for weighing and earmarking. The cow's attentiveness towards the calf and willingness to protect it were the central parameters to evaluate maternal temperament (chapter 3). In protective cows, the human handler is considered to be a threat for the calf. Consequently, the basic principle of variation in individual behavioral responses of the cows is also fear, as stated by Grandin and Johnson (2005) and Turner and Lawrence (2007). This is confirmed by research of Martin et al. (2004) who studied the fear response of ewes during handling of their lambs to evaluate maternal protective behavior.

Apparently, all the traits measured either at young age or in mature cattle indicate the same genetically specified temperamental trait of beef cattle. In particular, as unfamiliar close human contact is the main fear eliciting factor in all of the applied test procedures.

One of the main factors affecting the success of selection decisions is the heritability of the traits of interest. Additionally, genetic correlations among different attributes are of particular importance. They indicate whether selection in one trait will simultaneously result in favorable changes of another trait or, in the case of antagonistic relationships, if improvement of a trait changes another one for the worse.

Accordingly, to generate a base for future selection strategies, estimations of genetic (co)variance components among different temperamental traits were accomplished. The fundamental experiments have shown that the crush test and in the same way examination of flight-speed are appropriate tools to evaluate individual differences in temperament of German Angus, Charolais, Hereford, Limousin, and German Simmental beef cattle calves (chapter 2). Estimates of heritability were moderate, ranging between $h^2 = 0.11$ (crush score in Limousin cattle) and $h^2 = 0.36$ (flight-speed in Hereford cattle), thus indicating that scoring of behavioral agitation during restraint and recording of visual flight-speeds are reliable. As Mathiak (2002) suggested, the crush test is adapted for the determination of genetically based differences in beef cattle temperament.

A summary of all estimates of heritability is presented in table 4. The experiences during performance of the tests on commercial beef cattle farms have shown that an implementation in a routine weighing process is possible, without additional workload for record keeping or extra stress for the animals, supporting conclusions by Grignard et al. (2001).

Analyses of data collected in Rudlos between 1998 and 2006 (chapter 4) have shown that all the behavior scores recorded at young age, i.e. in a fixation test, a crush test and a docility test were moderately heritable. Heritability estimates of some of the variables of running or movement times were also high enough to be considered in selection decisions. Those variables which seem to be appropriate for a routine application are summarized in table 4, taking into account the genetic correlations among temperamental traits of young beef cattle.

In chapter 3 it was shown that maternal protective behavior is a moderately heritable trait in German Angus and German Simmental cows. Estimates for both breeds are presented in table 4. Using a larger set of data, an advanced examination of genetic (co)variance components was accomplished in chapter 4. Values were at the same level ($h^2 = 0.42$) for German Simmental cows but in German Angus heritability increased from $h^2 = 0.14$ to $h^2 = 0.25$ (table 4).

The global aim of this study was to examine temperamental traits of young beef cattle which are qualified for prediction of later maternal protective behavior of suckler cows. Up to date only little research was conducted to verify these relationships, although consistently requested (Le Neindre et al., 1995; Sandelin et al., 2005; Turner and Lawrence, 2007). Only Le Neindre et al. (2002) and Phocas et al. (2006) reported desirable genetic links between behavior scores of heifers during a docility test and their later maternal behavior measured in form of the time a cow licked her calf after calving. Estimates of genetic correlations were moderate with values of $r_g = 0.34$ and $r_g = 0.17$, respectively. Similar observations were made in sheep by Murphy et al. (1998) and Martin et al. (2004) who demonstrated that calm ewes were better mothers. These animals spent more time with their lambs, had a shorter flight distance when disturbed by humans and returned faster to their lambs than nervous ewes. In addition, Martin et al. (2004) stated that the poor maternal abilities of nervous ewes were the main factor of lamb mortality.

Table 4. Heritability estimates (h^2 ± SE) of temperamental traits of beef cattle measured in different test situations and at varying stages of life

Test	Breed	n	Sires (n)	Sex	Age	h^2 ± SE	Chapter
Fixation test							
Score	German Angus, German Simmental	1732	27	both	5 weeks	0.10 ± 0.02	4
Crush test							
Score	German Angus	706	40	both	6 – 8 month	0.15 ± 0.06	2
Score	Charolais	556	32	both	6 – 8 month	0.17 ± 0.07	2
Score	Hereford	697	40	both	6 – 8 month	0.33 ± 0.10	2
Score	Limousin	424	56	both	6 – 8 month	0.11 ± 0.08	2
Score	German Simmental	667	45	both	6 – 8 month	0.18 ± 0.07	2
Score	German Angus, German Simmental	1361	27	both	7 month	0.28 ± 0.04	4
Flight-speed test							
Score	German Angus	706	40	both	6 – 8 month	0.20 ± 0.08	2
Score	Charolais	556	32	both	6 – 8 month	0.25 ± 0.10	2
Score	Hereford	697	40	both	6 – 8 month	0.36 ± 0.06	2
Score	Limousin	424	56	both	6 – 8 month	0.11 ± 0.07	2
Score	German Simmental	667	45	both	6 – 8 month	0.28 ± 0.07	2
Docility test							
Running time alone	German Angus, German Simmental	1342	27	both	7 month	0.20 ± 0.04	4
Running time with man	German Angus, German Simmental	1342	27	both	7 month	0.16 ± 0.04	4
Score (Handler A)	German Angus, German Simmental	1342	27	both	7 month	0.29 ± 0.04	4
Score	German Angus, German Simmental	1342	27	both	7 month	0.35 ± 0.05	4
Maternal behavior test							
Score	German Angus	197	n.a.[1]	female	mature	0.14 ± 0.08	3
Score	German Simmental	193	n.a.	female	mature	0.42 ± 0.05	3
Score	German Angus	213	n.a.	female	mature	0.25 ± 0.05	3
Score	German Simmental	211	n.a.	female	mature	0.42 ± 0.03	3

[1]n.a. = not available.

Based on a large data set compiled between 1998 and 2008 at the experimental farm "Rudlos" of the University of Giessen on 240 German Angus and Simmental cows and their progeny, genetic relationships between individual temperamental traits of young beef cattle and later maternal protective behavior of mature suckler cows were estimated in chapter 4. Favorable genetic correlations among behavior scores of the calves and maternal protective behavior scores of the cows were consistent in both breeds. Consequently, scoring behavioral agitation of young animals seems to be appropriate for prediction of maternal temperament. Genetic selection of young beef cattle featured with desirable temperamental traits would rather result in more docile suckler cows. With regard to the definition of MBS and animal and handler safety (Turner and Lawrence, 2007), those cows with ratings of two or three are preferred under current farming conditions in Germany. Accordingly, genetic improvement of temperamental traits of young beef cattle will minimize the incidence of aggressive cows which are likely to attack the human handler during routine handling procedures involving their calves.

Conclusions

The results obtained within this thesis have shown that a reliable evaluation of beef cattle temperament is practicable on commercial farms. With regard to the workload required for record keeping on the farms, the crush test is the most suitable test procedure for routine practice. Several handling procedures are carried out using a crush, and additionally weighing of beef cattle is essential to comply with current regulations of the breeding associations. For these reasons an implementation of this behavior test is possible without additional workload for cattle handling, record keeping, or further stress for the animals. Heritability estimates of the crush score are high enough for genetic selection, both in varying beef cattle breeds (chapter 2), and if temperament is scored by different observers (chapter 4). Consequently, the crush test should be the method of choice for evaluation of beef cattle temperament on commercial farms to provide the data for a genetic evaluation system of beef cattle temperament. At the best, the test is accomplished in conjunction with performance testing of the breeding associations.

An improvement of beef cattle temperament based on genetic selection at young age is not accompanied by detrimental changes in economic efficiency. In fact, performance traits as average daily weight gain will increase and routine handling of beef cattle is facilitated.

Finally, such a selection for desirable temperament in young beef cattle is genetically correlated with later maternal protective behavior in suckler cows. Female calves selected for calm and docile behavior will also perform conveniently as a dam (chapter 4). These suckler cows will be more likely to remain docile during handling of their calves after parturition.

Thus, under current rearing conditions in Germany, temperament should be considered as an independent breeding goal in future selection strategies within the different breeds. Due to the fact that estimation of temperament EBVs was successfully realized in the purebred Limousin populations of Australia, New Zealand and North America estimation of breeding values should be the next goal to strive for. Although these advisements are true for German beef cattle production, they can only represent a base for other countries with completely different general conditions. Therefore, these relationships should be examined under American or Australian rearing conditions with a much higher degree of extensification of beef cattle production.

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ERKLÄRUNGEN

Hiermit erkläre ich, dass diese Arbeit weder in gleicher noch in ähnlicher Form bereits anderen Prüfungsbehörden vorgelegen hat.

Weiter erkläre ich, dass ich mich an keiner anderen Hochschule um einen Doktorgrad beworben habe.

Hiermit erkläre ich eidesstattlich, dass diese Dissertation selbstständig und ohne unerlaubte Hilfe angefertigt wurde.

Göttingen, 11. Dezember 2008