Aus dem Institut für Geflügelkrankheiten
des Fachbereichs Veterinärmedizin
der Freien Universität Berlin

Investigation of the prevalence of pathological carcass alterations at the processing plant in fattening turkeys reared in organic farming system in Germany

Inaugural-Dissertation
zur Erlangung des Grades eines
Doktors der Veterinärmedizin
an der
Freien Universität Berlin

vorgelegt von
Darja Freihold
Tierärztin aus Dortmund

Berlin 2021
Journal-Nr.: 4290

Aus dem Institut für Geflügelkrankheiten
des Fachbereichs Veterinärmedizin
der Freien Universität Berlin

Investigation of the prevalence of pathological carcass alterations at the processing plant in fattening turkeys reared in organic farming system in Germany

Inaugural-Dissertation
zur Erlangung des Grades eines
Doktors der Veterinärmedizin
an der
Freien Universität Berlin

vorgelegt von
Darja Freihold
Tierärztin
aus Dortmund

Berlin 2021

Journal-Nr.: 4290

Gedruckt mit Genehmigung
des Fachbereichs Veterinärmedizin
der Freien Universität Berlin

Dekan:	Univ.-Prof. Dr. Jürgen Zentek
Erster Gutachter:	Univ.-Prof. Dr. Dr. Hafez Mohamed Hafez
Zweiter Gutachter:	Univ.-Prof. Dr. Christa Thöne-Reineke
Dritter Gutachter:	Prof. Dr. Michael Pees

Deskriptoren (nach CAB-Thesaurus): turkeys, carcasses, prevalence, fattening, organic farming, meat production, meat quality, germany

Tag der Promotion: 26.05.2021

Table of Contents

List of abbreviations

AI	Avian Influenza
aMPV	Avian Metapneumovirus
B.U.T. 6/ TP 7	British United Turkeys 6/ Test Product 7
E. coli	*Escherichia coli*
e. g.	exempli gratia (*engl.* For example)
FC	Fowl Cholera
FPD	Foot Pad Dermatitis
Kelly BBB	Kelly Broad Breasted Bronze
kg	kilogram
m²	square meters
ME	Metabolic Energy
MJ	Mega Joule
ND	Newcastel Disease
ORT	*Ornithobacterium rhinotracheale*
spp.	subspecies
TOC	Turkey Osteomyelitis Complex
VC	visual classification
2-D-RGB image	Two dimensional Red Green Blue image (color space for digital images)

1. Introduction

In recent years there is a rising consciousness concerning food origin and quality. The demand for organic products in Germany has been increasing, which is underlined by the growing annual turnover (Statista 2019). In this context consumers do expect high animal welfare standards. Yet with only 2.4 % the organic turkey production accounts for just a small percentage of all fattening turkeys (Oekolandbau 2017). Apart from heavy turkey lines as B.U.T. 6/TP 7, of which only the hens are used for fattening, medium weighted turkeys such as Kelly Bronze are commonly used (Batkowska and Bordacki 2012). Currently there is neither particular an organic turkey breeding nor are there any organic parent flocks in Germany.

Apart from voluntary agreements between the government and the poultry producers' association from 2013 (Verband Deutscher Putenerzeuger 2013) setting minimum standards for poultry rearing, there are no legal requirements concerning turkey husbandry in particular. For the rearing of turkeys in organic farming systems there are higher requirements based on the Commission Regulation (EC) No 889/2008 (European Commission 2008), which determines basic conditions for organic production.

In the past examinations of conventional turkey flocks showed the relevance of contact dermatitis from an economic point of view as well as under animal welfare aspects (Bergmann et al. 2013; Krautwald-Junghanns et al. 2013; 2011). Husbandry deficiencies may lead to alterations of the foot pad within the first days after entry. During the rearing and fattening period, the prevalence and severity increases progressively. Studies investigating contact dermatitis among other carcass defects in turkeys reared in organic production system are rare (Bartels et al. 2020a; Hocking and Wu 2013; Ermakow 2012).

Investigating the prevalence of contact dermatitis and other husbandry related clinical pictures/disorders is the first step to define the current state of organic turkey farms and consequently detect husbandry deficiencies. The alterations to be examined are defined as animal welfare indicators for they allow conclusions about the animal's wellbeing.

To enable a standardized evaluation a uniform classification of these indicators is required. This guarantees comparability and reproducibility. Furthermore, it is important to define the exact time and place of the investigations. Examining the turkeys on the day of slaughter at the processing plant allows comparable and easily accessible results.

For conventionally kept turkeys, appropriate indicators have been defined. Foot pad dermatitis (FPD) and alterations of the breast skin, both frequently occurring alterations in

fattening turkeys, are the most important ones (Knierim et al. 2020). Additionally, other carcass defects can be used as well, above all the liver as the main metabolic organ.

In order to investigate animal welfare indicators exclusively in turkeys reared in organic production systems a prevalence study was conducted in Germany between 2015 and 2016. The examinations were carried out at the processing plant, which allow to determine the actual state of the turkeys at the end of the fattening period under uniform standards and furthermore allow to compare the participating farms.

The first part of the study deals with the prevalence of FPD in 31 turkey flocks. As the main husbandry related problem in modern conventional turkey production, the aim was to investigate turkeys reared in organic farming system (Freihold et al. 2019).

In the second part the same flocks were investigated with regard to defects of the carcasses. These included lesions of the breast skin, swelling of the hock joint and liver alterations (Freihold et al 2021).

2. Literature

2.1 Requirements for turkeys reared in organic production system

There are special requirements for animal husbandry in organic production system which are regulated by the Commission Regulation (EC) No 889/2008 (European Commission 2008).

The acquisition of conventional poults is only allowed in exemptions and is subject to authorization. They must not be older than three days on the date of entry. After additionally buying young birds of conventional origin, a conversion period of ten weeks is mandatory. The total area per production unit is not to exceed 1600 m² with a flock size not exceeding 2500 individuals, this applies to hens and toms. The stocking density is not allowed to exceed ten turkeys and 21 kg per m² net base area. For a wheeled pen up to 150 m² the stocking density must be 16 turkeys or 30 kg per net base area. The birds must have access to an exterior green area with a minimum size of 10 m² per turkey, with an opening to that area of 4 meters per every 100 m² net base area. For wheeled pens the size must be 2.5 m² per turkey. The minimum age of slaughter for heavy turkey breeds is 100 days for hens and 140 days for toms. Furthermore, these regulations demand stricter requirements concerning the feeding, especially regarding food additives (Kamphues et al. 2014; European Commission, 2008). Only feed material appearing in the positive list (no. 1804/1999 EU) and of 100 % organic origin is allowed to be used for the formulation. The application of synthetic amino acids or amino acids analogues is prohibited as well as transgenic animal feed. In contrast to organically bound trace elements, the addition of synthetic vitamins and minerals and trace elements of mineral origins is not allowed. A particular challenge following these guidelines is the supply with sufficient raw protein and amino acids, especially methionine, cysteine and lysine, as a result of the prohibition of extraction meal. The appropriate alimentation has to be implemented by an optimal compilation of high quality protein feedstuffs without an extensive increase in the raw protein content (Kamphues et al. 2014).

The European Commission also regulates the medical treatment (European Commission 2008). According to the law phytotherapeutic and homeopathic medicines should be preferred to chemical and synthetical medical agents. When the application of chemical medicines or antibiotics is inevitable, the use is only permitted under veterinary supervision. In turkeys whose productive lifecycle does not surpass one year the application is only allowed once in a turkey's life. Preventive administration of coccidiostatics is prohibited.

Following the demands of different organic farming associations there can even be more requirements. The products are labelled with the corresponding organic label, ensuring strict organic production conditions in accordance with the associations´ policy.

2.1.1 Disposition of diseases in organic farming systems

The legal requirements for organic poultry farming systems might create various problems for the animal keepers. Due to strict regulations they might not be able to meet all the animals' requirements thereby creating problems for animal health and welfare. As a consequence of the restrictions concerning the application of chemotherapeutics as a treatment for diseases prevention is especially important in organic production systems (Hörning 2003). This includes to strengthen the body's own natural resistance by improving husbandry conditions, adapted feeding and reducing performance stress. The actual aim of the law (European Commission, 2008) is a higher standard of animal welfare as well as a better consumer protection and food safety compared to conventionally produced food. In organic production animal health is considered to be the basis for stable performance with high product quality (Rahmann et al. 2002). However, a lower stocking density as well as access to an outdoor area and the stricter regulations concerning the application of medication, especially antibiotics, do not necessarily lead to better animal health and higher product quality (Schumacher and Rahmann 2008; Fehlhaber 2005).

According to Rahmann et al. (2005) organic poultry farming faces several problems. Exemptions are still common (e. g. outdoor access). The use of feed of 100 % organic origin is only partly possible, therefore conventional feed is still important. The stocking densitiy (animals per m²) can mostly be described as factory farming because the available area is often not used entirely. The green areas are frequently contaminated with excreta and therefore hygienically and organically critical. Contamination with biotic (mycotoxins, bacteria) and non-biotic agents occurs easily. Animal-friendly husbandry is often not met because of old buildings and investment backlogs. Homogenous structure of the flocks leads to a lack of social behaviour. Feather pecking and cannibalism cause animal suffering and a considerable damage to the image of organic poultry farming.

An important aspect of organic poultry farming are the regulations concerning nutrition. It has a direct impact on the excreta and consequently on the litter condition (Kamphues et al. 2011). The supply with sufficient raw protein and essential amino acids in particular, especially sulfur containing amino acids, are nutrition relevant challenges. Increasing the content of raw protein in order to ensure the needs-based supply with essential amino acids may lead to unsatisfactory conditions of the excreta. A higher amount of raw protein binding electrolytes which are eliminated through the renal system may cause an increased glomerular filtration rate and thereby a higher litter moisture.

Different studies show that a lower energy content is associated with an increased food intake (Bellof et al. 2005; Flachowsky 1973). This relation can be used to ensure the sufficient supply with essential amino acids in organic poultry production, for the feed has comparatively low contents of essential amino acids. Schmidt and Bellof (2006) proved that organic feed with low energy content (≤ 11 MJ/kg ME) had the highest level of non-starch polysaccharides which led to an unsatisfactory condition of the excreta. The higher water proportion has a negative impact on the litter condition.

Additionally, turkeys reared in organic production system have poorer feed conversion compared to conventional turkeys which has a negative impact on the ecological track record. Studies by Bellof et al. (2014; 2011) showed that turkeys with access to an outdoor area have a significantly higher feed intake of 35g/d compared to a control group kept indoors. This might be a result of the increased maintenance requirement when an outdoor area is available.

The influence of an outdoor area on animal health, especially on the occurrence of foot pad dermatitis (FPD), was described for broilers by Pagazaurtundua and Warris (2006). The comparison between broilers reared in organic farming system on the one hand, and conventional farming system on the other, showed a higher prevalence of FPD in the broilers with access to an outdoor area. Berk (2013) confirmed these results investigating three turkey breeds with or without access to an outdoor area. Furthermore, access to an outdoor area might increase the risk of infections, endoparasitosis in particular (Hörning 2003). Considering the reduced use of the outdoor area during the winter months the benefits for animal welfare are not necessarily fulfilled (Bellof et al. 2014; 2011).

Ermakow (2012) stated in her investigation comparing carcass examinations of turkeys reared in organic and conventional farming system that organic turkey farming is basically an animal and environment-friendly system. Its aim is a higher standard of animal welfare, animal health and food safety. But her results proved that the same health issues as found in conventionally reared turkeys can affect turkeys reared in organic farming system. In some cases, animal health can even be worse. A higher animal health status of turkeys reared in organic farming system compared to turkeys reared in conventional farming system could not be confirmed, rather the contrary. Her examinations showed that the total discarding (kg) was significantly higher in organic turkeys (1.9 %) than in conventional turkeys (1.4 %). The same applied for the downgrading of whole carcasses (organic turkeys: 44.2 %; conventional turkeys: 34.2 %), whereas the downgrading of parts of the carcasses was significantly lower in organic turkeys (44.9 %) than in conventional turkeys (57.2 %). Regarding the organs declared unfit for human consumption there was no significant difference between both production systems (organic turkeys: 8.9 %, conventional turkeys: 8.8 %). The results show that certain health issues cannot

be solved by changing the production system. The quality of care and health management are significant influencing factors in turkey production.

Dressel et al. (2019) came to similar results comparing carcass examinations of turkeys reared in conventional and in organic production system. Apparently, the conditions for organic turkey fattening do not necessarily lead to improved animal health. According to her examinations the risk of developing serositis is eight times higher in turkeys reared under organic farming conditions. Furthermore, the risk of carcasses declared unfit for human consumption was twice as high in organic turkey hens than in hens reared in conventional farming system. Whereas the risk of discarding the whole carcass of toms was the same in both production systems.

The arithmetic mean for downgrading of the whole carcass was slightly higher in turkeys reared in organic production system (1.76 %) than in turkeys reared under conventional farming conditions (1.42 %).

2.2 Animal welfare indicators

Pathological changes, such as foot pad dermatitis, disorders in the musculoskeletal system, alterations of the internal organs, especially the liver as the central metabolic organ, and dermatitis commonly occur in fattening turkeys (Allain et al. 2013; Krautwald-Junghanns et al. 2011; Shepherd and Fairchild 2010; Hafez et al. 2004; Huff et al. 2000). Not only conventional turkey flocks are affected, but also those reared in organic poultry farming system (Bartels et al. 2020a; Freihold et al. 2019; Ermakow 2012; Wu and Hocking 2011).

Multiple interacting factors are assumed to contribute to the occurrence of these alterations. Genetics (breed, sex), the management and husbandry conditions (stocking density, litter material, litter condition, top-dressing frequency, nutrition) are discussed to have an influence. The litter condition itself depends on the material (wood-shavings, chopped straw), ventilation and heating system, the management and the amount and the state of the excreta which depends on the feed and health (due to enteric disorders or malnutrition) (Bartels et al. 2020a; Erasmus 2017; Kamphues et al. 2014; Krautwald-Junghanns et al. 2011; Youssef et al. 2010; Rudolf 2008; Hafez et al. 2005b; Mayne, 2005; Martrenchar et al. 1999).

Most alterations are potentially painful or lead to a deterioration in animal health and therefore may be used as indicators for animal welfare and to detect husbandry deficiencies. Furthermore, they serve for evaluating and comparing farms (Sinclair et al. 2015; Weber Wyneken et al. 2015; Watanabe et al. 2013; Krautwald-Junghanns et al. 2011). For doing so they must be examined under uniform standards that allow comparability and reproducibility.

Therefore, a clear scoring of the indicators is indispensable. In order to establish a precautionary monitoring, it has to be non-extensive and easy to perform under field conditions. Doing the examination at the slaughterhouse allows consistent and standardized investigations and thereby an introduction of a benchmarking system (Andersseon and Toppel 2014; Allain et al. 2013; Hocking et al. 2008). According to Stracke et al. (2020) commonly used five-point visual scoring (VC) assessment of FPD based on the size of the lesion is reliable in representing the dimension of foot pad lesions. Ulcerations have a significant effect on the size of the lesion and thereby on the size of the foot pad.

In order to evaluate animal welfare at the slaughterhouse Allain et al. (2013) suggest an assessment based on multiple criteria and not only on one single type of lesion.

In addition to scoring at the slaughterhouse farm production records, such as the mortality rate and preceding diseases and treatments, give an overall view of the flocks. Following the German Animal Welfare Act animal keepers are obliged to regularly conduct self-monitoring as a means of early detection of food pad dermatitis (Federal Republic of Germany 2017). Slaughterhouse records are useful to deduce information about the relevance of certain risk factors of management conditions (Neroli et al. 2020). This helps to enforce early detection of animal welfare related problems. According to Toppel et al. (2019) on-farm monitoring of the foot pads is necessary to improve foot pad health. Evaluating the foot pads in a four-week interval allows conclusions about success and the need of management measures, for it matches the time for formation of scar tissue (Toppel et al. 2019). In order to improve animal welfare in turkey husbandry both feet should be examined and the more affected foot should be evaluated.

Only both, early detection and standardized examinations at the slaughterhouse, can assure comprehensive examinations that may lead to targeted measures.

2.2.1 Foot pad dermatitis

Foot pad dermatitis (FPD) is a common alteration in fattening turkeys (Bergmann et al., 2013; Krautwald-Junghanns et al. 2011; Shepherd and Fairchild 2010; Hafez et al. 2004). It does not only affect turkeys reared in conventional production system but also those in organic production systems (Habig et al. 2017; Hocking and Wu 2013).

FPD is a pathological alteration of the plantar skin that begins as an inflammation and hyperkeratosis of the scales and can develop into a necrotic lesion and deep ulcerations up to a plantar abscess (Shepherd and Fairchild 2010; Mayne et al. 2004; Clark et al. 2002). These

studies show that the medial foot pad and the weight bearing metatarsal pads are worst affected. Ascending infections can occur and may affect the joints leading to severe inflammation.

Stracke et al. (2021) investigated the occurrence of alterations of the digital pads. The results showed no equivalence in occurrence and severity of alterations found in the metatarsal pads compared to the digital foot pads. Lesions of the digits were already present in standard FPD score 0. There was no obvious differentiation between the higher scores 2-4. The inconsistent development of the alterations might be a result of the birds trying to relieve the digital pads when affected by putting weight on the metatarsal pads which have more pronounced fat structures (Corpora adiposa plantaria superficialia et profunda).

Foot pad alterations may appear in the first few days of life, but more severe lesions are mostly seen during the fattening period (Bergmann et al. 2013; Krautwald-Junghanns et al. 2011; Mayne et al. 2006). Krautwald-Junghanns et al. (2011) observed first alterations of the foot pad a few days after entry followed by a progressive deterioration within the next weeks. At the age of 22 to 35 days 17.4 % of the turkeys showed hyperkeratosis, 33.6 % had dirt adhesions that could not be removed without loss of tissue and 12.6 % already showed superficial epithelial necrosis. Only 36.7 % did not have any alteration of the foot pad. During the fattening period the condition of the foot pads worsened. In the 16th week one third of the toms and two thirds of the hens showed deep ulcerations of the foot pad and in half of the toms and about one third of the hens epithelial necrosis could be found. Only 4 % of the toms and 0,4 % of the hens were without clinical signs of FPD.

The lesions of the foot pad can heal rapidly by secondary intention (Mayne et al. 2007; Platt et al. 2004). This replacement tissue has a bright and even surface. Its flexibility is decreased and it has to be regarded as a profound alteration of the original tissue.

The pathogenesis of FPD is multifactorial, but poor litter condition, in particular wet litter, has been described to be the main cause (Vinco et al. 2017; Hübel et al. 2014; Abd El-Wahab et al. 2012; Wu and Hocking 2011; Mayne et al. 2007; Martland 1984). A study by Schumacher et al. (2012) showed that single spots or areas with increased litter moisture are sufficient to cause a higher prevalence as well as severity of FPD. The litter condition depends on the litter material itself, the degree of humidity, different management aspects (ventilation and heating system and the frequence of spreading new litter material) and the amount and condition of the excrements. The latter in turn is influenced by the feed and intestinal functions and thus enteric disorders.

Abd El-Wahab et al. (2012) investigated the influence of different litter materials under different humidity levels (35 %, 50 % and 65 % moisture). The study revealed a higher severity of FPD in those turkey poults kept on wet litter. The severity of FPD increased only slightly after doubling the exposure time (4h to 8h) for the lower moisture (35 % and 50 %), for the wettest litter (65 %) a stronger increase was observed. They resumed that even an exposure of 4 hours per day or less might result in higher severity of FPD. These observations confirm those of Youssef et al. (2010), who investigated the influence of litter moisture on the occurrence and severity of FPD in turkey poults, came to similar results.

Furthermore, a genetic predisposition is discussed to have an effect, when taking into account sex and breed. The influence of the sex is discussed controversially. Mayne et al. (2005) stated that there are gender specific differences concerning the fat and collagen content of the foot pad, which leads to a higher predisposition for FPD in hens. But regarding the influence of the litter condition another aspect should be considered. The higher stocking density in female flocks may be responsible for the increased prevalence of FPD in hens (Ellerich, 2012). This leads to a higher excretion rate per m² causing poorer litter conditions (Ellerich 2012; Krautwald-Junghanns et al. 2011; Rudolf 2008). There are studies dealing with the influence of stocking density on the occurrence of FPD, revealing a positive correlation (Erasmus 2017; Hafez et al. 2005b; Martrenchar et al. 1999). Additionally, the effect of a higher density of individuals on the stable environment (temperature, air flow/ventilation) in turn influences the litter condition (Ziegler et al. 2013).

FPD is potentially painful and is therefore a profound animal welfare issue (Sinclair et al. 2015; Weber Wyneken et al. 2015; Watanabe et al. 2013). Buda et al. (2002) found sensory nerve endings with mechanoreceptors and nociceptors. Severe lesions lead to lameness, which has to be regarded as an indicator for a sensation of pain (Spindler 2007). A resulting decrease in movement associated with severe lesions may lead to a lower food intake (Mayne et al. 2007).

This impact on animal wellbeing in connection with the pathogenesis that is linked to husbandry conditions makes FPD a suitable animal welfare indicator.

There are currently only a few studies dealing with the specific rearing requirements for turkeys in organic farming systems and its potential effect on the prevalence of FPD and animal health and performance (Bartels et al. 2020a; Freihold et al. 2019; Habig et al. 2017; Hocking and Wu 2013; Ermakow 2012).

The standard European scoring system for FPD is a five-point visual score (VC) which is based on the lesion size (Hocking et al., 2008), with Score 0 being a foot pad without any alteration. Score 1 describes small punctual lesions that affect less than 10 % of the foot pad. Depending

on the size of the alteration score 2 (< 25 %), score 3 (< 50 %) and score 4 (> 50 %) are defined.

Stracke et al. (2020) evaluated the reliability and validity of this score by implementing histopathological analysis. The results showed that VC is reliable in representing the dimension of the alteration. The size of the foot pad lesion is influenced by the severity of the ulcerations but there was no clear pattern of histopathological parameters in the respective VC scoring system. Furthermore, re-epithelialised granulation tissue was found in 65.2 % of the foot pads. Currently this is not included in standard visual scoring (VC) but might be a valuable indicator for retrospective conclusions about foot pad health during the entire husbandry period. Toppel et al. (2019) evaluated optical illusion of necrotic areas of the foot pad by comparing human subjective examinations to technical visual scoring. The results showed that lesions of the foot pad were given lower scores when evaluated by visual scoring compared to human assessment. The underlying problem is a lack of anatomic and macroscopic definition of the foot pad. The alterations were quantified in proportion to the perceived metatarsal pad and the image system used does not consider three-dimensionality. As a result, the size of the foot pad is not clear and might be perceived as too large in relation to the altered area.

Another study by Stracke et al. (2021) showed a high correlation between the full scoring system (including digital pads) and the standard scoring. Including the digital pads in the scoring by adding a binomial score (yes/no) might be beneficial, especially with regard to upcoming automatic assessment of FPD (2-D-RGB image analysis). This might prevent false assessments of visual scoring when it is based on the size of the metatarsal pad only. Taking the whole foot, including the digital pads, as a reference might reduce the error rate, which confirms Toppel et al. (2019).

Additionally, including scar tissue as a separate score can be used in order to differentiate between the need for management intervention and the success of already implemented measures (Toppel et al. 2019).

2.2.2 Breast skin lesions

Another common alteration in fattening turkeys are lesions of the breast skin, a form of contact dermatitis. It often occurs in turkeys reared in conventional farming systems. Compared to foot pad dermatitis and other skin lesions this has a higher economical relevance for it can lead to an impairment or to discarding the carcass.

Changes range from local restricted ulcerations (breast buttons) to fluid filled breast blisters of different sizes (hygroma) and pus-filled enlarged bursae (purulent bursitis) (Kamyab 2001). Breast buttons, which are ulcerative lesions of the skin overlying the sternum (Gonder and Barnes 1987), are mainly caused by local irritation by coarse and damp litter material (Krautwald-Junghanns et al. 2013; Mitterer-Istyagin et al. 2011). Breast buttons form well restricted areas. They can be removed during the examination at the processing plant without having an effect on the rest of the carcass. An impairment for the affected animals is not proven (Tilley et al. 1996).

Breast buttons should be distinguished from breast blisters, the encapsulated inflammation of the bursa praesternalis which is caused by prolonged pressure from sitting rather than local irritation (McCune and Dellmann 1968). They emerge as a consequence of increased accumulation of fluid inside of the bursa praesternalis. Depending on the severity and accompanying inflammatory processes, it is possible that parts or even the whole carcass needs to be discarded. A damage may contaminate the carcass and surrounding equipment. Further strain may lead to prolonging and enlargement of the bursa and the emergence of a hygroma (Bergmann 2001).

Concerning the etiology of purulent bursitis infectious agents such as *Staphylococcus* spp., *Streptococcus* spp., *E. coli* and *Mycoplasma* spp. are involved and lead to a pus-filled bursa praesternalis (Ermakow 2012; Mitterer-Istyagin et al. 2011; Tilley et al. 1996).

Not only the litter material is responsible for the occurrence of breast skin lesions but also factors such as body weight and the feather cover of the breast have an influence (Newberry 1993).

During the early rearing period lesions of the breast skin are of little significance (Tilley et al. 1996; Newberry 1993). However, Newberry (1993) showed that breast buttons first appeared between the fourth and eighth week but could heal and disappear within the time of four weeks. Additionally, he observed a relation between a higher body weight and reduced feather cover over the keel with the appearance of breast buttons.

A study by Mitterer-Istyagin et al. (2011) showed that alterations of the breast skin mainly appeared during the later fattening period. In the 16th week 12.51 % of the investigated turkeys showed breast buttons, 0.41% hygromas and 0.13% bursitis sternalis. Toms were much more affected than hens. Mitterer-Istyagin et al. (2011) considered the higher body weight and the resulting higher lying phases as the main cause, which lead to pressure associated alterations of the breast skin. The examinations at the slaughter plant confirmed the higher prevalence in

toms. Allain et al. (2013) came to similar results finding 1.5 % enlarged sternal bursae in turkey carcasses and a higher prevalence of breast buttons with an average of 30.1 %.

Lesions of the breast skin have a high economic importance for they lead to considerable economic losses as they result in downgrading at the slaughterhouse (McEwen and Barbut 1992). In addition, the potential painfulness has to be regarded as a profound animal welfare issue. The prevalence of breast skin alterations is considerably lower in turkeys reared in organic production systems, but the occurrence has already been proven. (Dressel et al. 2019; Ermakow 2012). By comparing carcass examinations of turkeys reared in organic and conventional farming system at the slaughterhouse Ermakow (2012) described a significantly higher prevalence of infected breast blister in conventional turkeys (17.1 %) than in organic turkeys (7.6 %). These results were confirmed by Dressel et al. (2019) (organic turkeys: 0.05 %, conventional turkeys: 0.29 %).

2.2.3 Liver alterations

The investigation of the liver at the slaughterhouse is highly relevant as it is the main metabolic organ. Liver infections have an impact on animal health and food safety. The turkey livers enter the food chain as a fresh good or as a processed product. As a consequence, its condition is essential for food safety. Discarding at the slaughterhouse may lead to economic losses.

Alterations can occur due to infectious and non-infectious agents (Bergmann 2001). Changes vary from color deviation, over fatty degeneration, necrosis, abscesses and fibrosis or cirrhosis. Swelling of the liver tissue mostly accompanies other alterations. The green discoloration of the liver is frequently seen in fattening turkeys. Adolescent male turkeys in particular are affected. The green liver syndrome is mostly part of the turkey osteomyelitis complex (Huff et al. 2000; Hafez and Jodas 1997). Not necessarily, but often arthritis/synovitis or osteomyelitis occur simultaneously. The lesions occur in association with bacterial infections with many opportunistic agents, mainly *Staphylococcus aureus* and *Escherichia coli.* Studies indicate that the infections occur as a result of decreased immune response (Huff 2000; Droual et al. 1996; Bayyari 1994). Bayyari et al. (1994) also described cases without osteomyelitis.

A yellow discoloration caused by fatty degeneration is barely described in fattening turkeys (Popp et al. 2014). It is mostly seen in female breeding animals but may also occur in heavy male turkeys as a consequence of accumulation of excessive fat in the liver cells (Gazdzinski et al. 1994). The liver parenchyma is then swollen and fragile. Causative factors can be hypoxia, anemia or infectious agents and toxins. Malnutrition and hormonal imbalances can

be involved (Bergmann 2001). The affected livers are discarded and, depending on the stage of steatosis, the whole carcass may be as well.

Liver necrosis is mostly induced by infectious agents (Bergmann, 2001). These range from bacteria (*Salmonella* spp.*, Pasteurella* spp.*, Mycoplasma* spp.*, Staphyloccocus* spp.*, Campylobacter* spp.) over viruses (e. g. Adenovirus, Reovirus) to protozoa (*Histomonas meleagridis*). *Histomonas meleagridis* causes pathognomonic yellowish demarcated necrosis and furthermore severe hepatitis (Hafez and Jodas 1997). Apart from infectious agents, toxins and ischemic conditions can cause liver necrosis (Bergmann 2001).

Abscesses are caused by infectious agents leading to demarcated inflammation (Bergmann 2001). Depending on the spread of this infection, whether there are focal, multifocal or diffuse abscesses, the livers are partly or completely discarded in the slaughter process.

Fibrosis and cirrhosis are caused by proliferation of connective tissue. The livers are hardened, decreased in size and deformed. Fibrosis can be result of severe chronic hepatitis or venous blood congestion. Cirrhosis is usually caused by infectious or toxic agents accompanied by a damage of the parenchyma (Bergmann 2001). Both are rarely seen in turkeys at the slaughterhouse (Ermakow 2012; Bergmann 2001).

The procedures at the slaughterhouses do hardly ever allow to retrace the corresponding carcass. Therefore, it is not possible to prove links to other carcass defects by doing examinations at the processing line.

2.2.4 Arthritis

Pathological alterations that lead to movement disorders are collectively referred to as Beinschwäche-Syndrom regardless of the etiology and pathogenesis (Hafez et al. 2005a; Korfmann 2003; Hafez 1999; Hirt 1996). This includes various diseases of the musculoskeletal system such as alterations affecting the skeleton, joints, tendon sheaths and the foot pads, not always accompanied by clinical signs (Hafez 1999; Jordan 1990).

Depending on the severity and location such alterations might lead to stunted growth, animal losses and less weight gain which in turn causes economical loss. Furthermore, the resulting pain has to be seen as an important animal welfare concern.

Infectious diseases of the muscolosceletal system are called osteomyelitis, arthritis or tendovaginits depending on the location. The intertarsal joint (hock joint) is mostly affected (Bergmann 2001). Inflammation of the leg joints and arthritis lead to inactivity and increased

contact to the litter which in turn may result in a higher risk of contact dermatitis (Youssef et al. 2010; Mayne et al. 2007).

Dressel et al. (2019) investigated turkey carcasses at the processing plant over a period of two years. Her results showed a significant higher prevalence of arthritis in turkeys reared in organic farming system (0.43 %) compared to turkeys reared under conventional farming conditions (0.04 %). This confirmed the study by Ermakow (2012) who found a generally high prevalence of arthritis in turkeys of both farming systems. The prevalence in organic turkeys was 16.9 %, whereas in conventional turkeys it was 11.5 %.

Allain et al. (2013) found a positive correlation between turkey flocks with arthritis and the occurrence of severe foot lesions such as swelling and ulceration of the foot pad and deviated toes.

A link between the occurrence of inflammatory lesions of bones and/or joints and the green discoloration of the liver has been shown. This is defined as the turkey osteomyelitis complex (TOC). It includes normal appearing processed turkey carcasses that contain lesions including green discoloration of the liver, arthritis/synovitis, soft-tissue abscesses and osteomyelitis of the proximal tibia (Huff et al, 2000). Most carcasses affected by TOC also show a green discoloration of the liver, whereas most carcasses exhibiting a green liver do not have TOC (Food Safety and Inspection Service, 2014). Causing infectious agents are opportunistic organisms, mainly *Escherichia coli* and *Staphylococcus aureus* (Huff 2000; Droual et al. 1996; Bayyari 1994). That suggests that the occurrence is influenced by deficiencies in the host immune response rather than by the virulence of the causative agents (Huff et al. 2000). Mainly male fattening turkeys are affected.

Depending on the severity of the finding during slaughter inspection TOC may lead to the discarding of the liver, parts of the carcass or even the whole carcass.

2.2.5 Further organ findings

2.2.5.1 Skin Lesions

According to Krautwald-Junghanns et al. (2009) skin lesions are mainly a result of scratch marks with increasing prevalence with advancing age. Wounds may occur as a result of limited space when one or more turkeys walk above the other (Bergmann 2001; Proudfoot and Hulan, 1985). Lesions caused primarily by scratching can be extended, especially when bleeding occurs, by pecking either self-inflicted or by conspecifics. In the worst case the seriously affected turkeys die or have to be culled by the farmer. Injurious pecking, feather pecking and

cannibalism can lead to injuries and death. They are a crucial problem concerning animal welfare and regarding economic reasons (Berk et al. 2006). It mainly appears on scarcely feathered body parts such as the head, throat, neck, feet and cloaca (Hafez, 1996; Berk, 2002). Furthermore, the tips of the wings and the tails can be affected. Results by Krautwald-Junghanns et al. (2011) also showed that the mainly affected body parts were the head, especially the snood, and the back. Feather pecking can be considered as a preliminary stage to injurious pecking (Krautwald-Junghanns et al. 2009; Damme and Hildebrand, 2002). Allain et al. (2013) found a positive correlation between feather pecking and the occurrence of leg problems (arthritis, deviated toes and swelling of the foot pad) whereas these lesions and evidence of feather pecking were negatively correlated with the most severe scratches. This negative correlation may be a result of decreased activity when leg problems occur.

Injurious pecking is one of the main animal welfare issues in fattening turkeys (Bartels et al. 2020b). Its cause is considered as multifactorial (Dalton et al. 2013). External influences such as deficiencies in husbandry conditions or inadequate feeding and internal influences like breed and sex are discussed to be potential factors leading to injurious pecking (Ferrante et al. 2019; Dalton et al. 2018, 2013; Erasmus 2017; Duggan, 2014; Spindler, 2007). Beak trimming, which is the main measurement to reduce injurious pecking, is prohibited in organic turkey production (Dalton et al., 2017; European Commission, 2008). Lower light intensity in turkey sheds did not prove to be sufficiently effective by not substantially reducing mortality rates (Marchewka et al. 2019).

Carcass examinations at the slaughterhouse by Ermakow (2012) showed a significantly higher prevalence of infected skin lesions in turkeys reared in conventional production system (22.6 %) compared to organic turkeys (14.1 %). This confirms the results of other studies showing that possibilities for retreating due to lower stocking densities under organic rearing conditions may prevent aggressive behaviour (Strassmeier 2007; Platz et al. 2006).

In contrast to the results of Ermakow (2012) a study conducted by Dressel et al. (2019) found a higher prevalence of lesions and hematomas in turkeys reared in organic production system (organic: 0.16 %; conventional: 0.05 %).

Skin lesions and hematomas can also be a result of abusive behaviour during catching, loading, transport and unloading (Fehlhaber, 2001). Krautwald-Junghanns et al. (2009) found fresh fractures and hematomas occurred in 6.77 % respectively 7.38 % of the hens and in 5.54 % respectively 6.22 % of the toms.

Cutaneous lesions seem to be related to poor animal welfare and should be routinely included in carcass inspections at the slaughterhouse (Allain et al., 2013). These examinations in

addition to collected data on farm level may help to determine the relevance of risk factors of certain management conditions (Neroli et al. 2020; Allain et al. 2013).

2.2.5.2 Serositis

Respiratory diseases in fattening turkeys lead to high economic losses because of increased mortality rate, decreased weight gain and downgrading at the slaughterhouse (Hafez 1999).

Several pathogens are incriminated as a possible cause for the respiratory diseases of turkeys either alone (mono-causal) or in synergy with different other micro-organisms (multi-causal) or accompanied by non-infectious factors such as poor management, inadequate ventilation, high stocking density, poor litter conditions, poor hygiene, high ammonia level and the type of secondary infection. Worldwide the emerging and re-emerging respiratory diseases in turkeys are caused by Avian Metapneumovirus (aMPV), *Ornithobacterium rhinotracheale* (ORT) and Fowl cholera (FC) infections, as well as *Pasteurella multocida, E. coli, Streptococcus and Staphylococcus spp.* and *Aspergillus fumigatus* (Hafez 2009, 1996). In addition, Avian Influenza (AI), Newcastle disease (ND), adenovirus and Mycoplasma infections appear to cause problems in some countries (Hafez 2009). The infectious agents are transmitted horizontally via air, people, objects and other vectors. Vertical transmission was described for Mycoplasma infections (Hafez and Jodas 1997). Besides respiratory symptoms (rhinitis, tracheitis, pneumonia, air sacculitis) turkeys that died on the farm often show pericarditis and peritonitis.

Serositis is commonly caused by airborne and nasal or oral infections with one or more pathogenic agents (Bergmann 2001). Other potential entry gates for micro-organisms are lesions of the food pads or the breast skin (Rautenschlein and Ryll 2014). Additionally, non-inflammatory processes caused by defective hemostatic regulations are described (Bergmann 2001). Sub-clinical inflammations are often first discovered at the slaughterhouse.

The study by Ermakow (2012) showed a significantly higher prevalence of serositis in turkeys kept in organic farming system (32.7 %) compared to conventionally reared turkeys (18.5 %). According to the evaluation by Dressel et al. (2019) the probability of finding serositis during carcass examinations is eight times higher in organic turkeys than in conventional turkeys. The restrictions concerning the use of antibiotics may cause protraction of infections that cannot be prevented by vaccination or treated with phytotherapeutics. Husbandry related strain and hence an increased risk of infections probably leads to higher prevalence of serositis in turkeys reared in organic farming system (Ermakow 2012). The occurrence of serositis and adhesions in the thoracic and abdominal area can lead to a downgrading and the total discarding of the carcasses (Rautenschlein and Ryll 2014; Ermakow 2012; Hafez and Jodas 1997).

3. Publications

This cumulative thesis is based on two publications, which have been published in approved peer-reviewed scientific journals.

Publication 1: Investigation of the prevalence and severity of foot pad dermatitis at the slaughterhouse in fattening turkeys reared in organic production systems in Germany.

Journal publication name: Poultry Science

Poult. Sci. 98: 1559–1567, 2019

DOI: http://dx.doi.org/10.3382/ps/pey473

Own share in this publication: collection of data at the slaughterhouse, including investigation of the turkeys pre-mortem and examination of the foot pads post-mortem. Evaluation and statistical analysis of the results and creation of the manuscript.

Publication 2: Investigation of the occurrence of pathological carcass alterations at the processing plant in meat turkeys reared in organic production systems in Germany

Journal publication name: Journal of Applied Poultry Research

J. Appl. Poult. Res. 30:100145, 2021

DOI: https://doi.org/10.1016/j.japr.2021.100145

Own share in this publication: collection of data at the slaughterhouse, including investigation of the turkeys pre-mortem and of the carcasses at the processing line. Examination of the breast skin, the intertarsal joints (hock joints) and the livers at the processing line. Evaluation and statistical analysis of the results and creation of the manuscript.

3.1 Publication 1

DOI: http://dx.doi.org/10.3382/ps/pey473

ANIMAL WELL-BEING AND BEHAVIOR

Investigation of the prevalence and severity of foot pad dermatitis at the slaughterhouse in fattening turkeys reared in organic production systems in Germany

D. Freihold,[*,†] T. Bartels,[†,§] S. Bergmann,[‡] J. Berk,[§] F. Deerberg,[#] A. Dressel,[¶] M. H. Erhard,[‡] O. Ermakow,[**] M. Huchler,[†] M.-E. Krautwald-Junghanns,[†] B. Spindler,[††] S. Thieme,[*,†,‡‡] and H. M. Hafez[*,1]

[*]*Institute of Poultry Diseases, Faculty of Veterinary Medicine, Freie Universität Berlin, Germany;* [†]*Clinic for Birds and Reptiles, Faculty of Veterinary Medicine, University of Leipzig, Germany;* [‡]*Chair of Animal Welfare, Ethology, Animal Hygiene and Animal Husbandry, Faculty of Veterinary Medicine, LMU Munich, Germany;* [§]*Institute of Animal Welfare and Animal Husbandry, Friedrich-Loeffler-Institut, Celle, Germany;* [#]*Oeko-Berater, Beratung & Projektmanagement Ökologischer Landbau;* [¶]*Veterinär- und Lebensmittelüberwachungsamt, Landkreis Stendal, Germany;* [**]*Fachdienst 39, Landkreis Ludwigslust-Parchim, Germany;* [††]*Institute for Animal Hygiene, Animal Welfare and Farm Animal Behavior, University of Veterinary Medicine Hanover, Foundation, Germany; and* [‡‡]*Institute of Food Safety and Food Hygiene, Working Group Meat Hygiene and Technology, Faculty of Veterinary Public Health, Freie Universität Berlin, Germany*

ABSTRACT The present study shows the prevalence and severity of foot pad dermatitis (FPD) in turkeys reared in organic production systems assessed at slaughterhouses in Germany. The investigations of altogether 1,860 turkeys of the strains Kelly Broad Breasted Bronze (Kelly BBB; 540 toms, 540 hens) and British United Turkeys (B.U.T.) 6 and the Test Product 7 (TP 7; 780 hens) showed that 97.7% of the examined turkeys were diagnosed with different degrees of FPD. Only 4.6% of the toms and 1.3% of the hens had feet without lesions. Most frequent were necrotic lesions measuring up to 2 cm in diameter (64.3% of all turkeys). Extensive necrotic lesions of the foot pads (toms: 29.8%; hens: 12.4%) and necrosis of superficial scales (toms: 11.3%; hens: 7.6%) were less frequent. Plantar abscesses were rare findings (1.9%). In general, the feet of the Kelly BBB hens were more affected by foot pad lesions than those of the Kelly BBB toms. There were significant differences between the investigated flocks concerning the occurrence of foot pad lesions. The aim in rearing turkeys must be the reduction of FPD.

Key words: organic poultry farming, fattening turkeys, foot pad dermatitis, animal welfare, husbandry conditions

2019 Poultry Science 98:1559–1567
http://dx.doi.org/10.3382/ps/pey473

INTRODUCTION

Foot pad dermatitis (**FPD**), also known as plantar pododermatitis, is a condition characterized by lesions on the foot pads of poultry. The lesions vary from hyperkeratosis to severe erosions and ulceration (Clark et al., 2002; Mayne et al., 2004; Shepherd and Fairchild, 2010). These alterations may appear in the first few days of life, but more severe lesions are mostly seen during the fattening period (Mayne et al., 2006; Bergmann et al., 2013). The lesions can heal rapidly by secondary intention (Platt et al., 2004; Mayne et al., 2007). Generally, the plantar area of the foot and the weight bearing metatarsal pads are mostly affected. Several predisposing factors such as genetic line, rapid growth, feed, stocking density, litter quality, and diet composition have been discussed (Martrenchar et al., 1999; Hafez et al., 2005; Mayne, 2005; Rudolf, 2008; Youssef et al., 2011; Krautwald-Junghanns et al., 2013; Kamphues et al., 2014; Erasmus, 2017). Above all, high litter moisture is considered to be the main cause for FPD (Martland, 1984; Mayne et al., 2007; Abd El-Wahab et al., 2011; Wu and Hocking 2011; Vinco et al., 2017a). Foot pad dermatitis commonly occurs in fattening turkeys (Huff et al., 2000; Hafez et al., 2004a; Hafez et al., 2004b; Bergmann, 2006; Shepherd and Fairchild, 2010; Krautwald-Junghanns et al., 2013). Not only turkey flocks reared under conventional husbandry

Received May 22, 2018.
Accepted November 21, 2018.
[1]Corresponding author: hafez@vetmed.fu-berlin.de

conditions are affected, but also flocks reared in organic poultry farming systems (Hocking and Wu, 2013).

These alterations are potentially painful and can, therefore, be used as indicators of animal welfare (Watanabe et al., 2013; Sinclair et al., 2015; Weber Wyneken et al., 2015). Since the amendment of the German Animal Welfare Act of 2013 July 13, animal caretakers are required to self-monitor with the help of appropriate animal welfare indicators (Federal Republic of Germany, 2017). Consequently, this is a means of evaluating and comparing different poultry farms. Establishing a precautionary monitoring system would allow an early detection of husbandry and management failures. It has to be non-extensive and easy to perform under field conditions. Several approaches to assess turkey welfare at the slaughterhouse are available and described (Hocking et al., 2008; Hocking et al., 2008; Allain et al., 2013). One of the most important innovations was the implementation of a health control program as a benchmarking system to ensure valid comparability of the poultry farms (Putenerzeuger, 2013; Andersson and Toppel, 2014).

Currently, there are only a few studies published related to rearing requirements of organic turkey farms and its potential effect on animal health, performance, and prevalence of FPD (Ermakow, 2012; Hocking and Wu, 2013; Habig et al., 2017).

The aim of the present study was to evaluate the prevalence and severity of foot pad lesions in turkeys reared in organic production systems at the slaughterhouse with special attention to stocking density, fattening duration, gender, and strain.

MATERIAL AND METHODS

Animals

All investigations were carried out exclusively postmortem at slaughterhouses in Germany officially approved for slaughter of fattening turkeys.

In total, 12 organic turkey farms were investigated. Five farms reared both sexes of a medium weighted turkey strain with colored plumage and melanized scales on the legs and feet (Kelly Broad Breasted Bronze [**Kelly BBB**]) and seven farms reared hens of heavy weighted white feathered turkeys (supplied by Aviagen Turkeys; 5× British United Turkeys [**B.U.T.**] 6 and 2× Test Product 7 [**TP 7**]). For the evaluation, the results of all Aviagen hens were pooled since only two TP 7 farms were investigated and in principle comparable results concerning health and performance parameters can be expected (Simon, 2016). The investigations covered with two exceptions (farms 2 and 9): two flocks of each farm in two successive fattening periods; one during the summer months and one during winter time. In total 31 flocks (B.U.T. 6 or TP 7 hens: $n = 13$, the Kelly BBB hens: $n = 9$, and Kelly BBB toms: $n = 9$), were investigated.

All participating farms follow the legal requirements concerning organic farming that are determined by the Commission Regulation (EC) No 889/2008, laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labeling of organic products with regard to organic production, labeling, and control (European Commission, 2008).

Data Assessment at the Processing Plant

The scoring of the foot pads was carried out at the processing plant directly after slaughter. Three slaughterhouses across Germany were involved. The examinations were carried out by two observers with the help of a data entry form. A joint training at the slaughterhouse in the run up of the project ensured consistent evaluations.

From each flock, 60 random samples (both feet) were taken and scored. Depending on the speed of the slaughter line, every fifth to tenth turkey was investigated. In total, 1,860 fattening turkeys from 31 flocks were investigated (Kelly BBB toms: $n = 540$; Kelly BBB hens: $n = 540$; and B.U.T. 6 or TP 7 hens: $n = 780$).

The scoring of the foot pad health followed the same scoring system as described by Krautwald-Junghanns et al. (2011). It is designed in compliance with that evolved by Clark et al. (2002). The score consists of five categories as follows:

- score 0: surface of the skin of the foot pads without alterations, reticular scales regular developed, covering the whole plantar skin
- score 1: minimal alterations, several necrotic scales
- score 2: moderate alterations, necrotic lesions up to 2 cm in diameter, ablation of the horny layer of the epidermis
- score 3: pronounced alterations, necrotic lesions over 2 cm in diameter, deep lesions of the plantar skin. Extensive ablation of the epidermis with crater formation
- score 4: plantar abscess

Additional information about the flock-related data (average weight, age, strain, and sex) from the day of slaughter was collected (Tables 4 and 5).

Statistical Analysis

Statistical analysis of the data was done with IBM SPSS Statistics 22. If the double-sided P-value was lower than 0.05 results were considered as significant. For the prevalence rates of foot pad lesions a 95% confidence interval (**CI**) was calculated. Since the collected data are a random sample from the true population the CI provides a range of values for estimating the unknown population parameter. The interval limits comprise in 95% of all cases the true parameter of the whole population.

Table 1. Prevalence of foot pad lesions in organic Kelly Broad Breasted Bronze (Kelly BBB) toms and hens and British United Turkeys (B.U.T.) 6 or Test Product 7 (TP 7) hens at the processing plant. Numerical data in parentheses are 95% confidence interval (CI).

		Foot pad dermatitis (FPD) score				
Turkey lineand sex	Number	0	1	2	3	4
Kelly BBB toms* ($n = 540$)	(n)	25	61	286	161	7
	(%)	4.6 (3.4, 5.9)[a]	11.3 (9.4, 13.2)[a]	53.0 (50.0, 56.0)[a]	29.8 (27.1, 32.5)[a]	1.3 (0.6, 2.0)[a]
Kelly BBB hens*# ($n = 540$)	(n)	10	66	316	120	28
	(%)	1.9 (1.1, 2.7)[b,c]	12.2 (10.3, 14.2)[a,c]	58.5 (55.6, 61.4)[a,c]	22.2 (19.7, 24.7)[b,c]	5.2 (3.9, 6.5)[b,c]
B.U.T. 6 or TP 7 hens# ($n = 780$)	(n)	7	34	594	144	1
	(%)	0.9 (0.4, 1.4)[c]	4.4 (3.4, 5.4)[d]	76.2 (74.0, 78.4)[d]	18.5 (16.5, 20.5)[c]	0.1 (0.0, 3.1)[d]

*Significance regarding sex ($P = 0.00$).
#Significance regarding strain ($P = 0.24$).
[a,b]Means within each FPD score of Kelly BBB toms and Kelly BBB hens lacking a common superscript differ significantly ($P < 0.05$).
[c,d]Means within each FPD score of Kelly BBB hens and B.U.T. 6 or TP 7 hens lacking a common superscript differ significantly ($P < 0.05$).

Testing the functional relationship between the target value (FPD) and potentially influencing factors (sex, age, strain, body weight, and stocking density) was done with multivariable ordinal logistic regression. This is used to analyze the potential effect of the independent variables (influencing factors) on the dependent variable (FPD).

For analyzing the differences between males and females, only the results of the Kelly BBB flocks were included. Concerning the differences between the genetic lines, only the results of the female flocks were analyzed.

RESULTS

Nearly all examined turkeys showed some degree of FPD (97.7% [95% CI: 97.0, 98.4]). On the other hand, only 4.6% [95% CI: 3.4, 5.9] of the Kelly BBB toms, 1.9% [95% CI: 1.1, 2.7] of the Kelly BBB hens, and 0.9% [95% CI: 0.4, 1.4] of the B.U.T. 6 or TP 7 hens had no alterations of the foot pads (Table 1). All investigated flocks were affected to some extent (Tables 2 and 3).

The statistical comparison of the left and right foot concerning FPD revealed a positive correlation between both feet (Spearman correlation: $r = 0.626$, $P \leq 0.01$), so there was no considerable difference between both feet. Consequently, only the left foot was included in further calculations.

Generally, hens were significantly more often and more severely affected than the toms ($P \leq 0.05$) (Table 1). Hens showed fewer feet without any alterations (score 0) and more frequently plantar abscesses (score 4) than toms. Necrotic lesions measuring >2 cm in diameter or deep lesions (score 3) were found more often in Kelly BBB toms than in Kelly BBB hens (hens: 22.2% [95% CI: 19.7, 24.7], toms: 29.8% [95% CI: 27.1, 32.5]).

There was a significant relation between the stocking density (birds/m^2) on the day of slaughter and the occurrence of FPD ($P \leq 0.01$) analyzing the total data of all investigated turkey flocks or the data of female flocks (Tables 4 and 5). For the toms exclusively, there was no significant relation between the stocking density (birds/m^2 and kg/m^2) and the occurrence of FPD (Table 5). In general, the number of birds/m^2 was higher in female flocks than in male flocks.

There were significant differences ($P \leq 0.05$) concerning the prevalence of FPD between the farms (Tables 2 and 3). In 14 out of 22 female flocks, all investigated birds were affected to some degree (Table 2). As concerns the toms, two examined flocks (flock 2 and 4) showed a prevalence of 100% of affected foot pads (Table 3).

Alterations of score 4, plantar abscesses, were rarely seen. At this point, again differences between the farms became apparent. In three farms keeping hens, foot pad alterations of score 4 could be detected in at least one flock (flocks 1, 2, 4, and 16; see Table 2).

Analyzing the results of the female flocks, there was no significant difference between the two turkey strains regarding the incidence of FPD ($P \geq 0.05$).

A higher prevalence of more severe lesions (scores 3 and 4) was found in hens and toms of Kelly BBB in comparison to the B.U.T. 6 or TP 7 hens. 76.2% [95% CI: 74.0, 78.4] of the B.U.T. 6 or TP 7 hens and still more than half of the Kelly BBB (hens: 58.5% [95% CI: 55.6, 61.4]; toms: 53.0% [95% CI: 50.2, 56.0]) showed moderate lesions (score 2) (Table 1). Foot pads without any alterations were more frequently seen in both sexes of Kelly BBB turkeys (hens: 1.9% [95% CI: 1.1, 2.7], toms: 4.6% [95% CI: 3.4, 5.9]) than in B.U.T. 6 or TP 7 hens (0.9% [95% CI: 0.4, 1.4]).

The duration of the fattening period (hens: between 17 and 23 wk of age; toms: between 22 and 24 wk) did not have a significant influence on the occurrence of FPD (Tables 4 and 5). Additionally no seasonal effects could be evidenced. There was no difference between the two fattening periods ($P \geq 0.05$).

DISCUSSION

Foot pad dermatitis is currently an important animal welfare issue. While there are many studies concerning FPD in conventional turkey farms, only a few examinations have been analyzing organic turkey production systems (Clark et al., 2002; Hafez et al., 2004b; Krautwald-Junghanns et al., 2011; Habig et al., 2017).

Table 2. Prevalence of foot pad lesions in hens from 5 organic farms rearing 9 flocks of Kelly Broad Breasted Bronze (Kelly BBB) strain ($n = 540$) and 7 organic farms rearing 13 flocks of British United Turkeys (B.U.T.) 6 or Test Product 7 (TP 7) strain ($n = 780$) at the slaughterhouse. Presentation of the percentage of foot pad dermatitis (FPD) ordered according to the farms. Numerical data in parentheses are 95% confidence interval (CI). Age is given in wk.

				FPD score				
Farm	Turkey strain	Flock age	Number	0	1	2	3	4
1	Kelly BBB	1	(*n*)	0	2	5	27	26
		20 wk	(%)	0.0	3.3	8.3	45.0	43.3
		($n = 60$)	CI	(0.0, 0.0)	(0.0, 7.8)	(1.3, 15.3)	(32.4, 57.6)	(30.8, 55.8)
		2	(*n*)	0	0	36	23	1
		18 wk	(%)	0.0	0.0	60.0	38.3	1.7
		($n = 60$)	CI	(0.0, 0.0)	(0.0, 0.0)	(47.6, 72.4)	(26, 50.6)	(0.0, 5.0)
2	Kelly BBB	3	(*n*)	3	30	25	2	0
		18 wk	(%)	5.0	50.0	41.7	3.3	0.0
		($n = 60$)	CI	(0.0, 10.5)	(37.3, 62.7)	(29.2, 54.2)	(0.0, 7.8)	(0.0, 0.0)
3	Kelly BBB	4	(*n*)	0	12	26	21	1
		18 wk	(%)	0.0	20.0	43.3	35.0	1.7
		($n = 60$)	CI	(0.0, 0.0)	(8.9, 30.1)	(30.8, 55.8)	(22.9, 37.1)	(0.0, 5.0)
		5	(*n*)	0	1	53	6	0
		20 wk	(%)	0.0	1.7	88.3	10.0	0.0
		($n = 60$)	CI	(0.0, 0.0)	(0.0, 5.0)	(80.2, 96.4)	(2.4, 17.6)	(0.0, 0.0)
4	Kelly BBB	6	(*n*)	2	9	38	11	0
		21 wk	(%)	3.3	15.0	63.3	18.3	0.0
		($n = 60$)	CI	(0.0, 7.8)	(6.0, 24.0)	(51.1, 75.5)	(8.5, 28.1)	(0.0, 0.0)
		7	(*n*)	3	9	45	3	0
		19 wk	(%)	5.0	15.0	75.0	5.0	0.0
		($n = 60$)	CI	(0.0, 10.5)	(6.0, 24.0)	64.0, 86.0)	(0.0, 10.5)	(0.0, 0.0)
5	Kelly BBB	8	(*n*)	0	2	34	24	0
		20 wk	(%)	0.0	3.3	56.7	40.0	0.0
		($n = 60$)	CI	(0.0, 0.0)	(0.0, 7.8)	(44.2, 69.2)	(27.6, 52.4)	(0.0, 0.0)
		9	(*n*)	2	1	54	3	0
		18 wk	(%)	3.3	1.7	90.0	5.0	0.0
		($n = 60$)	CI	(0.0, 7.8)	(0.0, 5.0)	(82.4, 97.6)	(0.0, 10.5)	(0.0, 0.0)
6	B.U.T. 6	10	(*n*)	0	6	52	2	0
		17 wk	(%)	0.0	10.0	86.7	3.3	0.0
		($n = 60$)	CI	(0.0, 0.0)	(2.4, 17.6)	(78.1, 95.3)	(0.0, 7.8)	(0.0, 0.0)
		11	(*n*)	3	8	48	1	0
		18 wk	(%)	5.0	13.3	80.0	1.7	0.0
		($n = 60$)	CI	(0.0, 10.5)	(4.7, 21.9)	(69.9, 90.1)	(0.0, 5.0)	(0.0, 0.0)
7	B.U.T. 6	12	(*n*)	0	0	56	4	0
		20 wk	(%)	0.0	0.0	93.3	6.7	0.0
		($n = 60$)	CI	(0.0, 0.0)	(0.0, 0.0)	(87.0, 99.6)	(0.4, 13.0)	(0.0, 0.0)
		13	(*n*)	1	7	52	0	0
		18 wk	(%)	1.7	11.7	86.7	0.0	0.0
		($n = 60$)	CI	(0.0, 5.0)	(3.6, 19.8)	(78.1, 95.3)	(0.0, 0.0)	(0.0, 0.0)
8	B.U.T. TP 7	14	(*n*)	0	1	15	44	0
		20 wk	(%)	0.0	1.7	25.0	73.3	0.0
		($n = 60$)	CI	(0.0, 0.0)	(0.0, 5.0)	(14.0, 36.0)	(62.1, 84.5)	(0.0, 0.0)
		15	(*n*)	0	0	58	0	0
		18 wk	(%)	0.0	3.3	96.7	0.0	0.0
		($n = 60$)	CI	(0.0, 0.0)	(0.0, 7.8)	(92.2, 101.2)	(0.0, 0.0)	(0.0, 0.0)
9	B.U.T. TP 7	16	(*n*)	0	0	22	37	1
		19 wk	(%)	0.0	0.0	36.7	61.7	1.7
		($n = 60$)	CI	(0.0, 0.0)	(0.0, 0.0)	(24.5, 48.9)	(49.4, 74.0)	(0.0, 5.0)
10	B.U.T. 6	17	(*n*)	0	0	47	13	0
		19 wk	(%)	0.0	0.0	78.3	21.7	0.0
		($n = 60$)	CI	(0.0, 0.0)	(0.0, 0.0)	(67.9, 88.7)	11.3, 32.1)	(0.0, 0.0)
		18	(*n*)	1	0	42	17	0
		19 wk	(%)	1.7	0.0	70.0	28.3	0.0
		($n = 60$)	CI	(0.0, 5.0)	(0.0, 0.0)	(58.4, 81.6)	(16.9, 39.7)	(0.0, 0.0)
11	B.U.T. 6	19	(*n*)	0	0	47	13	0
		20 wk	(%)	0.0	0.0	78.3	21.7	0.0
		($n = 60$)	CI	(0.0, 0.0)	(0.0, 0.0)	(67.9, 88.7)	(11.3, 32.1)	(0.0, 0.0)
		20	(*n*)	0	1	48	11	0
		20 wk	(%)	0.0	1.7	80.0	18.3	0.0
		($n = 60$)	CI	(0.0, 0.0)	(0.0, 5.0)	(69.9, 90.1)	(8.5, 28.1)	(0.0, 0.0)
12	B.U.T. 6	21	(*n*)	0	8	50	2	0
		21 wk	(%)	0.0	13.3	83.3	3.3	0.0
		($n = 60$)	CI	(0.0, 0.0)	(4.7, 21.9)	(73.9, 92.2)	(0.0, 7.8)	(0.0, 0.0)
		22	(*n*)	2	1	57	0	0
		23 wk	(%)	3.3	1.7	95.0	0.0	0.0
		($n = 60$)	CI	(0.0, 7.8)	(0.0, 5.0)	(89.5, 100.5)	(0.0, 0.0)	(0.0, 0.0)
Mean value			(*n*)	0.8	4.5	41.4	12	1.3
			(%)	1.3	7.6	68.9	20.0	2.2

Table 3. Prevalence of foot pad lesions in toms from 5 organic farms rearing 9 flocks of Kelly Broad Breasted Bronze (Kelly BBB) strain ($n = 540$) at the slaughterhouse. Presentation of the percentage of foot pad dermatitis (FPD) ordered according to the farms. Numerical data in parentheses are 95% confidence interval (CI). Age is given in wk.

				FPD score				
Farm	Turkey strain	Flock age	Number	0	1	2	3	4
1	Kelly BBB	1	(*n*)	1	8	26	25	0
		22 wk	(%)	1.7	13.3	43.3	41.7	0.0
		($n = 60$)	CI	(0.0, 5.0)	(4.7, 21.9)	(30.8, 55.8)	(29.2, 54.2)	(0.0, 0.0)
		2	(*n*)	0	2	31	25	2
		22 wk	(%)	0.0	3.3	51.7	41.7	3.3
		($n = 60$)	CI	(0.0, 0.0)	(0.0, 7.8)	(39.1, 64.3)	(29.2, 54.2)	(0.0, 7.8)
2	Kelly BBB	3	(*n*)	1	5	48	6	0
		22 wk	(%)	1.7	8.3	80.0	10.0	0.0
		($n = 60$)	CI	(0.0, 5.0)	(1.3, 15.3)	(69.9, 90.1)	(2.4, 17.6)	(0.0, 0.0)
3	Kelly BBB	4	(*n*)	0	8	35	17	0
		22 wk	(%)	0.0	13.3	58.3	28.3	0.0
		($n = 60$)	CI	(0.0, 0.0)	(4.7, 21.9)	(45.8, 70.8)	(16.9, 39.7)	(0.0, 0.0)
		5	(*n*)	1	0	19	37	3
		23 wk	(%)	1.7	0.0	31.7	61.7	5.0
		($n = 60$)	CI	(0.0, 5.0)	(0.0, 0.0)	(19.9, 43.5)	(49.4, 74.0)	(0.0, 10.5)
4	Kelly BBB	6	(*n*)	5	10	37	8	0
		23 wk	(%)	8.3	16.7	61.7	13.3	0.0
		($n = 60$)	CI	(1.3, 15.3)	(7.3, 26.1)	(49.4, 74.0)	(4.7, 21.9)	(0.0, 0.0)
		7	(*n*)	4	2	26	27	1
		24 wk	(%)	6.7	3.3	43.3	45.0	1.7
		($n = 60$)	CI	(0.4, 13.0)	(0.0, 7.8)	(30.8, 55.8)	(32.4, 57.6)	(0.0, 5.0)
5	Kelly BBB	8	(*n*)	9	24	24	3	0
		23 wk	(%)	15.0	40.0	40.0	5.0	0.0
		($n = 60$)	CI	(6.0, 24.0)	(27.6, 52.4)	(27.6, 52.4)	(0.0, 10.5)	(0.0, 0.0)
		9	(*n*)	4	2	40	13	1
		22 wk	(%)	6.7	3.3	66.7	21.7	1.7
		($n = 60$)	CI	(0.4, 13.0)	(0.0, 7.8)	(54.8, 78.6)	(11.3, 32.1)	(0.0, 5.0)
Mean value			(*n*)	2.8	6.8	31.8	17.9	0.8
			(%)	4.6	11.3	53.0	29.8	1.3

The results revealed that nearly all examined turkeys showed a certain degree of FPD at the slaughterhouse. More than 90% showed necrotic lesions (scores 1 to 3) or plantar abscesses (score 4), only 2.3% were unaffected.

The results of the present investigation show that hens were more frequently and more seriously affected than toms. Differences concerning the prevalence of FPD between both sexes may be due to the higher number of birds/m^2 (Tables 2 and 3). For organic poultry farming, the stocking density should not exceed 10 birds/m^2, or 21 kg/m^2 (European Commission, 2008). Hens are often reared in a higher number of birds/m^2, which take up more feeds what leads to a greater amount of excreta and thereby to higher litter moisture (Rudolf, 2008; Krautwald-Junghanns et al., 2011; Ellerich, 2012). The results of the present study reveal a relation between the stocking density and the occurrence of FPD. This confirms other studies which reported that a higher stocking density is associated with higher incidence of FPD (Noll et al., 1991; Martrenchar et al., 1999; Martrenchar et al., 2001; Hafez et al., 2005; Erasmus, 2017). The above-mentioned results lead to the litter condition as the decisive factor. Poor litter quality has a great influence on the emergence of foot pad lesions. High litter moisture in particular is presumed to be a main cause for such alterations (Martland, 1984; Clark et al., 2002; Mayne et al., 2007; Berk et al., 2013).

The difference between the investigated flocks (Tables 2 and 3) underlines the crucial role of management in the emergence of FPD and its multifactorial etiology. It is important to detect farms with a high prevalence of FPD to initiate specific means to decrease it. Besides the various influencing factors on foot pad health that concern all turkey production systems, like sex, strain, litter and feeding (Mayne, 2005; Shepherd and Fairchild, 2010; Tabler et al., 2013; Vinco et al., 2017a), there are further aspects to consider for organic poultry farming (Sundrum et al., 2004; Rahmann et al., 2005). As the access to an outdoor area is mandatory for turkeys reared under organic poultry farming system, its impact on foot pad health is an interesting issue. The measurement of this influence is difficult to conduct. The condition of the area depends on weather and climate. Ponding can lead to humid milieu around the feet and thereby to increasing inflammation of the foot pads. The difficulty is to measure which and how often birds use the outdoor access, how long they stay there, and whether they stand in the puddles or on dry ground. According to Pagazaurtundua and Warris (2006) and Berk (2013), birds with access to an outdoor area show a higher prevalence of FPD, but further studies investigating this impact with special regard to the above-mentioned factors are of interest. In addition, turkeys have a longer rearing period under organic farming system. This means that the birds remain longer on the same litter leading to adverse litter condition if not managed properly. Furthermore, the farmers are often not able to meet the turkeys' feeding requirements due to legal regulations prohibiting

Table 4. Flock and animal related data of hens from 5 organic farms rearing 9 flocks of Kelly Broad Breasted Bronze (Kelly BBB) strain (n = 540) and 7 organic farms rearing 13 flocks of British United Turkeys (B.U.T.) strain (n = 780) at the day of slaughter.

Farm	Turkey strain	Flock	Flock size (n)	Stocking density	Age on slaughter	Average weight on slaughter
1	Kelly BBB	1	2,124	2.31 birds/m^2 24.9 kg/m^2	20 wk	10.8 kg
		2	1,851	2.21 birds/m^2 22.82 kg/m^2	18 wk	10.3 kg
2	Kelly BBB	3	2,478	2,38 birds/m^2 15.3 kg/m^2	18 wk	8.5 kg
3	Kelly BBB	4	2,505	2.13 birds/m^2 19.4 kg/m^2	18 wk	9.1 kg
		5	1,852	1.5 birds/m^2 15.7 kg/m^2	20 wk	10.3 kg
4	Kelly BBB	6	2,194	1.79 birds/m^2 18.63 kg/m^2	21 wk	10.4 kg
		7	2,012	1.61 birds/m^2 14.75 kg/m^2	19 wk	9.2 kg
5	Kelly BBB	8	1,975	1.86 birds/m^2 20.85 kg/m^2	20 wk	11.2 kg
		9	1,513	1.43 birds/m^2 14.26 kg/m^2	18 wk	10 kg
6	B.U.T. 6	10	2,462	1.8 birds/m^2 14.73 kg/m^2	17 wk	8.2 kg
		11	1,760	1.28 birds/m^2 14.64 kg/m^2	18 wk	11.4 kg
7	B.U.T. 6	12	2,627	2.06 birds/m^2 23.11 kg/m^2	20 wk	11.2 kg
		13	1,733	–*	18 wk	10.4 kg
8	B.U.T. TP 7	14	3,147	36.6 kg/m^2	20 wk	11.6 kg
		15	3,321	2.01 birds/m^2 20.13 kg/m^2	18 wk	10.2 kg
9	B.U.T. TP 7	16	2,416	1.34 birds/m^2 14.62 kg/m^2	19 wk	10.9 kg
10	B.U.T. 6	17	2,310	1.77 birds/m^2 16.29 kg/m^2	19 wk	9.2 kg
		18	2,280	1.75 birds/m^2 17.67 kg/m^2	18 wk	10.1 kg
11	B.U.T. 6	19	2,111	2.08 birds/m^2 20.15 kg/m^2	20 wk	9.7 kg
		20	2,248	2.22 birds/m^2 23.97 kg/m^2	20 wk	10.8 kg
12	B.U.T. 6	21	2,342	1.46 birds/m^2 10.52 kg/m^2	21 wk	7.2 kg
		22	3,111	1.94 birds/m^2 22.2 kg/m^2	23 wk	11.4 kg

*Data not available.

the addition of synthetic amino acids, vitamins, minerals, and trace elements (European Commission, 2008). Inadequate formulation may lead to malnutrition or intestinal disorders and thereby to higher litter moisture. Bellof et al. (2010) compared various "organic" feed mixtures with different energy contents, which revealed that the mixture containing the lowest energy value contained the highest amount of non-starch polysaccharide, thus leading to poor condition of excreta. Lack of essential amino acids and higher amounts of raw protein and thereby protein bound electrolytes, which are eliminated through the renal system, have an influence on the health condition of the birds and the condition of the excreta (Jeroch, 2013; Kamphues et al., 2014).

All these aspects need to be considered when a high prevalence of FPD at the slaughterhouse shall lead to controls and targeted measures on the farm.

In addition to the husbandry conditions themselves, the turkey strain might be interesting for the animal caretaker for deciding which is most suitable for organic poultry farming systems. The present study does not provide a clear answer to that subject for there is no significant difference between both strains ($P \geq 0.05$) (Table 2). Similar results were found in the study by Platz et al. (2003), investigating the same conventional turkey breeds under organic outdoor rearing conditions.

Comparing the obtained results with those from conventional turkeys investigated at the slaughterhouse following the same study setup, no significant differences were observed concerning the occurrence of FPD (Krautwald-Junghanns et al., 2011). In general, conventional turkeys were more often affected; however, turkeys reared under organic poultry systems showed more severe lesions like scores 3 and 4. Both hens

Table 5. Flock and animal related data of toms from 5 organic farms rearing 9 flocks of Kelly Broad Breasted Bronze (Kelly BBB) strain ($n = 540$) at the day of slaughter.

Farm	Turkey strain	Flock	Flock size (n)	Stocking density	Age on slaughter	Average weight on slaughter
1	Kelly BBB	1	1,647	0.69 birds/m^2 11.26 kg/m^2	22 wk	16.3 kg
		2	1,820	0.76 birds/m^2 10.99 kg/m^2	22 wk	14.4 kg
2	Kelly BBB	3	2,328	2.24 birds/m^2 11.7 kg/m^2	22 wk	10.1 kg
3	Kelly BBB	4	1,268	1.03 birds7m^2 15.87 kg/m^2	22 wk	15.5 kg
		5	904	1 bird/m^2 12.75 kg/m^2	23 wk	16.0 kg
4	Kelly BBB	6	853	0.86 birds/m^2 13.60 kg/m^2	23 wk	15.9 kg
		7	939	1.08 birds/m^2 19.59 kg/m^2	24 wk	18.2 kg
5	Kelly BBB	8	885	1.15 birds/m^2 22.14 kg/m^2	23 wk	19.2 kg
		9	860	1.12 birds/m^2 20.61 kg/m^2	22 wk	18.4 kg

and toms reared under conventional poultry farming system showed more low-grade alterations (score 1). More than half of all examined turkeys, reared under conventional or organic farms or both, showed moderate lesions, score 2. That means FPD is an important welfare issue in both rearing systems.

The question is at which point do these lesions become a relevant animal welfare issue? It is decisive whether only severe lesion scores or whether the general occurrence of foot pad lesions is of importance. Decisive is the depth of alterations, which determines the clinical relevance. Because of the resulting pain, such pathological alterations have to be seen as an impact on animal health and consequently a relevant animal welfare issue (Sinclair et al., 2015; Weber Wyneken et al., 2015). Therefore, FPD is a suitable indicator for animal welfare (Watanabe et al., 2013). The problem is that it can only be measured when the damage has already occurred. The most convenient place to do the survey is at the slaughterhouse. Following the health control program implemented by Andersson and Toppel (2014), a standardized benchmarking system using a uniform scoring system has to be established in every slaughterhouse for both turkeys reared in conventional and organic production system. As a result, it has to provide simplified information about the status quo, especially deficiencies like excessive stocking densities, inadequate litter management and feeding, in the management of the farms. It has to be clearly identified at which point an intervention is necessary. This can only be implemented by defining a threshold. Following the project of Vinco et al. (2017b), a trigger level can be calculated with the help of a formula for simplifying the scoring.

As a further approach to decrease FPD not only by assessing the prevalence rate at the slaughterhouse, the German Animal Welfare Act demands self-monitoring by the animal caretaker using appropriate animal welfare indicators (Federal Republic of Germany, 2017). Only by this means early detection of foot pad lesions is possible and can lead to timely intervention. Another point to prevent the occurrence of FPD is the monitoring of the litter moisture in the barn. Studies show that the visual scoring of litter condition is most reliable as compared to the measurement with the help of portable instruments (Vinco et al., 2017b).

A new avenue to early detection of inflammatory processes of the foot pad gives a recent study by Moe et al. (2018) revealing a negative association between the foot pad temperature and the visual detected early stages of FPD, assuming that the inflammatory processes in the early stages of FPD are either negligible or hyperkeratosis is shielding heat emission of the foot pad. Using infrared thermography could be new possibility for early detection of FPD, but more studies concerning foot pad temperature in relation to with FPD are necessary.

Taking these early assessment methods of animal welfare indicators going along with a generally mandatory and uniform benchmarking system at all slaughterhouses targeted measures can be taken. A survey of FPD prevalence is the starting point to implement a controlling program by documenting the status quo and by detecting problematic farms.

Taking into account today's poultry farming system, both conventional and organic, it does not seem possible to avoid the occurrence of foot pad lesions completely. Foot pad dermatitis has to be seen as a profound animal welfare issue and the aim has to be to reduce its occurrence and to have intact foot pads in the long term.

ACKNOWLEDGMENTS

The project was financially supported by the German Federal Ministry of Food and Agriculture (BMEL)

through the Federal Scheme for Organic Farming and Other Forms of Sustainable Agriculture (BÖLN)

REFERENCES

Abd El-Wahab, A., A. Beineke, M. Beyerbach, C. F. Visscher, and J. Kamphues. 2011. Effects of floor heating and litter quality on the development and severity of foot pad dermatitis in young turkeys. Avian Dis. 55:429–434.

Andersson, R., and K. Toppel. 2014. Identifizierung und Erprobung von Parametern zur Indikatorbildung und als Instrument des Controllings - mit Fokus auf Mortalität, Fußballengesundheit, Arzneimitteleinsatz. Puten-Controlling, Kurztitel. Pages 7–54.

Allain, V., D. Huonnic, M. Rouina, and V. Michel. 2013. Prevalence of skin lesions in turkeys at slaughter. Br. Poult. Sci. 54: 33–41.

Bellof, G., G. Dusel, and E. Schmidt. 2010. Einfluss eines Multienzymkomplexes auf die Mastleistung und den Schlachtkörperwert von Putenhähnen des Genotyps "BIG 6" in der ökologischen Putenmast. Arch. Geflügelk. 74:13–20.

Bergmann, S., N. Ziegler, T. Bartels, J. Hubel, C. Schumacher, E. Rauch, S. Brandl, A. Bender, G. Casalicchio, M. E. Krautwald-Junghanns, and M. H. Erhard. 2013. Prevalence and severity of foot pad alterations in German turkey poults during the early rearing phase. Poult. Sci. 92:1171–1176.

Bergmann, S. M. 2006. Vergleichende Untersuchung von Mastputenhybriden (B.U.T. Big 6) und einer Robustrasse (Kelly Bronze) bezüglich Verhalten, Gesundheit und Leistung in Freilandhaltung. Diss. Ludwig-Maximilians-Univ., Munich.

Berk, J. 2013. Behaviour and health of different turkey genotypes with outdoor access. Understanding Behaviour to Improve Livelihood: Proc. 47th Congr. Int. Soc. Appl. Ethol., Florianópolis, Brazil.

Berk, J., C. Schumacher, M. E. Krautwald-Junghanns, M. Martin, and T. Bartels. 2013. Verweildauer von Mastputen verschiedener Herkünfte im Bereich von Tränke- und Fütterungseinrichtungen. Appl. Agric. Forestry Res. 63:245–254.

Clark, S., G. Hansen, P. McLean, P. Bond, W. Wakeman, R. Meadows, and S. Buda. 2002. Pododermatitis in turkeys. Avian Dis. 46:1038–1044.

Ellerich, R. 2012. Prävalenz von Veränderungen der Haut und ihrer Anhangsorgane bei Mastputen. Diss. Univ. Leipzig, Leipzig.

Erasmus, M. A. 2017. A review of the effects of stocking density on turkey behavior, welfare, and productivity. Poult. Sci. 96:2540–2545.

Ermakow, O. 2012. Ergebnisse der Fleischuntersuchung bei Puten aus ökologischer und konventioneller Haltung. Diss. Univ. Leipzig, Leipzig.

European Commission. 2008. Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control. Official Journal of the European Union. L 250/251 - L 250/284.

Federal Republic of Germany. 2017. Tierschutzgesetz in der Fassung der Bekanntmachung vom 18. Mai 2006 (BGBl. I S. 1206, 1313), das zuletzt durch Artikel 141 des Gesetzes vom 29. März 2017 (BGBl. I S. 626) geändert worden ist.

Habig, C., B. Spindler, M. Beyerbach, and N. Kemper. 2017. Evaluation of foot pad health and live weights in two lines of turkey hens kept under organic husbandry conditions in Germany. Berl. Munch. Tierarztl. Wochenschr. 130:250–257.

Hafez, H. M., M. Rudolf, S. Haase, R. Hauck, K.-P. Behr, V. Bergmann, and R. Günther. 2005. Influence of stocking density and litter material on the incidence of pododermatitis of turkeys. Pages 101–109. Proceedings of the 3rd International Meeting of the Working Group 10 (Turkey) of WPSA. H. M. Hafez editor. Turkey production: prospects on future developments, Berlin, 09-11.6.2005. Berlin. Mensch & Buch Verlag. ISBN: 3-89820-993-8.

Hafez, H. M., K. Wäse, S. Haase, T. Hoffmann, and O. Simon. 2004a. Leg disorders in various lines of commercial turkeys with especial attention to pododermatitis. Proc. 5th Int. Symp. Turkey Dis., Berlin.

Hafez, H. M., K. Wäse, S. Haase, T. Hoffmann, O. Simon, and V. Bergmann. 2004b. Pododermatitis in several commercial turkey lines. Pages 11–18. Proceedings of the 5th International Symposium on Turkey Diseases Berlin. H. M. Hafez editor. German Veterinary Medical Society (DVG-Service-GmbH, Giessen 2004). ISBN: 3-938026-15-4.

Hocking, P. M., and K. Wu. 2013. Traditional and commercial turkeys show similar susceptibility to foot pad dermatitis and behavioural evidence of pain. Br. Poult. Sci. 54:281–288.

Hocking, P. M., R. K. Mayne, R. W. Else, N. A. French, and J. Gatcliffe. 2008. Standard European footpad dermatitis scoring system for use in turkey processing plants. Worlds Poult. Sci. J. 64:323–328.

Huff, G. R., W. E. Huff, N. C. Rath, and J. M. Balog. 2000. Turkey osteomyelitis complex. Poult. Sci. 79:1050–1056.

Jeroch, H. 2013. Fütterung des Mastgeflügels. Pages 423–441 in Geflügelernährung. J. Zentek ed., Eugen Ulmer KG, Stuttgart.

Kamphues, J., P. Wolf, M. Coenen, K. Eder, C. Iben, E. Kienzle, A. Liesegang, K. Männer, Q. Zebeli, and J. Zentek. 2014. Ernährung verschiedener Spezies. Pages 452–463 in Supplemente zur Tierernährung. J. Kamphues, M., and H. Schaper ed., Stuttgart.

Krautwald-Junghanns, M. E., S. Bergmann, M. H. Erhard, K. Fehlhaber, J. Hübel, M. Ludewig, H. Mitterer-Istyagin, N. Ziegler, and T. Bartels. 2013. Impact of selected factors on the occurrence of contact dermatitis in Turkeys on commercial farms in Germany. Animals 3:608–628.

Krautwald-Junghanns, M. E., R. Ellerich, H. Mitterer-Istyagin, M. Ludewig, K. Fehlhaber, E. Schuster, J. Berk, S. Petermann, and T. Bartels. 2011. Examinations on the prevalence of footpad lesions and breast skin lesions in British United Turkeys Big 6 fattening turkeys in Germany. Part I: Prevalence of footpad lesions. Poult. Sci. 90:555–560.

Martland, M. F. 1984. Wet litter as a cause of plantar pododermatitis, leading to foot ulceration and lameness in fattening turkeys. Avian Pathol. 13:241–252.

Martrenchar, A., D. Huonnic, J. P. Cotte, E. Boilletot, and J. P. Morisse. 1999. Influence of stocking density on behavioural, health and productivity traits of turkeys in large flocks. Br. Poult. Sci. 40:323–331.

Martrenchar, A., D. Huonnic, and J. P. Cotte. 2001. Influence of environmental enrichment on injurious pecking and perching behaviour in young turkeys. Br. Poult. Sci. 42:161–170.

Mayne, R. K. 2005. A review of the aetiology and possible causative factors of foot pad dermatitis in growing turkeys and broilers. Worlds Poult. Sci. J. 61:256–267.

Mayne, R. K., R. W. Else, and P. M. Hocking. 2004. 2004 Spring meeting of the WPSA UK branch posters. Br. Poult. Sci. 45:S41–S42.

Mayne, R. K., R. W. Else, and P. M. Hocking. 2007. High litter moisture alone is sufficient to cause footpad dermatitis in growing turkeys. Br. Poult. Sci. 48:538–545.

Mayne, R. K., P. M. Hocking, and R. W. Else. 2006. Foot pad dermatitis develops at an early age in commercial turkeys. Br. Poult. Sci. 47:36–42.

Moe, R. O., J. Bohlin, A. Flo, G. Vasdal, H. Erlandsen, E. Guneriussen, E. C. Sjokvist, and S. M. Stubsjoen. 2018. Effects of subclinical footpad dermatitis and emotional arousal on surface foot temperature recorded with infrared thermography in turkey toms (Meleagris gallopavo). Poult. Sci. 97:2249–2257.

Noll, S. L., M. E. El Halawani, P. Waibel, P. Redig, and K. Janni. 1991. Effect of diet and population density on male turkeys under various environmental conditions.: 1. Turkey growth and health performance. Poult. Sci. 70:923–934.

Platt, S., S. Buda, and K. D. Budras. 2004. The repair of foot pad lesions in commercial turkeys. Proc. 5th Int. Symp. Turkey Dis., Berlin.

Pagazaurtundua, A., and P. D. Warris. 2006. Levels of foot pad dermatitis in broiler chickens reared in 5 different systems. Br. Poult. Sci. 47:529–532.

Platz, S., J. Berger, F. Ahrens, U. Wehr, W. Rambeck, W. Amselgruber, and M. H. Erhard. 2003. Health, productivity and behaviour of conventional turkey breeds under ecological outdoor

rearing conditions. XIth Int. Congr. Anim. Hyg. Mexico City. https://www.isah-soc.org/?Events/Congresses/2003-Mexico.

Putenerzeuger, Verband Deutscher. 2013. Bundeseinheitliche Eckwerte für eine freiwillige Vereinbarung zur Haltung von Mastputen. Accessed Dec. 2017. http://www.zdg-online.de/uploads/tx_userzdgdocs/VDP_Broschuere_EckwerteMastputen_29-04_1_ohne_Unterschriften.pdf.

Rahmann, G., R. Koopmann, and R. Oppermann. 2005. Can organic farming rely on animal husbandry as a focus for the future – The recent performance of organic farms and the right development paths to follow? Pages 657–660. Proc. Ende der Nische - 8. Wissenschaftstagung Ökologischer Landbau, Kassel. http://orgprints.org/5168/1/127_8wita_%C3%96kotierhaltung.pdf.

Rudolf, M. 2008. Influence of stocking density and litter material on pododermatitis in turkeys. Diss. Freie Universität Berlin, Berlin.

Shepherd, E. M., and B. D. Fairchild. 2010. Footpad dermatitis in poultry. Poult. Sci. 89:2043–2051.

Simon, I. 2016. Neue Putenlinien im Vergleich. Versuchs- und Bildungszentrum Haus Düsse. Landwirtschaftskammer Nordrhein-Westfalen. Accessed Jul. 2018. http://www.landwirtschaftskammer.de/duesse/tierhaltung/gefluegel/versuche/puten/2014_neue_putenlinien.pdf.

Sinclair, A., C. Weber Wyneken, T. Veldkamp, L. J. Vinco, and P. M. Hocking. 2015. Behavioural assessment of pain in commercial turkeys (Meleagris gallopavo) with foot pad dermatitis. Br. Poult. Sci. 56:511–521.

Sundrum, A., T. Benninger, and U. Richter. 2004. Statusbericht zum Stand des Wissens über die Tiergesundheit in der Ökologischen Tierhaltung. Schlussfolgerungen und Handlungsoptionen für die Agrarpolitik. Univ. Kassel, Kassel. Pages 6–92. http://orgprints.org/5232/1/5232-03OE672-unikassel-sundrum-2004-tiergesundheit-sq.pdf.

Tabler, T., J. Wells, W. Zhai, H. M. Yakou, and Y. Linag. 2013. What causes Footpad Dermatitis in Poultry? Mississippi State University Extension Service. https://extension.msstate.edu/sites/default/files/publications/publications/p2769.pdf.

Vinco, L. J., S. Giacomelli, L. Campana, G. Lombardi, P. M. Hocking, and T. Veldkamp. 2017a. Identifying on-farm factors affecting foot pad lesions. Pages 28–33. Proc. 11th Turkey Science and Production Conference. https://www.researchgate.net/publication/316097223_Identifying_on-farm_factors_affecting_foor_pad_lesions.

Vinco, L. J., S. Giacomelli, L. Campana, G. Lombardi, P. M. Hocking, and T. Veldkamp. 2017b. Litter moisture assessment and foot pad dermatitis scoring as animal welfare indicators in commercial turkey production. . Pages 35–43. Proceeding of 9th International Meeting of the Working Group 10 (Turkey) of WPSA. H. M. Hafez editor. Turkey Production and Health: Challenges and opportunities.

Watanabe, T. T. N., S. Lolli, L. Ferrari, and V. Ferrante. 2013. Review of the physiological and pathological welfare indicators applied in turkeys (Meleagris gallopavo). Biotechnol. Anim. Husbandry 29:727–740.

Weber Wyneken, C., A. Sinclair, T. Veldkamp, L. J. Vinco, and P. M. Hocking. 2015. Footpad dermatitis and pain assessment in turkey poults using analgesia and objective gait analysis. Br. Poult. Sci. 56:522–530.

Wu, K., and P. M. Hocking. 2011. Turkeys are equally susceptible to foot pad dermatitis from 1 to 10 weeks of age and foot pad scores were minimized when litter moisture was less than 30%. Poult. Sci. 90:1170–1178.

Youssef, I. M., A. Beineke, K. Rohn, and J. Kamphues. 2011. Effects of litter quality (moisture, ammonia, uric acid) on development and severity of foot pad dermatitis in growing turkeys. Avian Dis. 55:51–58.

3.2 Publication 2

DOI: https://doi.org/10.1016/j.japr.2021.100145

Investigation of the occurrence of pathological carcass alterations at the processing plant in meat turkeys reared in organic production systems in Germany

D. Freihold,[*,†,1] T. Bartels,[†,§] S. Bergmann,[‡] J. Berk,[§] F. Deerberg,[#] A. Dressel,[‖] M. H. Erhard,[‡] O. Ermakow,[¶] M. Huchler,[†] B. Spindler,[**] S. Thieme,[*,†,2] M.-E. Krautwald-Junghanns,[†] and H. M. Hafez[*]

[*]Institute of Poultry Diseases, Faculty of Veterinary Medicine, Freie Universität Berlin, Berlin, Germany; [†]Clinic for Birds and Reptiles, Faculty of Veterinary Medicine, University of Leipzig, Leipzig, Germany; [‡]Chair of Animal Welfare, Ethology, Animal Hygiene and Animal Husbandry, Faculty of Veterinary Medicine, Ludwig-Maximilians-University, Munich, Germany; [§]Institute of Animal Welfare and Animal Husbandry, Friedrich-Loeffler-Institut, Celle, Germany; [#]Oeko-Berater, Beratung & Projektmanagement Ökologischer Landbau, Böseeckendorf, Germany; [‖]Veterinär- und Lebensmittelüberwachungsamt, Landkreis Stendal, Germany; [¶]Fachdienst Veterinär- und Lebensmittelüberwachung, Landkreis Ludwigslust-Parchim, Parchim, Germany; and [**]Institute for Animal Hygiene, Animal Welfare and Farm Animal Behaviour, University of Veterinary Medicine Hannover, Foundation, Hannover, Germany

Primary Audience: Official Veterinarians, Poultry Breeders, Farm Managers

SUMMARY

In the present study the occurrence of turkey carcass alterations such as breast skin lesions, liver lesions, and swelling of the hock joint in turkeys reared in organic farms was investigated at slaughterhouses in Germany. The examinations included 1,860 turkey carcasses of 2 turkey lines Kelly Broad Breasted Bronze(BBB) (540 toms and 540 hens) and British United Turkeys (Big 6 and The Test Product 7) (780 hens). The results showed that breast skin lesions were rare (1.7%). On the other hand, liver lesions were a common finding in both hens and toms. Nearly half of all investigated turkeys were affected (49.3%). Swelling of the hock joint was detected in 17.3% of all investigated turkeys; the occurrence in Kelly BBB toms was significantly higher than in hens (toms: 28.7%; hens: 16.9%). In general, there were significant differences between the investigated flocks. Carcass lesions are a major animal welfare concern, which affect conventional and organic reared turkeys. Investigating the occurrence of carcass lesions provides the necessary precondition to establish a benchmarking system to evaluate and compare turkey farms. The aim is to reduce and/or eliminate these alterations in the long term in order to improve animal welfare.

Key words: organic rearing of meat turkey, carcass investigation at slaughterhouse (breast skin lesion, liver alteration, swelling of the hock joint), animal welfare

2021 J. Appl. Poult. Res. 30:100145
https://doi.org/10.1016/j.japr.2021.100145

[1]Corresponding author: darja.freihold@fu-berlin.de
[2] Present address: Institute of Food Safety and Food Hygiene, Working Group Meat Hygiene and Technology, Faculty of Veterinary Public Health, Freie Universität Berlin.

DESCRIPTION OF PROBLEM

Currently, there is great concern about health problems and animal welfare issues in turkey farms in the European Union. In the case of organic turkey production in particular, the consumer expects high animal welfare standards. Therefore, it is important to understand the relationship between husbandry conditions, as well as animal-related factors and their subsequent impact on health conditions. According to a published report on a new animal health strategy for the European Union, the concept of animal health should cover not only the absence of disease in animals, but also the relationship between the animals' health and their welfare. It should also emphasize social, economic, and ethical considerations, as well as support the achievement of a high level of environmental protection (European Commission, 2007).

Apart from voluntary agreements between the poultry producers' association (Putenerzeuger, 2013) and the government setting minimum standards for turkey husbandry, there are no legal rules for turkey rearing in particular. Yet there are tighter requirements for turkeys reared in organic farming systems based on the European Commission (**EC**) Regulation No. 898/2008 (European Commission, 2008), which determines basic conditions for organic production. It specifies a maximum herd size of 2,500 birds per stable and stocking density of 10 turkeys or 21 kg/m^2. Furthermore, the regulation stipulates a minimum age of slaughter for heavy turkey breeds, which is 100 d for hens and 140 d for toms. In addition, there are stricter requirements concerning feeding, especially regarding food additives, which have to be of organic origin 100% and need to appear in the positive list (European Commission, 2008; Kamphues et al., 2014).

In turkey production welfare-related problems such as breast skin lesions, pathologic lesions of the internal organs, in particular the liver as the central metabolic organ, arthritis, and footpad dermatitis (**FPD**) play an important role (Ermakow, 2012; Allain et al., 2013; Hafez and Hauck, 2014). Both conventional and organic turkey production are affected (Mitterer-Istyagin et al., 2011; Ermakow, 2012).

Breast blisters are an encapsulated inflammation of the bursa sternalis; in the 1940s the condition was described by Hodgson and Gutteridge (1941) and O'Neil (1943). It mostly leads to a downgrading at the processing plant (McEwen and Barbut, 1992). It should be distinguished from the ulcerative lesions of contact dermatitis in the skin overlying the sternum. Both may be found in the same flock (Martland, 1985), but the breast blisters are more probably due to prolonged pressure from lying rather than contact irritation (McCune and Dellmann, 1968). Changes range from focal ulcerative dermatitis (breast buttons), to breast blisters (hygromas), to purulent bursitis (Kamyab, 2001). Breast buttons are locally restricted ulcerations, which allow further processing of the breast muscle after removal (Gonder and Barnes, 1987). Hygromas are serous fluid-filled blisters of different sizes, whereas with purulent bursitis the enlarged bursa sternalis is pus-filled. In such cases infectious agents such as *Staphylococcus* spp., *Streptococcus* spp., *Escherichia coli*, and also *Mycoplasma* spp. could be detected (Tilley et al., 1996; Mitterer-Istyagin et al., 2011; Ermakow, 2012). As a consequence, the downgrading can affect the whole breast muscle or even the complete carcass (McEwen and Barbut, 1992; Hörning et al., 2004). These alterations mainly occur in conventionally reared turkeys (Ermakow, 2012). Lesions of the breast skin can also be a result of contact dermatitis, which is mostly caused by high pressure on the breast muscle and local irritation by coarse litter material and dampness (Adams et al., 1967; Miner and Smart, 1974; Mitterer-Istyagin et al., 2011; Krautwald-Junghanns et al., 2013). According to Mc Ewan and Barbut (1992) and Mitterer-Istyagin et al. (2011), the prevalence is higher in toms than in hens. Rapid weight gain and alterations in the skeletal system leading to increasing inactivity of the turkeys and longer periods of lying on wet litter areas are presumed to be the main causes (Tilley et al., 1996; Berk et al., 2013). Poor litter conditions increase the risk, which lead to additional local irritation (Newberry, 1993; Tilley et al., 1996).

Alterations of the liver also commonly occur in meat turkeys (Koglin, 2004; Ermakow, 2012). These can be caused by either infectious or non-infectious agents (Bergmann, 2001). A swelling of the liver tissue often

accompanies other alterations such as discoloration of the hepatic tissue, necrosis, abscesses, granulomas, or fibrosis, and cirrhosis. Yellow discoloration can be caused by degeneration, lipidosis, various noxae, malnutrition, or hormonal imbalances (Bergmann, 2001). Green discoloration is mostly a part of the turkey osteomyelitis complex, often accompanied by inflammation of the hock joint (Hafez, 1997; Huff et al., 2000). *Staphylococcus aureus* and *E. coli* are described to be the causative pathogens. However, cases of green discoloration without osteomyelitis have also been described (Bayyari et al., 1994). Liver necrosis can be caused by infections, intoxication, or ischemia (Bergmann, 2001).

In order to evaluate animal welfare of meat turkeys it is important to investigate the occurrence of pathologic lesions that have a considerable influence on animal welfare. Consequently, these can be used as animal welfare indicators. There are only a few published studies dealing with carcass alterations of turkeys reared in organic farming systems (Ermakow, 2012). Based on the preceding project by Mitterer-Istyagin et al. (2011), investigating carcass defects in conventional turkeys, the aim of this study was to survey the occurrence of these alterations in turkeys reared in organic production systems. Special attention was paid to the potential influence of gender, turkey line, age, body weight, and stocking density at the time of slaughter.

MATERIALS AND METHODS

Data Assessment at the Processing Plant

All investigations were carried out between July 2015 and May 2016 at three different slaughterhouses across Germany, which are officially authorized for the slaughter of meat turkeys reared under organic farming systems.

External examination of the carcasses and the livers was done at the processing line immediately after slaughter. Due to spatial circumstances and hygiene requirements at the slaughterhouse only visual examinations of the carcasses and the livers were possible; no incisions were done. The two observers, both veterinarians, previously went through training at the slaughterhouse to ensure uniform evaluations. The training was conducted by an official veterinarian. The observers' mutual assessment was tested afterward by examining the carcasses independently.

In total 1,860 turkeys originating from 12 participating organic farms were examined. Five farms reared both sexes of a medium-weighted turkey line (Kelly Broad Breasted Bronze [**BBB**]) with colored plumage, reared in separate pens, and 7 farms reared hens of heavy-weighted, white plumaged turkeys (5 × British United Turkeys [**B.U.T.** 6] and 2 × Test Product 7 [**TP 7**] by Aviagen Turkeys, Tattenhall, Chesshire, UK). The results of all Aviagen turkeys were analyzed together because basically comparable results concerning health and performance parameters can be expected. According to Aviagen turkeys, in the 15th week, B.U.T. 6 hens showed a live weight of 10.45 kg and B.U.T. TP 7 hens 10.76 kg. With 2.36 kg feed/kg increase in live weight the feed conversion is only slightly better in B.U.T. TP 7 hens than in B.U.T. 6 hens (2.34 kg feed/kg increase in live weight) (Aviagen turkeys a, b).

Apart from two exceptions (farms 2 and 9) due to organizational difficulties, all the farms were investigated in two successive grow out periods, one during summer (P1) and one during winter (P2). Each investigation consisted of a random sample of 60 turkeys/flock. Altogether 31 flocks (B.U.T. 6 or TP 7 hens: $n = 13$; Kelly BBB hens: $n = 9$, and Kelly BBB toms: $n = 9$) were investigated. Depending on the speed of the evisceration line, every fifth to 10th turkey was examined.

All participating farms were expected to follow the legal requirements concerning organic farming that are specified by the EC Regulation No. 889/2008 [3].

Based on the preceding project by Mitterer Istyagin et al. (2011), the following pathologic lesions were documented:

- breast skin lesions: focal ulcerative dermatitis (breast buttons), breast blister (hygroma), purulent inflammation of bursa sternalis
- liver alterations: green discoloration of the liver, liver swelling, fatty liver degeneration, necrosis, and abscess
- swelling of the hock joint (external examination, without incision)

The results were determined by the presence or absence of the respective lesion. Due to the speed of the processing line and the spatial conditions, it was not possible to assign the examined livers to a certain carcass, without disturbing the slaughter process. Therefore, the assignment of the livers to a certain carcass was not possible and all calculated relations were on the flock level.

Additionally, data about flock size, stocking density, age, and average body weight on the day of slaughter were provided by the participating farms (Tables 1 and 2). The average body weight was calculated after weighing the whole flock at the slaughterhouse.

Statistical Analysis

Statistical analysis of the data was performed with IBM SPSS Statistics 22 (IBM Corporation, Armonk, NY). Results were considered significant if the double-sided *P*-value was lower than 0.05. For the rate of occurrence of pathological lesions of the breast skin, liver alterations, and swelling of the intertarsal joints 95% CI was calculated. Since the collected data are a random sample from the true population, the CI provides a range of values for estimating the unknown population parameter. The interval limits comprise in 95% of the cases the true parameter from the whole population.

The functional relationship between the measurement variables/influencing factors (sex, age, line, body weight, stocking density) and the nominal variable/target value (swelling of the hock joint, breast skin lesions, liver alterations) was calculated with multiple logistic regression (McDonald, 2014). It analyzes the potential effect of independent variables on one dependent variable and is often used by epidemiologists. It is an extension of bivariate regression in which two or more independent variables (influencing factors) are simultaneously taken into consideration to predict a value of a dependent variable (target value) for each subject. The selection of independent variables is based on husbandry and animal-related factors that can be measured and purposely be changed or controlled. They are defined as exposure, risk factors, or other characteristics being observed or measured that are hypothesized to influence the dependent variable (Principles of Epidemiology in Public Health: Glossary, 2006).

Pearson's correlation, which is commonly used for numerical variables, was used for analyzing the functional relationship between the age and average body weight of each investigated flock (Nettleton, 2014).

Statistical comparison between the two investigated periods (P1 and P2) was conducted with an independent sample *t*-test, which determines whether the two groups are significantly different from each other on one variable of interest (StatsTest, 2020).

To determine potential differences between the male and female flocks only the results of Kelly BBB toms and Kelly BBB hens were included, whereas the comparison between turkey breeds included the results of Kelly BBB hens and B.U.T. 6/TP 7 hens.

RESULTS

There was no significant difference between the two observed periods (P1 and P2).

As shown in Table 1, the hens were slaughtered at ages from 17 to 23 wk. The average weight ranged between 7.2 and 11.6 kg. Seven out of 22 flocks did not reach the average slaughter weight of 10 kg. There is a significant relation between the age and the average body weight on the day of slaughter ($P < 0.05$).

The maximum flock size was exceeded by four flocks (12, 14, 15, and 22). The stocking density (kg/m^2) was higher than allowed in five flocks (1, 2, 12, 20, and 22), but it never exceeded the maximum number of birds/m^2. There was no significant relation between the stocking density or the weight and the investigated target values (breast skin lesion, liver alteration, swelling of the hock joint).

The relation between the average body weight of each investigated flock and the age was significant with $P < 0.01$.

Looking at the animal-related data of the toms (Table 2), it is striking that one flock (3) reached an average body weight of only 10.1 kg, whereas all other flocks were slaughtered with an average weight between 14.4 kg (2) and 19.2 kg (8). The highest weight gain was achieved on farm 5, with 19.2 and 18.4 kg. For this farm, there was a significant relation between the age and the average body weight ($P < 0.01$).

Table 1. Animal-related data of hens from 5 organic farms rearing 9 flocks of Kelly BBB strain (n = 540) and 7 organic farms rearing 13 flocks of B.U.T. strain (n = 780) at the day of slaughter.

Farm Turkey line	Flock	Flock size	Stocking density	Age on slaughter (wk)	Average weight on slaughter (kg)
1 Kelly BBB	1	2,124	2.31 birds/m^2 24.9 kg/m^2	20	10.8
	2	1,851	2.21 birds/m^2 22.82 kg/m^2	18	10.3
2 Kelly BBB	3	2,478	2.38 birds/m^2 15.3 kg/m^2	18	8.5
3 Kelly BBB	4	2,505	2.13 birds/m^2 19.4 kg/m^2	18	9.1
	5	1,852	1.5 birds/m^2 15.7 kg/m^2	20	10.3
4 Kelly BBB	6	2,194	1.79 birds/m^2 18.63 kg/m^2	21	10.4
	7	2,012	1.61 birds/m^2 14.75 kg/m^2	19	9.2
5 Kelly BBB	8	1,975	1.86 birds/m^2 20.85 kg/m^2	20	11.2
	9	1,513	1.43 birds/m^2 14.26 kg/m^2	18	10
6 B.U.T. 6	10	2,462	1.8 birds/m^2 14.73 kg/m^2	17	8.2
	11	1,760	1.28 birds/m^2 14.64 kg/m^2	18	11.4
7 B.U.T. 6	12	2,627	2.06 birds/m^2 23.11 kg/m^2	20	11.2
	13	1,733		18	10.4
8 B.U.T. TP 7	14	3,147	36.6 kg/m^2	20	11.6
	15	3,321	2.01 birds/m^2 20.13 kg/m^2	18	10.2
9 B.U.T. TP 7	16	2,416	1.34 birds/m^2 14.62 kg/m^2	19	10.9
10 B.U.T. 6	17	2,310	1.77 birds/m^2 16.29 kg/m^2	19	9.2
	18	2,280	1.75 birds/m^2 17.67 kg/m^2	18	10.1
11 B.U.T. 6	19	2,111	2.08 birds/m^2 20.15 kg/m^2	20	9.7
	20	2,248	2.22 birds/m^2 23.97 kg/m^2	20	10.8
12 B.U.T. 6	21	2,342	1.46 birds/m^2 10.52 kg/m^2	21	7.2
	22	3,111	1.94 birds/m^2 22.2 kg/m^2	23	11.4

Abbreviations: B.U.T. 6, British United Turkey 6; Kelly BBB, Kelly Broad Breasted Bronze; n, sample size; TP 7, Test Product 7.

Furthermore, there was a significant relation between the stocking density (kg/m^2 and birds/m^2) and the occurrence of green liver discoloration ($P < 0.05$). No influence of the stocking density on the other target values could be proven.

Breast skin lesions were rarely observed throughout the investigations (Table 3). Toms were significantly more often affected than hens ($P < 0.05$). Only 30 out of 1,860 turkeys (1.7% [95% CI: 1.1, 2.3]) showed any alteration, mostly breast buttons (n = 27).

Only toms (n = 2) showed hygromas (0.4% [95% CI: 0.0, 0.9]) and, in one case, a purulent inflammation of the bursa sternalis (0.2% [95% CI: 0.0, 0.6]). There was a significant relation between the occurrence of breast lesions and the

Table 2. Animal-related data of toms from 5 organic farms rearing 9 flocks of Kelly BBB strain (n = 540) at the day of slaughter.

Farm Turkey line	Flock	Flock size	Stocking density	Age on slaughter (wk)	Average weight on slaughter (kg)
1 Kelly BBB	1	1,647	0.69 birds/m^2 11.26 kg/m^2	22	16.3
	2	1,820	0.76 birds/m^2 10.99 kg/m^2	22	14.4
2 Kelly BBB	3	2,328	2.24 birds/m^2 11.7 kg/m^2	22	10.1
3 Kelly BBB	4	1,268	1.03 birds/m^2 15.87 kg/m^2	22	15.46
	5	904	1 bird/m^2 12.75 kg/m^2	23	16
4 Kelly BBB	6	853	0.86 birds/m^2 13.60 kg/m^2	23	15.9
	7	939	1.08 birds/m^2 19.59 kg/m^2	24	18.2
5 Kelly BBB	8	885	1.15 birds/m^2 22.14 kg/m^2	23	19.2
	9	860	1.12 birds/m^2 20.61 kg/m^2	22	18.4

Abbreviations: Kelly BBB, Kelly Broad Breasted Bronze; n, sample size.

body weight and the age of the turkeys ($P < 0.05$).

Alterations of the liver were a common finding in both hens and toms (Table 4). Nearly half of all examined turkeys showed at least one alteration (49.3% [95% CI: 47.0, 51.6]). There were great differences between the investigated flocks concerning the incidence of liver alterations (Figures 1 and 2). The most frequent alteration was green discoloration of the liver (29.8% [95% CI: 27.7, 31.9]). Kelly BBB hens were significantly more often affected than the B.U.T. 6/TP 7 hens (Kelly BBB hens: 33.2% [95% CI: 29.2, 37.2]; B.U.T. 6/TP 7 hens: 24.0% [95% CI: 21.0, 27.0]).

Swelling of the liver occurred in 15.9% (95% CI: 14.2, 17.6) of all examined turkeys. Toms were significantly more often affected than hens ($P < 0.05$). A relation between the turkey lines and liver swelling could not be determined. Concerning fatty degeneration, there was no difference between Kelly BBB toms and hens or Kelly BBB hens and B.U.T. 6/TP 7 hens (Kelly BBB toms: 8.5% [95% CI: 6.1, 10.9]; Kelly BBB hens: 8.5% [95% CI: 6.1, 10.9]; B.U.T. 6/TP 7: 8.6% [95% CI: 6.6, 10.6]). On the other hand, there was a significant correlation between the body weight and the occurrence of fatty degeneration of the liver ($P < 0.05$). Necrosis was significantly more often seen in B.U.T. 6/TP 7 hens than in Kelly BBB hens (B.U.T. 6/TP 7 hens: 17.3% [95% CI: 14.6, 20.0]; Kelly BBB hens: 4.6% [95% CI: 2.8, 6.4]), but no significant difference between Kelly BBB hens and Kelly BBB toms was observed ($P > 0.05$) (Kelly BBB toms: 5.4% [95% CI: 3.5, 7.3]).

Abscesses in the liver were the least common alteration (1.4% [95% CI: 0.9, 1.9]). There was no significant relation between its occurrence and the turkey lines or sex ($P > 0.05$).

Swelling of the hock joint was found in 17.3% (95% CI: 15.6, 19.0) of all examined turkeys (Table 5), with 28.7% (95% CI: 24.9, 32.5) in the Kelly BBB toms, which were significantly more affected than Kelly BBB hens (16.9% [95% CI: 13.7, 20.1]) ($P < 0.05$). 9.7% of B.U.T. 6/TP 7 hens showed joint swelling (95% CI: 7.6, 11.8), which differed significantly from Kelly BBB hens ($P < 0.05$). There was a significant relation between the occurrence of joint swelling and the body weight and the stocking density ($P < 0.05$). In addition, there was a significant relation between swelling of the hock joint and green discoloration of the liver with regard to the results of the whole examined flock, meaning on herd basis (r = 0.131; $P < 0.05$).

Table 3. Occurrence of breast skin lesions in turkey reared in organic farms at the slaughterhouses; numerical data in brackets are 95% CI.

		Breast skin alterations		
Turkey line and sex	Number	Breast button	Hygroma	Purulent Bursitis
Kelly BBB hens[1,2] (n = 540)	[n]	1	0	0
	[%]	0.2 [0.0, 0.6][b,c]	0.0 [0.0, 0.0][a,c]	0.0 [0.0, 0.0][a,c]
B.U.T. 6/TP 7 hens[2] (n = 780)	[n]	1	0	0
	[%]	0.2 [0.0, 0.5][c]	0.0 [0.0, 0.0][c]	0.0 [0.0, 0.0][c]
Kelly BBB toms[1] (n = 540)	[n]	25	2	1
	[%]	4.6 [2.8, 6.4][a]	0.4 [0.0, 0.9][a]	0.2 [0.0, 0.6][a]

[a,b]Means within each breast skin alterations of Kelly BBB toms and Kelly BBB hens lacking a common superscript differ significantly ($P < 0.05$).

[c]Means within each breast skin alteration of Kelly BBB hens and B.U.T. 6/TP 7 hens lacking a common superscript differ significantly ($P < 0.05$).

Abbreviations: B.U.T. 6, British United Turkey 6; Kelly BBB, Kelly Broad Breasted Bronze; n, sample size; TP 7, Test Product 7.

[1]Significance regarding sex ($P < 0.05$).

[2]Significance regarding strain ($P > 0.05$).

DISCUSSION

Carcass inspections at the slaughterhouses are important tools to monitor animal health and welfare. The aim of this study was to investigate the occurrence of pathologic lesions of the carcasses in organically reared turkeys in Germany and to use these as animal welfare indicators. The occurrence of FPD in organic reared turkeys was recently published (Freihold et al., 2019).

In the present investigations, breast lesions were rarely seen. Only a few turkeys, mostly toms, showed breast buttons. Hygromas and purulent inflammation of the bursa sternalis were more rare and seen only in toms. Compared to the investigations of conventional turkeys in Germany following the same study setup (Mitterer-Istyagin et al., 2011; Krautwald-Junghanns et al., 2013), turkeys reared in organic production systems were significantly less affected. In both the above-mentioned investigations, there was a significant positive relation between the body weight and the occurrence of breast lesions. With increasing

Table 4. Occurrence of liver alterations in turkeys reared in organic farms at slaughterhouses; numerical data in brackets are 95% CI.

		Liver alterations				
Turkey line and sex	Number	Swelling	Fatty degeneration	Green discoloration	Necrosis	Abscess
Kelly BBB toms[1]	[n]	111	46	188	29	8
(n = 540)	[%]	20.6 [17.2, 24.0][a]	8.5 [6.1, 10.9][a]	34.8 [30.8, 38.8][a]	5.4 [3.5, 7.3][a]	1.5 [0.5, 2.5][a]
Kelly BBB hens[1,2]	[n]	66	46	179	25	4
(n = 540)	[%]	12.2 [9.4, 15.0][b,c]	8.5 [6.1, 10.9][a,c]	33.2 [29.2, 37.2][a,c]	4.6 [2.8, 6.4][a,c]	0.7 [0.0, 1.4][a,c]
B.U.T. 6/TP 7 hens[2]	[n]	119	67	187	135	14
(n = 780)	[%]	15.3 [12.8, 17.8][c]	8.6 [6.6, 10.6][c]	24.0 [21.0, 27.0][d]	17.3 [14.6, 20.0][d]	1.8 [0.8, 2.8][c]

[a,b]Means within each liver alteration of Kelly BBB toms and Kelly BBB hens lacking a common superscript differ significantly ($P < 0.05$).

[c,d]Means within each liver alteration of Kelly BBB hens and B.U.T. 6/TP 7 hens lacking a common superscript differ significantly ($P < 0.05$).

Abbreviations: B.U.T. 6, British United Turkey 6; Kelly BBB, Kelly Broad Breasted Bronze; n, sample size; TP 7, Test Product 7.

[1]Significance regarding sex ($P < 0.05$).

[2]Significance regarding strain ($P > 0.05$).

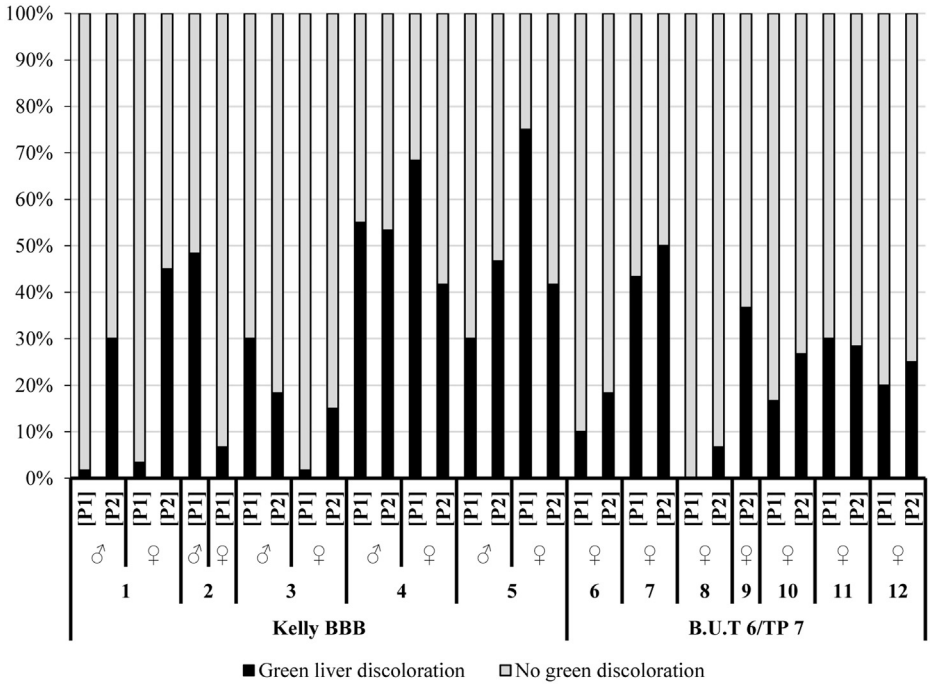


Figure 1. Farm-specific occurrence of green liver discoloration in turkeys reared in organic farms at the slaughterhouses. P: observed fattening period; P1: summer period; P2: winter period. Arabic numerals: examined farms. Abbreviations: B.U.T. 6, British United Turkey 6; Kelly BBB, Kelly Broad Breasted Bronze; TP 7, Test Product 7.

body weight, the turkeys spend more time lying down (Berk et al., 2013). The higher occurrence of breast skin alterations in toms, due to longer grow out periods and accordingly higher body weights, is in line with other studies that showed the same results (McEwen and Barbut, 1992; Mitterer-Istyagin et al., 2011; Ermakow, 2012). The higher age of toms on the day of slaughter and, as a result, higher body weight do not suggest conclusions about the impact of sex on the occurrence of breast lesions. Another important aspect is that wet and coarse-structured litter increases local irritation of the breast skin (Tilley et al., 1996). Therefore, litter material and management are important tools to reduce lesions of the breast (Newberry, 1993; Tilley et al., 1996; Berk et al., 2013).

Severe lesions are potentially painful and therefore an important animal welfare concern and hence a suitable indicator for animal welfare (Newberry, 1993; Mitterer-Istyagin et al., 2011; Watanabe et al., 2013). Investigations under uniform standards at the slaughterhouse would allow the establishment of a benchmarking system for all meat turkey farms (Allain et al., 2013). According to Andersson and Toppel (2014), breast skin lesions are "soft" indicators and results are difficult to standardize. Another instrument of welfare control is self-monitoring performed by farm owners using appropriate animal welfare indicators as described by the German Welfare Act since its amendment on 13th July 2013 (Federal Republic of Germany, 2017). This shows the importance of standardization of evaluation, including photographical means and inspector training. Without reliability and reproducibility of the results, no generally valid benchmarking can be introduced.

Furthermore, the liver as a major metabolic organ may offer valuable evidence about the health conditions of turkeys. Liver lesions were a common finding in this study. Nearly half of all examined turkey carcasses showed pathologic liver changes (Table 4). Green discoloration, which was the most frequent finding, can be associated with the turkey osteomyelitis complex. In this case, a correlation to the occurrence of joint swell or osteomyelitis could not be determined for a single animal (Huff et al., 2000). Furthermore, a valid diagnosis of

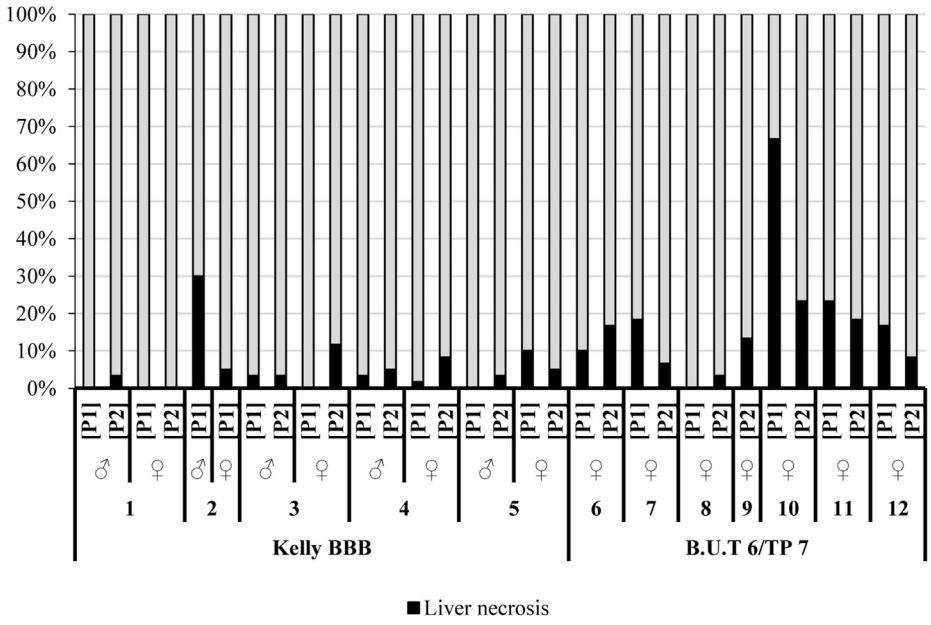


Figure 2. Farm-specific occurrence of liver necrosis in turkeys reared in organic farms. P: observed fattening period; P1: summer period; P2: winter period. Arabic numerals: examined farms. Abbreviations: B.U.T. 6, British United Turkey 6; Kelly BBB, Kelly Broad Breasted Bronze; TP 7, Test Product 7.

arthritis is only possible by incising the relevant joint. On flock basis, there was a significant relation between the occurrence of green liver and swelling of the hock joint within the investigated flocks. Mostly the toms were affected. Further investigations in relation to turkey osteomyelitis complex in flocks reared under organic production systems are needed. A closer examination of the carcasses, including incisions of the joints and microbiological examinations of the joints and livers, needs to be done. This might be the only way to gather valid results about the relation between inflammation of the hock joint and liver alterations.

Table 5. Occurrence of swelling of the hock joint in turkeys reared in organic farms at slaughterhouses; numerical data in brackets are 95% CI.

Turkey line and sex	Number	Swelling of hock joint
Kelly BBB toms[1]	[n]	155
(n = 540)	[%]	28.7 [24.9, 32.5][a]
Kelly BBB hens[1,2]	[n]	91
(n = 540)	[%]	16.9 [13.7, 20.1][b,c]
B.U.T. 6/TP 7 hens[2]	[n]	76
(n = 780)	[%]	9.7 [7.6, 11.8][d]

[a,b]Means within a column of Kelly BBB toms and Kelly BBB hens lacking a common superscript differ significantly ($P < 0.05$).

[c,d]Means within a column of Kelly BBB hens and B.U.T. 6/TP 7 hens lacking a common superscript differ significantly ($P < 0.05$).

Abbreviations: B.U.T. 6, British United Turkey 6; Kelly BBB, Kelly Broad Breasted Bronze; n, sample size; TP 7, Test Product 7.

[1]Significance regarding sex ($P < 0.05$).

[2]Significance regarding strain ($P < 0.05$).

A significant relation between the stocking density and the occurrence of green liver discoloration was detected exclusively in toms. The male flocks never exceeded the required stocking density whereas some of the female flocks did. Information about the presence or absence of pathogenic agents causing the green liver discoloration might be helpful to understand the pathogenesis in this specific case. The risk of infection might increase with a higher stocking density. The fact that Kelly BBB hens were significantly more affected than B.U.T. 6/TP 7 hens suggests an influence of the turkey line on its occurrence.

Liver necrosis was significantly higher in B.U.T. 6/TP 7 hens. This is mostly caused by infectious agents such as bacteria, viruses, and parasites. Furthermore, ischemic or toxic conditions can lead to necrosis (Bergmann, 2001). Both, liver necrosis and green livers were

significantly more common in turkeys reared in organic production systems than in turkeys reared in conventional systems (Mitterer-Istyagin et al., 2011). Access to an outdoor area and thus higher exposure to potentially infectious agents can increase the risk of infection (Kijlstra and Eijck, 2006). Additionally, legally restricted medical treatment may have an influence on the risk of infections (European Commission, 2008). In addition, malnutrition, especially the lack of essential amino acids and biotin and excessive potassium, can be a further factor, which might have a major impact on animal health and welfare (Bergmann, 2001; Kamphues et al., 2014). The remarkable differences between the investigated flocks prove the influence of rearing and farm management on the health of the turkeys. Without knowing the major cause for liver necrosis in turkeys reared in organic farming systems, it is not possible to identify the influencing factor of farm management, which emphasizes the importance of further investigations.

The fact that liver lesions were detected at the processing plant makes it clear that the turkeys did not necessarily show any clinical signs of impaired liver function. In most cases, there were only changes in the liver while the rest of the carcass did not show any further lesions. However, even without discarding the whole carcass, any damage of the hepatic tissue has to be considered as a profound health encroachment.

Further investigations of the livers, especially microbiological tests to find pathogenic agents, need to be performed. By detecting the causative factor of liver alterations, it may be possible to find out why the occurrence is significantly higher in turkeys reared under organic farming systems. As a consequence, it might be possible to implement adjustments to farm management in order to reduce the occurrence in the long term.

In addition, the swelling of joints is a major animal welfare concern. It is accompanied by pain and may lead to a decrease in activity and more frequent skin irritation due to longer lying periods (Duncan et al., 1991). The treatment of arthritis caused by infectious agents is of major importance. However, the limitation of medical application in organic poultry farming makes appropriate treatment more difficult (European Commission, 2008). Therefore, the aim has to be the prevention of joint inflammation. In the case of this study, external examination of the hock joints is not sufficient to draw conclusions about their real condition. Without incisions it is not possible to detect inflammation and, above all, the causative agent. Consequently, standardized examination of the joints at the slaughterhouse is difficult to implement, as incisions on a regular basis are not in compliance with the standard procedures at the processing line. And yet a study about the swelling of the joints including external examinations and incisions might be helpful to understand its causative factors and thus find means to reduce its occurrence.

At some point animal welfare, especially concerning the necessity of treatment and control of infections, collides with the EC Regulation on organic production and labeling of organic products (European Commission, 2007; European Commission, 2008). Limitations of medical treatment are an important issue, but the aim should not be to increase the use of antibiotics and chemical medication, but to improve animal husbandry conditions in order to prevent health problems and infections. The animals' health should not suffer because of the requirements of organic farming which have animal welfare as a main aim (Duncan, 2001).

Monitoring at the slaughterhouse helps to determine husbandry deficiencies and to implement a benchmarking system for all turkey farms. The assessment of the occurrence of breast lesions, liver alterations, and FPD, as described by Freihold et al. (2019), is useful as these are animal welfare indicators for organic turkey farms. However, swelling of the hock joints, as observed in this study, does not allow direct conclusions about husbandry deficiencies. Standardization of the evaluation including photographical means and inspectors is of major importance. Inspector training on one hand and uniform scoring and evaluations criteria on the other are necessary preconditions for a reliable benchmarking system.

The ultimate aim is to determine the weak points on the farm level and support the owner to reduce and/or eliminate them in order to improve animal welfare.

CONCLUSIONS AND APPLICATIONS

1. This study shows the relevance of monitoring defined animal welfare indicators at

the slaughterhouse in order to determine husbandry deficiencies in organic turkey farming. The aim is the implementation of a generally valid benchmarking system for all turkey farms, conventional and organic. Standardized examination methods using uniform scoring are the essential condition. Suitable animal welfare indicators have to be easy to examine at the slaughter line without disturbing the process, in compliance with all hygiene regulations.

2. Examination of the breast skin should be included in standardized inspections at the slaughterhouse, whereas visual examination of the livers and joints is not sufficient. In these cases, further investigations would be necessary.
3. Breast skin lesions are suitable animal welfare indicators that allow conclusions to be drawn about husbandry deficiencies. External examination is sufficient to detect alterations and it is easy to perform under field conditions.
4. Liver alterations indicate poor health conditions, but they do not allow a direct conclusion about specific husbandry deficiencies. Additional examinations such as parasitological and microbiological testing are required to find the causative agent. Further investigations concerning liver alterations in turkeys reared under organic farming systems will be of major interest in order to find the causative factor and, eventually, to find management adjustment to prevent their occurrence. Standardized investigations of the livers at the slaughterhouse are not easy to implement.
5. Visual examination of the hock joint swelling alone is not sufficient to determine arthritis and its cause. Incisions and further diagnosis are not possible without interfering with the slaughter process and without endangering hygiene standards.

ACKNOWLEDGMENTS

The project was financially supported by the German Federal Ministry of Food and Agriculture (BMEL) through the Federal Scheme for Organic Farming and Other Forms of Sustainable Agriculture (BÖLN).

DISCLOSURES

The authors declare no conflicts of interest.

REFERENCES

Adams, A. W., C. W. Carlson, A. J. Kahrs, and J. L. Fry. 1967. Realtionship of Several environmental factors to the incidence of breast blisters in Large Type male Market turkeys. Poult. Sci. 46:569–577.

Allain, V., D. Huonnic, and M. Rouina. 2013. "Prevalence of skin lesions in turkeys at slaughter". Br. Poult. Sci. 54:33–41.

Andersson, R., and K. Toppel. 2014. Putencontrolling. Pages 109–114 in Tiergerechtheit Bewerten. R. Zapf and U. Schultheiß, eds. Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL), Darmstadt, Germany.

Aviagen Turkeys. 2020a. Accessed Oct. 2020. http://www.aviagenturkeys.com/de-de/products/b-u-t-6.

Aviagen Turkeys. 2020b. Accessed Oct. 2020. http://www.aviagenturkeys.com/uploads/2017/01/19/POCLLTP7_V1_TP7_Commercial%20Live%20Goals_UK.pdf.

Bayyari, G. R., W. E. Huff, R. A. Norton, J. K. Skeeles, J. N. Beasley, N. C. Rath, and J. M. Balog. 1994. A Longitudinal-study of green-liver osteomyelitis complex in commercial turkeys. Avian Dis. 38:744–754.

Bergmann, V. 2001. "Fleischhygienisch relevante Erkrankungen des Geflügels". Pages 78–182 in Praxis der Geflügelfleischuntersuchung. R. Fries, V. Bergmann, and K. Fehlhaber, eds. Schlütersche GmbH & Co KG, Hannover.

Berk, J., C. Schumacher, M.-E. Krautwald-Junghanns, M. Martin, and T. Bartels. 2013. Verweildauer von Mastputen verschiedener Herkünfte im Bereich von Tränke- und Fütterungseinrichtungen. Appl. Agric. For. Res. 63:245–254.

Centers of Disease Control and Prevention. 2006. "Glossary" in Principles of Epidemiology in Public Health Practice. Page 30333. Glossary Page 22. 3rd ed. U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES, Centers for Disease Control and Prevention (CDC), Office of Workforce and Career Development, Atlanta, GA.

Duncan, I. J. H., E. R. Beatty, P. M. Hocking, and S. R. I. Duff. 1991. Assessment of pain associated with degenerative Hip Disorders in Adult male turkeys. Res. Vet. Sci. 50:200–203.

Duncan, I. J. H. 2001. Animal welfare issues in the poultry Industry: is there a Lesson to Be Learned? J. Appl. Anim. Welf. Sci. 4:207–221.

Ermakow, O. 2012. Ergebnisse der Fleischuntersuchung bei Puten aus ökologischer und konventioneller Haltung. Dissertation Universität Leipzig, Leipzig, Germany.

European Commission. 2007. A new a nimal health Strategy for the European union (2007-2013) where "prevention is better than cure". Accessed Aug. 2020. https://ec.europa.eu/food/sites/food/files/animals/docs/ah_policy_strategy_2007-13_en.pdf.

European Commission. 2008. Commission Regulation (EC) No 889/2008 of 5 September 2008 Laying Down Detailed Rules for the Implementation of Council Regulation (EC) No 834/2007 on Organic Production and Labelling of Organic Products with Regard to Organic Production, Labelling and Control. Official Journal of the European Union. L 250/251 - L 250/284, Brussels, Belgium.

Federal Republic of Germany. 2017. Tierschutzgesetz in der Fassung der Bekanntmachung vom 18. Mai 2006 (BGBl. I S. 1206, 1313), das zuletzt durch Artikel 141 des Gesetzes vom 29. März 2017 (BGBl. I S. 626) geändert worden ist. Accessed Oct. 2020. https://www.gesetze-im-internet.de/tierschg/BJNR012770972.html.

Freihold, D., T. Bartels, S. Bergmann, J. Berk, F. Deerberg, A. Dressel, H. M. Erhard, O. Ermakow, M. Huchler, M.-E. Krautwald-Junghanns, B. Spindler, S. Thieme, and H. M. Hafez. 2019. Investigation of the prevalence and severity of foot pad dermatitis at the slaughterhouse in fattening turkeys reared in organic production systems in Germany. Poult. Sci. 98:1559–1567.

Gonder, E., and H. J. Barnes. 1987. Focal ulcerative dermatitis ("breast buttons") in marketed turkeys. Avian Dis. 31:52–58.

Hafez, H. M., and R. Hauck. 2014. Genetic selection in turkeys and Broilers and their impact on health conditions. Accessed July 2019. https://www.researchgate.net/publication/254643462_GENETIC_SELECTION_IN_TURKEYS_AND_BROILERS_AND_THEIR_IMPACT_ON_HEALTH_CONDITIONS.

Hafez, H. M. 1997. "Brustblasenveränderungen [breast blisters]". Pages 210–211 in Putenkrankheiten Edited by Hafez and Jodas. Enke Verlag, Stuttgart.

Hodgson, G. C., and H. S. Gutteridge. 1941. A progress report from Canada of research on breast blisters. US Egg Poult. 47:150–155, 192.

Hörning, B., G. Trei, and C. Simantke. 2004. Ökologische Geflügelproduktion – Struktur, Entwicklung, Probleme, Politischer Handlungsbedarf. Abschlussbericht BLE, Bonn. Univ. Kassel. Accessed Sept. 2019. http://orgprints.org/8215/1/8215-02OE343-ble-unikassel-2004-sq-gefluegel.pdf.

Huff, G. R., W. E. Huff, N. C. Rath, and J. M. Balog. 2000. Turkey osteomyelitis complex. Poult. Sci. 79:1050–1056.

Kamphues, J., P. Wolf, M. Coenen, K. Eder, C. Iben, E. Kienzle, A. Liesegang, K. Männer, Q. Zebeli, and J. Zentek. 2014. "Ernährung verschiedener Spezies". Pages 452–463 in Supplemente zur Tierernährung. J. Kmaphues, ed. M. & H. Schaper, Germany, Stuttgart.

Kamyab, A. 2001. Enlarged sternal bursa and focal ulcerative dermatitis in male turkeys. Worlds Poult. Sci. J. 57:5–12.

Kijlstra, A., and I. A. J. M. Eijck. 2006. Animal health in organic livestock production systems: a review. NJAS 54:77–94.

Koglin, K. 2004. "Geflügeluntersuchung". Pages 205–217 in Lehrbuch Der Schlachttier- Und Fleischuntersuchung. D. M. Beutling, ed. Parey Verlag in MVS Medizinverlage Stuttgart GmbH & Co. KG, Stuttgart.

Krautwald-Junghanns, M. E., S. Bergmann, M. H. Erhard, K. Fehlhaber, J. Hübel, M. Ludewig, M. Mitterer-Istyagin, N. Ziegler, and T. Bartels. 2013. Impact of selected factors on the occurrence of contact dermatitis in turkeys on commercial farms in Germany. Animals 3:608–628.

Martland, M. F. 1985. Ulcerative dermatitis in broiler chickens: the effect of wet litter. Avian Pathol. 14:353–364.

McCune, E. L., and H. D. Dellmann. 1968. Developmental origin and structural characters of "breast blisters" in chickens. Poult. Sci. 47:852–858.

McDonald, J. H. 2014. Multiple logistic regression. Pages 247–253 in Handbook of Biological Statistics. 3rd ed. Sparky House Publishing, Baltimore, MD.

McEwen, S. A., and S. Barbut. 1992. "Survey of Turkey downgrading at slaughter - carcass defects and associations with Transport, Toenail Trimming, and Type of bird". Poult. Sci. 71:1107–1115.

Miner, M. L., and R. A. Smart. 1974. Causes of enlarged sternal bursas (breast blisters). Avian Dis. 19:246–266.

Mitterer-Istyagin, H., M. Ludewig, T. Bartels, M.-E. Krautwald-Junghanns, R. Ellerich, E. Schuster, J. Berk, S. Petermann, and K. Fehlhaber. 2011. Examinations on the prevalence of footpad lesions and breast skin lesions in BUT Big 6 fattening turkeys in Germany. Part II: prevalence of breast skin lesions (breast buttons and breast blisters). Poult. Sci. 90:775–780.

Nettleton, D. 2014. "Selection of variables and factor Derivation". Pages 79–104 in Commercial Data Mining. Processing, Analysis and Modeling for Predictive Analytics Projects. A. Dierna, ed. Elsevir Inc., San Francisco, CA.

Newberry, R. C. 1993. The role of Temperature and litter Type in the Development of breast buttons in turkeys. Poult. Sci. 72:467–474.

O'Neil, J. B. 1943. Morphology of the so-called "breast blisters". Poult. Sci. 22:457–458.

Putenerzeuger, V. D. 2013. Bundeseinheitliche Eckwerte für eine freiwillige Vereinbarung zur Haltung von Mastputen. Accessed July 2019. https://lkclp.de/uploads/files/bundeseinheitliche_eckwerte_mastputen.pdf.

StatsTest. Accessed Dec. 2020. https://www.statstest.com/independent-samples-t-test/.

Tilley, B. J., H. J. Barnes, and R. Scott. 1996. Litter and commercial Turkey strain influence on focal ulcerative dermatitis ("Breast buttons"). Appl. Poult. Res. 5:39–50.

Watanabe, T. T. N., S. Lolli, L. Ferrari, and V. Ferrante. 2013. Review of the physiological and pathological welfare indicators applied in turkeys (Meleagris gallopavo). Biotechnol. Anim. Husb. 29:727–740.

4. Discussion

The investigation of turkey carcasses at the slaughterhouse is a major instrument for monitoring husbandry conditions. In contrast to self-monitoring by the animal keeper, standardized post-mortem investigations allow a reliable comparability of different flocks and the implementation of a benchmarking system. Specific alterations of the carcass can be used as animal welfare indicators in order to monitor the need of management measures (Andersson and Toppel 2014).

The aim of this thesis was to determine the prevalence of carcass alterations used as animal welfare indicators of fattening turkeys reared in organic farming system at the slaughterhouse in Germany. The examinations included 1860 turkey carcasses originating from 12 different farms. Five farms reared Kelly BBB (Kelly Broad Breasted Bronze) toms and hens, five farms B.U.T. 6 (British United Turkey 6) hens and two farms Aviagen TP 7 (Test Product 7) hens. The first part of the study focused on the major animal welfare indicator, namely foot pad dermatitis (FPD) (see Appendix) (Freihold et al. 2019). The second part dealt with other important carcass alterations that are relevant for animal health and wellbeing. These included breast skin lesions, liver alterations and swelling of the hock joint (see Appendix) (Freihold et al. 2021).

Foot pad dermatitis (FPD) is a frequently occurring alteration in fattening turkeys which concerns animal health and welfare. It can be assumed that lesions of the foot pad are painful for the affected turkeys (Toppel et al. 2019). Consequently, it is a highly relevant and suitable animal welfare indicator.

Bergmann et al. (2013) showed that under sub-optimal conditions hyperkeratosis, epithelial necrosis and lesions of the foot pads may occur during the early rearing phase, which confirms previous studies (Schumacher et al. 2012; Mayne et al. 2006). In general, the prevalence and severity mostly increase during the fattening period (Bartels et al. 2020a; Krautwald-Junghanns et al. 2011), which is proven by a high prevalence of FPD at the slaughterhouse (Ermakow, 2012; Mitterer-Istyagin et al. 2011). This investigation confirms these results for turkeys reared in organic farming system (Bartels et al. 2020a; Freihold et al. 2019). Almost all investigated turkeys showed a certain degree of FPD, but the prevalence and severity varied significantly between the flocks (Freihold et al. 2019). Some performed better than others. This emphasizes the influence of farm management on the occurrence of FPD.

The current study showed a significantly higher prevalence and severity of foot pad lesions in hens than in toms (Freihold et al. 2019), which is in accordance with previous studies (Ellerich 2012; Krautwald-Junghanns et al. 2011; Rudolf 2008). Possible reasons may be the stocking density (No. of birds/m²), which is often higher in female flocks. A higher number of birds/m²

leads to more excreta per base area and thus to a higher litter humidity. However, low stocking densities (< 21 kg/m²) alone are no guarantee for ideal foot pad health (Bartels et al. 2020a; Habig et al. 2017).

The investigated turkey lines (Kelly BBB, B.U.T. 6 and Aviagen TP 7) showed no significant differences concerning the prevalence of FPD. However, the severity of the lesions was considerably different between the lines. Kelly BBB showed more unaffected and more severe lesions compared to B.U.T. 6/TP 7. No clear correlation can be found between the lines and the severity of FPD.

Compared to the preceding study by Mitterer-Istyagin et al. (2011) on conventional turkey farms, which followed the same study setup, we found a significantly lower prevalence of FPD in turkeys reared in organic husbandry conditions. They showed more unaffected footpads (Score 0) but also had a higher prevalence of foot pad abscesses (Score 4) than conventional turkeys. More than half of all examined turkeys, both conventional and organic, showed necrotic lesions >2 cm (Score 2). This goes in accordance with our results concerning the two investigated lines (Kelly BBB, B.U.T. 6/ TP7). It emphasizes the importance of FPD as an animal welfare issue in all farming systems.

The etiology of FPD is multifactorial, different causing factors are discussed. Genetics (Hafez et al. 2004) and various husbandry related factors (Ziegler et al. 2013; Shepherd and Fairchild, 2010) may play an important role. The litter material itself does have an influence on the foot pad health (Youssef et al. 2010, 2011; Berk 2009). Yet wet litter has been described to be the main cause (Vinco et al. 2017; Abd El-Wahab et al. 2011; Wu and Hocking 2011; Mayne et al. 2007; Martland, 1984). Litter moisture exceeding 30 % leads to pododermatitis in a short period of time (Schumacher et al. 2012; Wu and Hocking 2011). Even single sections inside the stable with increased moisture, which particularly occur close to the drinkers and feeding facilities, lead to higher prevalences of FPD (Schumacher et al. 2012). Other studies showed that litter moisture in some farms can exceed 70 % (Krautwald-Junghanns et al. 2013; Kamphues et al. 2011). This demonstrates the importance of sound husbandry conditions and farm management, although the regulations for organic poultry farming alone, including lower stocking densities, do not prevent high litter moisture (Bartels et al. 2020a).

The complex etiology of FPD means that different husbandry conditions need special attention. For organic poultry farming in particular the obligatory outdoor area of at least 10 m^2 per turkey is important. There are some publications which confirm the impact of outdoor access on the occurrence of FPD (Berk 2013; Pagazaurtundua and Warriss 2006). In general, the outdoor area differs among the farms and their state depends on the weather and climate conditions.

The most important risk factors are humidity and ponding, which also promote the entry of moisture into the stable. Additionally, high stocking densities near the stable may lead to a high risk of pollution with excreta, which destroys the turf and leads to a humid milieu around the feet. That may have negative consequences on the foot pad health and may increase the incidence and severity of FPD. In addition, the access to an outdoor area may have an influence on the risk/susceptibility of infectious diseases due to the increased exposure to potentially pathogen agents und should be considered.

Monitoring of FPD as the main animal welfare indicator at the slaughterhouse allows conclusions about husbandry deficiencies. A benchmarking system for FPD scoring has been established in most German slaughterhouses. Scores that are classified according to their severity (0-4) are easy to standardize and implement. Although VC (visual classification) seems to have good observer reliabilities concerning representation of the dimension of the foot pad lesion refinement is necessary (Stracke et al. 2020). Compared to manual assessment image systems might give lower FPD scores when the size of the metatarsal pad is not clearly defined. Including digital pads and scar tissue, which are a profound modification of the original tissue, as an additional binominal score would help to prevent distorted assessment (Stracke et al. 2021; Toppel et al. 2019).

Another commonly occurring location of contact **dermatitis is the breast skin** overlying the sternum. Depending on the etiology and clinical picture a distinction is made between breast buttons, hygromas and purulent bursitis (Kamyab 2001). Local irritation caused by coarse and damp litter material leads to locally restricted ulcerative lesions (breast buttons) whereas hygromas are the result of prolonged pressure on the breast skin (Gonder and Barnes 1987; McCune and Dellmann 1968). Bacterial infection of the lesion may lead to purulent inflammation of the bursa sternalis (Ermakow 2012; Mitterer-Istyagin et al. 2011; Tilley et al. 1996).

Breast skin lesions were rarely seen in this study (Freihold et al. 2021). The prevalence was significantly lower compared to the conventional turkeys investigated by Mitterer-Istyagin et al. (2001), following the same study setup. This confirms the results of Ermakow (2012) and Dressel et al. (2019) finding significantly fewer breast skin lesions in turkeys reared in organic farming system.

The significantly positive correlation between the body weight and the occurrence of breast skin lesions found in this study also compliments previous results as does the higher prevalence in toms compared to hens (Freihold et al. 2021; Ermakow 2012; Mitterer-Istyagin et al. 2011). The higher body weight of toms and turkeys reared at conventional farms leads to

longer resting periods and increases the pressure on the breast skin (Krautwald-Junghanns et al. 2009; Strassmeier 2007; Berk and Wartemann 2006). Further irritation caused by coarse and wet litter supports the emergence of breast skin lesions and may lead to more severe inflammation as a result of infection with pathogenic agents (Kamyab 2001; Tilley et al. 1996; Newberry et al. 1993).

Breast skin lesions are valuable animal welfare indicators for their impact on animal health and their economic relevance (Newberry 2013; Watanabe et al. 2013; Mittterer-Istyagin et al. 2011).

For assessing the breast skin at the processing line, a standardized scoring system, which is easy to perform under field conditions, is indispensable. Using a binominal score (yes/no) for separate alterations (breast buttons, hygromas, purulent bursitis) has proved practical during the present study (Freihold et al. 2021). This, however, requires uniform inspector training for all slaughterhouses. Establishing visual scoring (VC) could provide more reliable and reproducible results. Further studies assessing the viability and reliability of VC are necessary in order to introduce a uniform benchmarking system.

Contact dermatitis and skin injuries are potential entry ports for pathogen agents. Ascending infection can affect the joints and consequently lead to inflammatory processes as well as thereupon arising diseases of the internal organs.

Depending on the location infectious diseases of the musculoskeletal system are referred to as osteomyelitis, arthritis or tendovaginitis (Bergmann 2001). The most commonly affected joint is the hock joint.

Examination of the joints which focused on **swelling of the hock joint** showed that Kelly BBB were significantly more affected than B.U.T. 6/ TP 7 and the prevalence was significantly higher in Kelly BBB toms than in hens of the same line (Freihold et al. 2021). Ermakow (2012) found a significantly higher prevalence of arthritis in conventional toms than in hens as well, but no significant difference between toms and hens reared in organic farming system. A rapid increase in growth and weight of the birds have a direct influence on the occurrence of alterations in the musculoskeletal system, particularly in the physis of the femoral head and the tibiotarsus, the joints and the foot pads (Spindler 2007). The results of the present investigation support that statement and show a significant correlation between swelling of the hock joint and the average body weight of the flock (Freihold et al. 2021). This assertion is made with the reservation that there are no data about the weight of the single investigated turkey and as a result a direct allocation of the affected joint to the respective carcass was not feasible.

Previous investigations found a significantly higher prevalence of arthritis in turkeys reared in organic farming system compared to conventional farms (Dressel et al. 2019; Ermakow 2012). However, the multifactorial etiology of joint inflammations does not allow premature conclusions, since not only husbandry and management conditions but also age, line, severity and location of the alteration do have an influence on its occurrence (Ermakow 2012; Krautwald-Junghanns et al. 2009). Compared to conventional turkey farms husbandry conditions in organic production systems (e. g. outdoor access, restricted medication) may lead to higher risk of infection (Hörning 2003).

The analysis of joint swelling and **green liver discoloration** on flock level revealed a significant correlation. However, a direct allocation of the affected liver to the respective carcass was not possible during the regular slaughter process, which restricts the informative value of the data (Freihold et al. 2021). A green liver discoloration does not necessarily mean that the affected turkey suffers from arthritis/synovitis or osteomyelitis (FSIS 2014, Huff 2000). Further inspection of the affected joint and the respective liver including incisions and microbiological tests are necessary to increase validity of the results. This does not only apply to the diagnosis of Turkey Osteomyelitis Complex (TOC) but also to revealing the severity/extent of the joint alteration. In order to investigate the relation to animal related data (age, weight, sex, line) an exact allocation of the individual animal is indispensable. Examinations of this kind are not feasible during the regular slaughter process. External examination of joint swelling alone provides information about possible musculoskeletal diseases but is not sufficient for diagnosis.

In connection with ascending infections the **liver** as the major metabolic organ can reveal a lot about the health status of the turkey. Even without histopathological examinations the findings can give valid information about recent pathological conditions. There are various reasons for liver alterations in turkeys. Infectious and non-infectious etiologies are to distinguish (Bergmann, 2001). On the one hand, pathogens such as bacteria, viruses and parasites and on the other hand, toxins or malnutrition can be causative factors.

In the present study there was a high prevalence of liver alterations. Nearly half of all examined turkeys showed a certain macroscopic change (Freihold et al. 2021). Compared to the results of Mitterer-Istyagin et. al (2011) the prevalence of liver necrosis und green discoloration was significantly higher in turkeys reared in organic farming system than in conventional turkeys. The higher prevalence of green liver discoloration and necrosis in organic turkeys can be a result of higher risk of infection, due to outdoor access and hence increased exposure to pathogens and restricted application of antibiotics (Hörning 2003). Several bacterial agents such as *Escherichia coli* and *Staphylococcus aureus* seem to be the main cause (Huff 2000;

Droual et al. 1996; Bayyari 1994). However, turkeys with green livers do not necessarily have musculoskeletal alterations, whereas TOC is mostly accompanied by green discoloration of the liver tissue (FSIS 2014; Bayyari 1994). As a consequence, livers of carcasses without any altered appearance still require special attention during examination. The reason for the significant difference between B.U.T. 6/ TP 7 hens (17.3 %) and Kelly BBB hens (4.6 %) requires further research (Freihold et al. 2021).

Alternation of liver tissue is reliable evidence for an impaired animal health and it is a suitable animal welfare indicator but standardized investigations at the slaughterhouse are not easy to implement. They require uniform scoring, either using a binominal score (yes/no) for each alteration or metric scaling with various gradations (including size, extent, severity). In addition, uniform and reliable inspector training is indispensable.

In order to find the main causes of the observed alterations, especially with regard to the husbandry system, further studies conducting histological and microbiological testing of pathological changes are necessary.

In general, husbandry conditions for organic poultry farming, including lower stocking densities, access to an outdoor area as well as stricter regulations concerning medical treatment, do not necessarily lead to better animal health (Schumacher and Rahmann 2008; Fehlhaber 2005; Rahmann 2005). Current studies (Freihold et al. 2021, 2019) confirm the high prevalence of health issues in organic turkeys (Dressel et al. 2019; Ermakow 2012).

In order to reduce health disorders several management measures are necessary. They should be economically justifiable and in accordance with the legal regulations for organic farming. To decrease the occurrence of FPD and breast skin lesions, adjustments in litter management are indispensable. Improving the stable environment to ensure a better air flow is one approach (Ziegler et al. 2013). Using litter material with a higher water absorption capacity and nipple drinkers with pendulum to reduce splashing water would be another (Bartels et al. 2020a). Additional measures to improve litter condition are floor heating and integrating elevated planes made of bars in order to reduce direct contact to damp litter (Chuppava et al. 2018; Berk and Kirchner 2011; Kamphues et al. 2011). The latter does not only have a positive impact on foot pad health but on the occurrence of contact dermatitis in general.

Furthermore, adjustments to the outdoor area are necessary to decrease stocking densities near the stable. Using soil material which prevents ponding and hence entry of moisture into the stable might be beneficial.

Another important aspect in organic farming system is nutrition, because it has a direct impact on animal health (malnutrition, intestinal disorders) and the condition of the excreta thus on the

litter condition (Kamphues 2011). Especially the supply with essential amino acids is challenging without provoking poor condition of the excreta (Abd-El Wahab et al. 2011; Kamphues et al. 2011; Schmidt and Bellof 2006). Deficiencies in feeding turkeys in organic production system pose a challenge to the farmers. There is need of a better species-appropriate formulation which improves intestinal health and does not collide with guidelines for organic farming (Swalander et al. 2013; Kamphues et al. 2011).

The high impact of the body weight on the occurrence of musculoskeletal diseases and severe breast skin lesions justifies to argue for the use of medium weighted instead of heavy turkey breeds. The results by Olschewsky et al. (2021) showed a lower prevalence of animal welfare problems in medium weighted turkeys with decreased growth rates (Hockenhull Large Bronze and Hockenhull Black) than in comparable studies. However, concerning the occurrence of FPD these turkey lines showed higher prevalences compared to the investigated Kelly BBB. Decreased bodyweight alone does not necessarily lead to better foot pad health. This study does neither reveal a better foot pad health in the medium weighted Kelly BBB compared to the heavy weighted B.U.T. 6/ TP7 (Freihold et al. 2019). Further research concerning the use of alternative turkey lines with fewer health problems and good performance is needed.

In conclusion, many factors and possible influences on animal health and welfare need to be considered in order to reduce the prevalence of any alterations. These problems do not only affect turkeys reared in conventional farming system, but also those reared in organic farming system (Freihold et al. 2021, 2019; Bartels et al. 2020a; Dressel et al. 2019; Ermakow 2012). Both systems need constant monitoring of animal welfare indicators.

In addition to the alterations investigated in this study further organ findings such as skin lesions and serositis need further attention as potential animal welfare indicators (Bartels et al. 2020b; Dressel et al. 2019; Ermakow 2012). Injurious pecking is one of the main animal welfare concerns (Bartels et al. 2020b). Not only do affected turkeys suffer from pain, but ascending infections can also lead to joint inflammation and thus diseases of the internal organs. The negative impact on animal health justifies the inclusion in standard monitoring at the slaughterhouse. The problem, however, might be the implementation under field conditions. At some processing plants the inside of the carcasses, except for the liver, are removed through suction. The further processing and inspection of the inner carcass follows later on. In this case an examination of the lungs and air sacs is not possible.

In order to assess skin lesions at the slaughterhouse it is important to distinguish between old and fresh injuries. Skin lesions can occur as a result of abusive behaviour during catching, un-/loading and transport (Fehlhaber 2001). Furthermore, a standard scoring system that is easy

to perform during the slaughter process is necessary. On the one hand, the differentiation between scratches and injurious pecking and on the other hand, the location and severity of the lesions are crucial to allow conclusions about the cause and thereby about management deficiencies.

In principle, the monitoring of animal welfare indicators at the slaughterhouse is an appropriate means to survey animal health and to evaluate animal welfare standards (Vinoc et al. 2017). In addition to FPD, alterations such as breast skin lesions and liver alterations should be included in a standardized benchmarking system for organic and conventional turkeys. This allows detection of husbandry deficiencies and the need of management intervention. Furthermore, it helps to evaluate the success of already implemented measures.

However, post-mortem investigations alone are not sufficient to evaluate diseases and lesions that occur during the fattening period, because runting turkeys and dead-on farm animals will not go to slaughter (Dressel et al. 2019). Therefore, additional on-farm monitoring is important in order to detect animal welfare problems (Ferrante et al. 2019; Toppel et al. 2019). Self-monitoring carried out by the farmer since the amendment of the German Animal Welfare Act of 13 July 2013 (Federal Republic of Germany 2017) is the first step for early detection of foot pad lesions. On-farm monitoring of the foot pads in a 4-week interval would help to evaluate the success and the necessity of management measures for it matches the time of formation of scar tissue (Toppel et al. 2019).

The aim should not only be the fulfillment of minimum requirements for animal husbandry but also - with regard to the European Convention for the Protection of Animals kept for Farming Purposes – avoid unnecessary suffering following the concept of Five Freedoms (amongst other: freedom from pain, injury and disease) (Farm Animal Welfare Committee [FAWC] 2009).

5 Zusammenfassung

Untersuchung der Prävalenz von pathologischen Schlachttierkörperveränderung in ökologisch gehaltenen Mastputen in Deutschland

Die steigende Nachfrage nach Bio-Produkten in Deutschland hat zu einer Zunahme der ökologischen Geflügelhaltung geführt. Die Erwartungen, dass Puten, die unter ökologischen Bedingungen gehalten werden, einen besseren Gesundheitszustand aufweisen, werden nicht immer erfüllt. Es treten regelmäßig tierschutzrelevante Gesundheitsprobleme auf. Die Überwachung von Tierschutzindikatoren am Schlachthof ist ein wichtiges Mittel, um die Haltung und Management-Mängel in folgenden Herden zu verbessern.

Das Ziel der vorliegenden Arbeit waren Untersuchungen zur Erfassung der Prävalenz von pathologischen Schlachttierkörperveränderungen als Tierschutzindikatoren in ökologisch gehaltenen Mastputen in Deutschland.

Die Untersuchungen fanden im Zeitraum vom Juli 2015 bis Mai 2016 an drei verschiedenen Puten-Schlachthöfen in Deutschland statt. Insgesamt wurden 1860 Schlachttierkörper von 12 verschiedenen Betrieben untersucht. Sieben Betriebe hielten Hennen der schweren Putenlinie British United Turkey B.U.T 6 und Test Product 7. Zusätzlich hielten fünf Betriebe Hennen und Hähne der mittelschweren Putenrasse Kelly Broad Breasted Bronze (Kelly BBB). Von jeder geschlachteten Herde wurde eine zufällige Stichprobe von 60 Tieren auf folgende Parameter hin untersucht: Fußballenentzündung (FPD), Brusthautläsionen, Leberveränderungen und Schwellung des Intertarsalgelenkes.

Die Beurteilung der Fußballenentzündung wurde mit einem 5-stufigen Score durchgeführt (Score 0: unverändert; Score 1: oberflächliche Epithelnekrosen; Score 2: Nekrosen < 2 cm; Score 3: Nekrosen > 2 cm; Score 4: Ballenabszess). Die Ergebnisse zeigten, dass 97,7 % aller untersuchten Puten verschiedene Schweregrade von FPD aufwiesen. Nur 1,3 % der Hennen und 4,6 % der Hähne zeigten unveränderte Fußballen (Score 0). 64,3 % aller Puten hatten Nekrosen < 2 cm (Score 2). Oberflächliche Nekrosen (Score 1: Hähne: 11,3 %, Hennen: 7,6 %) und Nekrosen > 2 cm (Score 3: Hähne: 29,8 %, Hennen: 12,4 %) waren weniger häufig. Ballenabszesse (Score 4) wurden kaum gefunden (1,9 %). Generell waren die Fußballen der Kelly BBB Hennen häufiger betroffen als die der Kelly BBB Hähne. Verglichen mit den B.U.T. 6/TP 7 Hennen, hatten beide Geschlechter der Kelly BBB Puten häufiger hochgradige Läsionen (Score 3 und 4) aber auch häufiger unveränderte Fußballen (Score 0).

Die Untersuchung der Brusthaut wurde mithilfe eines Binominal-Scores (ja/nein) durchgeführt und umfasste Brustknöpfe, Brustblasen und eine purulente Entzündung der Bursa sternalis. Grundsätzlich waren Läsionen der Brusthaut ein seltener Befund (1,7 %). Insgesamt hatten nur 30 Puten folgende Veränderungen: 27 Brustknöpfe, zwei Brustblasen und eine purulente Bursitis. Hähne waren signifikant häufiger betroffen als Hennen.

Leberveränderungen wurden ebenso mithilfe eines Binominal-Scores (ja/nein) beurteilt. Die äußere Untersuchung umfasste grüne Lebern, Nekrosen, Leberschwellung, Leberverfettung und Abszesse. Nahezu die Hälfte aller untersuchten Puten waren betroffen (49,3 %). Der häufigste Befund waren grüne Lebern (29,8 %). Kelly BBB Hennen waren signifikant häufiger betroffen als B.U.T. 6/TP 7 Hennen. Die Prävalenz von Lebernekrosen war höher bei B.U.T. 6/TP 7 Hennen (17,3 %) verglichen mit Kelly BBB Hennen (4,6 %). Außerdem zeigten 15.9 % aller untersuchten Puten eine Leberschwellung, 8,6 % eine Leberverfettung und nur 1,4 % Leberabszesse.

Die äußere Untersuchung der Intertarsalgelenke ergab eine Gelenkschwellung bei 17,3 % aller untersuchten Puten, unter der Anwendung eines Binominal-Scores (ja/nein). Die Hähne waren signifikant häufiger betroffen als die Hennen (Hähne: 28,7 %, Hennen: 16,9 %).

Untersuchungen von Schlachttierkörperveränderungen sind ein sehr bedeutsames Verfahren zur Erfassung der tierschutzrelevanten Probleme sowohl bei ökologisch als auch konventionell gehaltenen Puten. Die Untersuchung von Tierschutzindikatoren hat sich bewährt, um problematische Betriebe zu ermitteln und den Status Quo zu beurteilen. Veränderungen wie FPD und Brusthautläsionen sind geeignete Tierschutzindikatoren. Untersuchungen, mithilfe eines Standard Scores, sind leicht unter Praxisbedingungen durchzuführen. Leberveränderungen sind ebenfalls geeignete Tierschutzindikatoren. Sie bieten wertvolle Informationen über die Tiergesundheit, allerdings ist es schwierig standardisierte Untersuchungen am Schlachthof zu etablieren. Die alleinige äußere Untersuchung der Intertarsalgelenke ist nicht ausreichend, um eine Arthritis zu diagnostizieren und Rückschlüsse über Haltungsbedingen ziehen.

Untersuchungen der Prävalenz von Tierschutzindikatoren bieten die nötigen Voraussetzungen, um eine Standard-Überwachung im Rahmen eines Bechmarkingsystems zu etablieren. Dies ermöglicht die Bewertung und den Vergleich der Betriebe und dementsprechend eine Beurteilung der Notwendigkeit Management Anpassungen und dem Erfolg von bereits durchgeführten Maßnahmen.

6. Summary

Investigation of the prevalence of pathological carcass alterations at the processing plant in fattening turkeys reared in organic farming system in Germany

The growing demand for organic products in Germany has led to an increase in organic poultry farming. Expectations of a better health status in turkeys reared in organic farming system are not always fulfilled and animal welfare related health problems still commonly occur. The monitoring of animal welfare indicators at the slaughterhouse is an important tool in order to be able to improve the husbandry and management deficiencies in further flocks. The aim of this study was to investigate the prevalence of pathological carcass alterations as animal welfare indicators at the processing plant in fattening turkeys reared in organic farming system in Germany.

The investigations were carried out between July 2015 and May 2016 at three different turkey slaughterhouses in Germany. In total, 1860 turkey carcasses originating from 12 organic farms were investigated. Seven farms reared hens of the heavy weighted British United Turkey B.U.T. 6 and Test Product TP 7. In addition, five farms reared both sexes of the medium weighted Kelly Broad Breasted Bronze (Kelly BBB). From each slaughtered flock a random sample of 60 birds was investigated for the following parameters: foot pad dermatitis (FPD), breast skin lesions, liver alterations and swelling of the hock joint.

The assessment of the foot pad dermatitis was performed using a five-grade scoring system (Score 0: unaffected; Score 1: necrosis of superficial scales; Score 2: necrotic lesions < 2 cm; Score 3: necrotic lesions > 2 cm; Score 4: plantar abscess). The results showed that 97.7 % of all examined turkeys suffered from different degrees of FPD. Only 1.3 % of the hens and 4.6 % of the toms showed unaffected foot pads (Score 0). 64.3 % of all turkeys had necrotic lesions < 2 cm (Score 2). Necrosis of superficial scales (Score 1: toms: 11.3 %, hens: 7.6 %) and necrotic lesions > 2 cm (Score 3: toms: 29.8 %, hens: 12.4 %) were less common. Plantar abscesses (Score 4) were rarely observed (1.9 %). In general, the foot pads of Kelly BBB hens were more affected than those of Kelly BBB toms. Compared to B.U.T. 6/TP 7 hens both sexes of Kelly BBB showed more severe lesions (Score 3 and 4), but also more unaffected foot pads (Score 0).

The examination of the breast skin was done by means of a binominal score (yes/no), including breast buttons, hygromas and purulent inflammation of the bursa sternalis. In general, breast skin lesions were a rare finding in all examined turkeys (1.7 %). In total, only 30 turkeys showed the following alterations: 27 breast buttons, two hygromas and one purulent bursitis. Toms were significantly more affected than hens.

Liver alterations were also assessed using a binominal score (yes/no). The external investigation covered green liver discoloration, necrosis, swelling of the liver, fatty liver degeneration and abscesses. Nearly half of all investigated turkeys were affected (49.3 %). Green liver discoloration was the most frequently detected alteration (29.8 %). Kelly BBB hens were significantly more often affected than B.U.T. 6/TP 7 hens. The prevalence of liver necrosis was significantly higher in B.U.T. 6/TP 7 hens (17.3 %) than in Kelly BBB hens (4.6 %). Furthermore, 15.9 % of all investigated turkeys showed swelling of the liver tissue, 8.6 % showed fatty liver degeneration and only 1.4 % had liver abscesses.

The external examination of the hock joint revealed a swelling in 17.3 % of all examined turkeys using a binominal score (yes/no). Toms were significantly more affected than hens (toms: 28.7 %, hens: 16.9 %).

Carcass alterations are a major animal welfare concern in fattening turkeys reared in organic and/or in conventional production system. In order to detect problematic farms and to evaluate the status quo, the examination of animal welfare indicators has been proven to be beneficial. Alterations such as FPD and breast skin lesions are suitable indicators. Examinations are easy to perform under field conditions using a standard scoring system. On the other hand, liver changes are also a further suitable indicator for animal welfare. They reveal valuable information about the birds' health, however, standardized investigations are not easy to implement at the slaughterhouse. Furthermore, the external investigation of the hock joints is also not sufficient to diagnose arthritis and to draw conclusions about husbandry conditions.

Investigating the prevalence of animal welfare indicators provides the necessary precondition in order to establish a standard monitoring embedded in a benchmarking system. This allows to evaluate and compare the farms and consequently to assess the need of management intervention and the success of already implemented measures.

7. References

Abd El-Wahab A, Beineke A, Beyerbach M, Visscher C F, Kamphues J (2011): Effects of floor heating and litter quality on the development and severity of foot pad dermatitis in young turkeys. Avian Dis. 55, 429-434

Abd El-Wahab A, Visscher C F, Beineke A, Beyerbach M, Kamphues J (2012): Experimental studies on the effects of different litter moisture contents and exposure time to wet litter on development and severity of foot pad dermatitis in young fattening turkeys. Arch. Geflügelk. 76, 55-62

Allain V, Huonnic, D, Rouina M, Michel V (2013): Prevalence of skin lesions in turkeys at slaughter. Br. Poult. Sci. 54, 33-41

Andersson, R.; Toppel, K. (2014): Identifizierung und Erprobung von Parametern zur Indikatorbildung und als Instrument des Controllings - mit Fokus auf Mortalität, Fußballengesundheit, Arzneimitteleinsatz. Kurztitel: Puten-Controlling. Abschlussbericht vom 15.12.2014. Accessed on 11.10.2020. Available from: http://www.ml.niedersachsen.de/download/95254/Abschlussbericht_Puten-Controlling_.pdf

Bartels T, Huchler M, Freihold D, Thieme S, Bergmann S, Berk J, Cramer K, Deerberg F, Dressel A, Erhard M H, Ermakow O, Pees M, Spindler B, Hafez H M, Krautwald-Junghanns M-E (2020a): Untersuchungen zur Prävalenz von Fußballenveränderungen bei ökologisch gehaltenen Mastputen und zu potenziellen Einflussfaktoren auf den Fußballenzustand. Berl Münch Tierarztl Wochenschr, 2020; 133. DOI: 10.2376/0005-9366-19014

Bartels T, Stuhrmann R A, Krause E T, Schrader L (2020b): Research Note: Injurious pecking in fattening turkeys (*Meleagris gallopavo* f. dom.)—video analyses of triggering factors and behavioral sequences in small flocks of male turkeys. Poult. Sci. 99, 6326–6331

Batkowska J, Brodacki A (2012): The usefulness of different commercial strains of slaughter turkey females for extensive system of management and feeding. Acta Agric. Scand. A 62, 135–141

Bayyari G R, Huff W E, Norton R A, Skeeles J K, Beasley J N, Rath N C, Balog J M (1994): A Longitudinal Study of Green-Liver Osteomyelitis Complex in Commercial Turkeys. Avian Dis. 38, 744-754

Bellof G, Schmidt E, Ristic M (2005): Einfluss abgestufter Aminosäuren-Energie-Verhältnisse im Futter auf die Mastleistung und den Schlachtkörperwert einer langsam wachsenden Herkunft in der ökologischen Broilermast. Arch. für Geflügelkunde 69, 252-260

Bellof G, Brandl M, Schmidt E (2011): Ökologische Putenmast: Abstimmung von Genotyp, Haltung und Fütterung. BÖLN-Bericht-ID 18771 (FKZ: 06OE234). Accessed on 13.12.2020. Available from: https://www.researchgate.net/publication/277843284_Okologische_Putenmast_Abstimmung_von_Genotyp_Haltung_und_Futterung

Bellof G, Brandl M, Schmidt E, Carrasco S, Schade B (2014): Einfluss unterschiedlicher Fütterungsintensität und Haltungsform auf die Mastleistung und den Schlachtkörperwert von langsam oder schnell wachsenden Genotypen in der ökologischen Putenmast. Europ. Poult. Sci. 78, 2014. Stuttgart: Eugen Ulmer Verlag - ISSN 1612-9199, DOI: 10.1399/eps.2014.31

Bergmann S, Ziegler N, Bartels T, Hubel J, Schumacher C, Rauch E, Brandl S, Bender A, Casalicchio G, Krautwald-Junghanns M-E, Erhard M H (2013): Prevalence and severity of foot pad alterations in German turkey poults during the early rearing phase. Poult. Sci. 92, 1171-1176

Bergmann V (2001): Fleischhygienisch relevante Erkrankungen des Geflügels. In: Praxis der Geflügelfleischuntersuchung/Hrsg.: Fries R, Bergamnn V, Fehlhaber K, S. 77-182 Hannover: Schlütersche Verlag – ISBN: 3-87706-591-0

Berk J. (2002): Haltung und Management in der heutigen Putenhaltung. In: Artgerechte Mastputenhaltung KTBL-Schrift 412, S. 29 - 42, Münster; Darmstadt: Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. – ISBN: 3-7843-2150-X

Berk J, Wartemann S (2006): Einfluss eines Putenmaststalles mit Außenklimabereich auf Leistung, Verhalten und Gesundheit von männlichen Puten. Dtsch Tierarztl Wschr 113, 107-10

Berk J (2013): Behaviour and health of different turkey genotypes with outdoor access. In: Understanding behaviour to improve livelihood. In: Proceedings of the "47th Congress of the International Society for Applied Ethology", Brazil/Hrsg.: Hötzel M J, Pinheiro Machado Filho L C, June 2–6, 2013, Florianopolis, Brazil, S.102

Buda S, Platt S, Budras K D (2002): Sensory nerve endings in the footpads of turkeys. In: Proceedings of the "4th International Symposium on Turkey Diseases", Germany/Hrsg.: Verlag Eugen Ulmer, Stuttgart, May 15 - 18, 2002, Berlin, Germany, S. 78-82

Chuppava B, Visscher C, Kamphues J (2018): Effect of different flooring designs on the performance and foot pad health in broilers and turkeys. Animals 8, 70

Clark S, Hansen G, McLean P, Bond P, Wakeman W, Meadows R, Buda S (2002): Pododermatitis in turkeys. Avian Dis. 46, 1038-1044

Dalton H A, Wood B J, Torrey S (2013): Injurious pecking in domestic turkeys: development, causes and potential solutions. World's Poult Sci J 69, 865-875

Dalton H A, Wood B J, Widowski T M, Guerind M T, Torrey S (2018): Comparing the behavioural organization of head pecking, severe feather pecking and gentle feather pecking in domestic turkeys. Appl. Anim. Behav. Sci. 204, 66-71

Damme K, Hildebrand R-A (2002): Geflügelhaltung – Legehennen, Puten und Masthähnchen. Stuttgart: Ulmer Eugen Verlag, ISBN: 3-8001- 3929-4

Dressel A, Krautwald-Junghanns M-E, Dressel H, Ermakow O, Preidl S, Bartels T (2019): Vergleichende Auswertung von Schlachtbefunden bei konventionell und ökologisch gehaltenen Mastputen. Berl Münch Tierarztl Wochenschr 132, 317-324

Droual R, Chin R P, Rezvani M (1996): Synovitis, osteomyelitis, and green liver in turkeys associated with Escherichia coli. Avian Dis. 40, 417-424

Duggan G, Widowski T, Quinton M, Torrey S (2014): The development of injurious pecking in a commercial Turkey facility. J Appl Poult Res 23, 2380-290

European Commission (2008): Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation /EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control. Official Journal of the European Union. L 250/251 - L 250/284

Ellerich R (2012): Prävalenz von Veränderungen der Haut und ihrer Anhangsorgane bei Mastputen. Dissertation Universität Leipzig, Leipzig, Germany

Erasmus M A (2017): A review of the effects of stocking density on turkey behavior, welfare, and productivity. Poult. Sci. 96, 2540-2545

Ermakow O (2012): Ergebnisse der Fleischuntersuchung bei Puten aus ökologischer und konventioneller Haltung. Dissertation Universität Leipzig, Leipzig, Germany.

Farm Animal Welfare Council (FAWC) (2009): Farm Animal Welfare in Great Britain: Past, Present and Future. Accessed on 25.01.2021. Available from: FAWC Report on Farm Animal Welfare in Great Britain: Past, Present and Future - GOV.UK (www.gov.uk)

Federal Republic of Germany (2017): Tierschutzgesetz in der Fassung der Bekanntmachung vom 18. Mai 2006 (BGBI. IS. 1206, 1313), das zuletzt durch Artikel 141 des Gesetzes vom 29. März 2017 (BGBI. IS. 626) geändert worden ist. Accessed on 10.12.2020. Available from: https://www.gesetze-im-internet.de/bundesrecht/tierschg/gesamt.pdf.

Fehlhaber K (2001): Bedeutung des Geflügelfleisches. In: Praxis der Geflügelfleischuntersuchung/Hrsg.: Fries R., Bergmann V., Fehlhaber K., S. 14 - 16, Hannover: Schlütersche GmbH& Co. KG – ISBN: 3-87706-591-0

Fehlhaber K (2005): Konventionell und ökologisch erzeugte Lebensmittel – ein Vergleich aus der Sicht mikrobiell und parasitär bedingter Risiken. In: "11. Workshop Konventionelle – ökologische Lebensmittel: Ein Vergleich"/Hrsg.: Heinrich-Stockmeyer-Stiftung, Osnabrück, October 20th, 2005, Osnabrück, Germany

Ferrante V, Lolli S, Ferrari L, Watanabe T T N, Tremolada C, Marchewka J, Estevez I (2019): Differences in prevalence of welfare indicators in male and female Turkey flocks (*Meleagris gallopavo*). Poult. Sci. 98, 1568-1574

Flachowsky G (1973): Der Einfluss eines variierenden Rohprotein- und Energiegehaltes im Mischfutter auf Lebendmassezunahme und den Futter-, RP- und Energieverzehr sowie -aufwand von Broilern. Archiv Tierernährung 23, 225-235

Food Safety and Inspection Service (2014): Accessed on 12.01.2021. Available from: https://www.fsis.usda.gov/wps/wcm/connect/d6f2ab31-8f0c-4086-9106-076a5fcaa845/PSITTurkey.pdf?MOD=AJPERES

Freihold D, Bartels T, Bergmann S, Berk J, Deerberg F, Dressel A, Erhard M H, Ermakow O, Huchler M, Krautwald-Junghanns M-E, Spindler B, Thieme S, Hafez H M (2019): Investigation of the prevalence and severity of foot pad dermatitis at the slaughterhouse in fattening turkeys reared in organic production systems in Germany. Poult. Sci. 98, 1559–1567

Freihold D, Bartels T, Bergmann S, Berk J, Deerberg F, Dressel A, Erhard M H, Ermakow O, Huchler M, Spindler B, Thieme S, Krautwald-Junghanns M-E, Hafez H M (2021): Investigation of the occurrence of pathological carcass alterations at the processing plant in meat turkeys reared in organic production systems in Germany. J Appl Poult Res 2021; 30:100145 https://doi.org/10.1016/j.japr.2021.100145

Gazdzinski P, Squires E J, Julian R J (1994): Hepatic Lipidosis in Turkeys. Avian Dis. 38, 379-384

Gonder E, Barnes H J (1987): Focal Ulcerative Dermatitis (Breast Buttons) in Marketed Turkeys. Avian Dis. 31, 52-58

Habig C, Spindler B, Beyerbach M, Kemper N (2017): Evaluation of footpad health and live weights in two lines of turkey hens kept under organic husbandry conditions in Germany. Berl Munch Tierarztl Wochenschr 130, 250-257

Hafez H M (1996): Übersicht über Probleme der haltungs- und zuchtbedingten Erkrankungen bei Mastputen. Arch. für Geflügelkunde 60, 249-56

Hafez H M, Jodas S (1997): Putenkrankheiten. Stuttgart: Enke Verlag – ISBN-10: 3432291612

Hafez H M (1999): Gesundheitsstörungen bei Puten im Hinblick auf die tierschutzrelevanten und wirtschaftlichen Gesichtspunkte. Arch. für Geflügelkunde 63, 73-76

Hafez H M, Wäse K, Haase S, Hoffmann T, Simon O (2004): Leg disorders in various lines of commercial turkeys with especial attention to pododermatitis. In: Proceedings.of the "5th International Symposium on Turkey Diseases", Berlin/Hrsg.: Hafez H M, Giessen: DVG-Service- GmbH, June 16-19, 2004, Berlin, Germany, S. 11-18

Hafez H M, Haase S, Wäse K, Hoffmann T, Hauck R, Simon O, Bergmann V (2005a): Zum "Beinschwäche-Syndrom" bei genetisch verschiedenen Putenlinien. Vom: 26. DVG- Kongress "Tierschutz, Leistung und Gesundheit", Berlin, April 1-2, 2005, Berlin, Germany, Posterbeitrag 34, 135

Hafez H M, Rudolf M, Haase S, Hauck R, Behr K P, Bergmann V, Günther R (2005b): Influence of stocking density and litter material on the incidence of pododermatitis of turkeys. In: Proceedings of the "3rd International Symposium of the Working Group 10 (Turkey) of WPSA. Turkey production: prospects on future developments"/Hrsg.: Hafez H M, Berlin: Mensch & Buch Verlag, S. 101-109, ISBN: 3-89820-993-8

Hafez H M (2009): Respiratory Diseases of Turkeys. In: Pathologia Aviária Revolledo/Hrsg.: L, Ferreira A J P, S. 468-479, Sao Paolo: Manole, Brazil - ISBN- 978-85-204-2058-4

Hirt H, Frohlich E, Oester H (1996): Leg weakness in meat hybrids of turkeys. Aktuelle Arbeiten zur artgemäßen Tierhaltung 1995. In: KTBL Schrift 373, S. 178-188, Darmstadt: Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V.

Hocking P M, Mayne R K, Else R W, French N A, Gatcliffe J (2008): Standard European footpad dermatitis scoring system for use in turkey processing plants. Worlds Poult Sci J 64, 323-328

Hocking P M, Wu K (2013): Traditional and commercial turkeys show similar susceptibility to foot pad dermatitis and behavioural evidence of pain. Brit. Poult. Sci. 54, 281-288

Hörning B (2003): Status Quo der ökologischen Geflügelhaltung in Deutschland. Fachbereich ökologische Agrarwissenschaften, Universität Kassel, Witzenhausen. Accessed on 05.01.2021. Available from: https://orgprints.org/1187/1/hoerning-2002-status-quo-gefluegel.pdf.pdf

Hübel J, Bergmann S, Ziegler N, Willig R, Truyen U, Erhard M H, Krautwald-Junghanns M-E (2014): Vergleichende Feldstudie zur Einstreufeuchtigkeit und zur Fusballengesundheit während der Aufzucht von Mastputen. Berl Munch Tierarztl Wochenschr 127, 274-289

Huff G R, Huff W E, Rath N C, Balog J M (2000): Turkey osteomyelitis complex. Poult. Sci. 79, 1050-1056

Jordan F T W (1990): Diseases of the muscoloskeletal system. In: Poultry Diseases/Hrsg.: Jordan F T W, 3. Aufl., S. 254-283; London: Saunders

Kamphues J, Youssef I M I, Abd El-Wahab A, Üffing B, Witte M, Tost M (2011): Einflüsse der Fütterung und Haltung auf die Fußballengesundheit bei Hühnern und Puten. Übers. Tierernährg. 39, 147-195

Kamphues J, Wolf P, Coenen M, Eder K, Iben C, Kienzle E, Liesegang A, Männer K, Zebeli Q, Zentek J (2014): Ernährung verschiedener Spezies. In: Supplemente zur Tierernährung/ Hrsg.: Kamphues J, S. 452-463, Stuttgart: M. & H. Schaper

Kamyab A (2001): Enlarged sternal bursa and focal ulcerative dermatitis in male turkeys. Worlds Poult Sci J 57, 5-12

Knierim U, Gieseke D, Michaelis S, Keppler C, Spindler B, Rauch E, Petermann S, Andersson R, Schultheiß U, Zapf R (2020): Tierschutzindikatoren: Leitfaden für die Praxis – Geflügel. Vorschläge für die Produktionsrichtungen Jung- und Legehenne, Masthuhn,

Mastpute. 2. Auflage, S. 77-78, Darmstadt: Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. - ISBN: 978-3-945088-77-7

Korfmann M A (2003): Zur Skelettentwicklung und Wachstumsdynamik der Beckengliedmaße bei Mastputen (makroskopische, mikroskopische, radiologische, osteodensitometrische und mineralstoffanalytische Verlaufsuntersuchungen) Dissertation Freie Universität Berlin, Berlin, Germany

Krautwald- Junghanns M-E, Ellrich R, Bähme J, Cramer K, Dellavolpe A, Mittererlstyagin H, Ludewig M, Fehlhaber K, Schuster E, Berk J, Aldehoff D, Fulhorst D, Kruse W, Dressel A, Noock U, Bartels T (2009): Erhebungen zur Haltung und Gesundheit bei Mastputen in Deutschland. Berl Münch Tierarztl Wschr 122, 271-83

Krautwald-Junghanns M-E, Ellerich R, Mitterer-Istyagin H, Ludewig M, Fehlhaber K, Schuster E, Berk J, Petermann S, Bartels T (2011): Examinations on the prevalence of footpad lesions and breast skin lesions in British United Turkeys Big 6 fattening turkeys in Germany. Part I: Prevalence of footpad lesions. Poult. Sci. 90, 555-560

Krautwald-Junghanns M-E, Bergmann S, Erhard M H, Fehlhaber K, Hübel J, Ludewig M, Mitterer-Istyagin H, Ziegler N, Bartels T (2013): Impact of Selected Factors on the Occurrence of Contact Dermatitis in Turkeys on Commercial Farms in Germany. Animals 3 (3), 608-628

Marchewka J, Vasdal G, Moe R O (2019): Identifying welfare issues in Turkey hen and tom flocks applying the transect walk method. Poult. Sci. 98, 3391-3399

Martland M F (1984): Wet Litter as a Cause of Plantar Pododermatitis, Leading to Foot Ulceration and Lameness in Fattening Turkeys. Avian Pathol 13, 241-252

Martrenchar A, Huonnic D, Cotte J P, Boilletot E, Morisse J P (1999): Influence of stocking density on behavioural, health and productivity traits of turkeys in large flocks. Brit. Poult. Sci. 40, 323-331

Mayne R K, Else R W, Hocking P M (2004): Histopathological changes that occur in the turkey foot pad as a result of wet and dry litter substrates. Br. Poult. Sci. 45 (1), 41-42

Mayne R K (2005): A review of the aetiology and possible causative factors of foot pad dermatitis in growing turkeys and broilers. Worlds Poult Sci J 61, 256-267

Mayne R K, Hocking P M, Else R W (2006): Foot pad dermatitis develops at an early age in commercial turkeys. Brit. Poult. Sci. 47, 36-42

Mayne R K, Else R W, Hocking P M (2007): High litter moisture alone is sufficient to cause footpad dermatitis in growing turkeys. Brit. Poult. Sci. 48, 538-545

McCune E L, Dellmann H D (1968): Developmental Origin and Structural Characters of Breast Blisters in Chickens. Poult. Sci. 47, 852- 858

McEwen S A, Barbut S (1992): Survey of Turkey Downgrading at Slaughter - Carcass Defects and Associations with Transport, Toenail Trimming, and Type of Bird. Poult. Sci. 71, 1107-1115

Mitterer-Istyagin H, Ludewig M, Bartels T, Krautwald-Junghanns M-E, Ellerich R, Schuster E, Berk J, Petermann S, Fehlhaber K (2011): Examinations on the prevalence of footpad lesions and breast skin lesions in BUT Big 6 fattening turkeys in Germany. Part II: Prevalence of breast skin lesions (breast buttons and breast blisters). Poult. Sci. 90, 775-780

Neroli S, Prestmo P G, Sheard P, Knowles T G, van Klink E G M (2020): Analysis of risk factors for dermatitis and cellulitis in turkeys using abattoir *post mortem* data. Brit. Poult. Sci. 61, 531-537

Newberry R C (1993): The Role of Temperature and Litter Type in the Development of Breast Buttons in Turkeys. Poult. Sci. 72, 467-474

Oekolandbau (2017): Ökologische Putenmast. Accessed on 12.01.2021. Available from: https://www.oekolandbau.de/landwirtschaft/tier/spezielle-tierhaltung/gefluegel/mastgefluegel/oekologische-putenmast/

Olschewsky A, Riehn K, Knierim U (2021): Suitability of Slower Growing Commercial Turkey Strains for Organic Husbandry in Terms of Animal Welfare and Performance. Front. Vet. Sci. 2021; 7:600846. doi: 10.3389/fvets.2020.600846

Pagazaurtundua A, Warris P D (2006): Levels of footpad dermatitis in broiler chickens reared in 5 different systems. Br. Poult. Sci. 47, 529-531

Platt S, Buda S, Budras K D (2004): The repair of foot pad lesions in commercial turkeys. In: Proceedings of the "5th International Symposium on Turkey Diseases", Berlin /Ed.: Hafez H M, Giessen: DVG-Service-GmbH, June 16-19, 2004, Berlin, Germany, S. 23-27

Platz S, Ahreus F, Bergmann S, Strassmeier P, Schweizer G, Erhard M (2006): Schwarze, weiße oder beide. In: DGS: Das Magazin für die Geflügelwirtschaft und Schweineproduktion, 48/Hrsg.: Zentralverband der Deutschen Geflügelwirtschaft e.V., S. 29- 33, Stuttgart: Verlag Eugen Ulmer – ISSN: 0948-4221

Popp C, Hauck R, Vahlenkamp T W, Lüschow D, Kershaw O, Hoferer M, Hafez H M (2014): Liver Pathology Associated with Increased Mortality in Turkey Breeder and Meat Turkey Flocks. Avian Dis. 58, 474-481

Proudfoot F, Hulan H (1985): Effects of stocking density on the incidence of scabby hip syndrome among broiler chickens. Poult. Sci. 64, 2001–2003

Rahmann G, Koopmann R, Hertzberg H (2002): Gesundheit erhalten statt Krankheiten kurieren, Tiergesundheit in Ökologischen Landbau, Forschungsreport 1/2002; 4-7. Accessed on 10.12.2020. Available from: https://www.openagrar.de/servlets/MCRFileNodeServlet/timport_derivate_00035528/zi032696.pdf

Rahmann G, Koopmann R, Oppermann R (2005): Can organic farming rely on animal husbandry as a focus for the future - The recent performance of organic farms and the right development paths to follow? In: Ende der Nische, Beiträge zur 8. Wissenschaftstagung Ökologischer Landbau /Hrsg.: Heß J, Rahmann G, S. 657-660, Kassel: University Press GmbH

Rautenschlein S, Ryll M (2014): Erkrankungen des Nutzgeflügels. Stuttgart: Eugen Ulmer Verlag – ISBN: 978-3-8252-8568-5

Rudolf M (2008): Influence of stocking density and litter material on pododermatitis in turkeys. Dissertation Freie Universität Berlin, Berlin, Germany

Schmidt E, Bellof G (2006): Einsatz ökologisch erzeugter Proteinträger in der Putenmast. Abschlussbericht zum BÖL-Forschungsprojekt Nr.: 03OE451. Accessed on 09.12.2020. Available from: https://orgprints.org/10902/1/10902-03OE451-fh-weihenstephan-schmidt-2006-putenmast.pdf

Schumacher U, Rahmann G (2008): Neues aus der ökologischen Tierhaltung 2008. In: Praxis trifft Forschung – Neues aus der Ökologischen Tierhaltung 2008/Hrsg.: Rahmann G, Schumacher U, S. 5-10, Braunschweig: Johann-Heinrich-von-Thünen-Institut, Bundesforschungsinstitut für ländliche Räume, Wald und Fischerei (vTI) - ISBN 978-3-86576-058-6

Schumacher C, Krautwald-Junghanns M-E, Hübel J, Bergmann S, Mädl N, Erhard M H, Berk J, Pees M, Truyen U, Bartels T (2012): Einfluss der Einstreufeuchte im Futter- und Tränkebereich auf die Fußballengesundheit von Mastputen in der Aufzuchtphase. Berl Münch Tierarztl Wochenschr 125, 379-385

Shepherd E M, Fairchild B D (2010): Footpad dermatitis in poultry. Poult. Sci. 89, 2043-2051

Sinclair A, Wyneken C W, Veldkamp T, Vinco L J, Hocking P M (2015): Behavioural assessment of pain in commercial turkeys (Meleagris gallopavo) with foot pad dermatitis. Brit. Poult. Sci. 56, 511-521

Spindler B (2007): Pathologisch-anatomische und histologische Untersuchungen an Gelenken und Fußballen bei Puten der Linie B.U.T. Big 6 bei der Haltung mit und ohne Außenklimabereich. Dissertation Universität Hannover, Hannover, Germany

Stracke J, Klotz D, Wohlsein P, Döhring S, Volkmann N, Kemper N, Spindler B, (2020): Scratch the surface: Histopathology of foot-pad dermatitis in turkeys (Meleagris gallopavo). Animal Welfare 29, 419-432

Stracke, J., N. Volkmann, F. May, S. Döhring, N. Kemper and B. Spindler (2021): Walking on Tiptoes: Pads Deserve Increased Attention When Scoring Footpad Dermatitis as an Animal Welfare Indicator in Turkeys. Front. Vet. Sci. 2021; 7:613516. doi: 10.3389/fvets.2020.613516

Strassmeier P (2007): Einfluss von Strukturelementen, Futterzusammensetzung und Witterung auf das Verhalten von gemischt gehaltenen BIG SIX und Kelly Bronze Puten in der Auslaufhaltung. Dissertation Ludwig-Maximilians-Universität München, München, Germany

Tilley B J, Barnes H J, Scott R (1996): Litter and Commercial Turkey Strain Influence on Focal Ulcerative Dermatitis ("Breast Buttons"). Appl. Poult. Sci. 5, 39-50

Toppel K, Spindler B, Kaufmann F, Gauly M, Kemper N, Andersson R (2019): Foot Pad Health as Part of On-Farm-Monitoring in Turkey Flocks. Front. Vet. Sci. 6:25. doi: 10.3389/fvets.2019.0002

Verband Deutscher Putenerzeuger (2013): Bundeseinheitliche Eckwerte für eine freiwillige Vereinbarung zur haltung von Mastputen. Accessed on 30.11.2020. Available from: https://www.bmel.de/SharedDocs/Downloads/DE/_Tiere/Tierschutz/ZDG-Eckwerte-Haltung-Mastputen.pdf;jsessionid=2E4F9FE87E7BC24670DB98FAF169DE03.intranet922?__blob=publicationFile&v=5

Vinco L J, Giacomelli S, Campana L, Lombardi G, Hocking P M, Veldkamp T (2017): Identifying on-farm factors affecting foot pad lesions. In: Proceedings of the "11th Turkey Science and Production Conference", Chester, March 8-10, 2017, Chester, UK, S. 28-33

Watanabe T T N, Lolli S, Ferrari L, Ferrante V (2013): Review of the physiological and pathological welfare indicators applied in turkeys (*Meleagris gallopavo*). Biotechnology in Animal Husbandry 29, 727-740

Weber Wyneken C, Sinclair A, Veldkamp T, Vinco L J, Hocking P M (2015): Footpad dermatitis and pain assessment in turkey poults using analgesia and objective gait analysis. Br. Poult. Sci. 56, 522-530

Wu K, Hocking P M (2011): Turkeys are equally susceptible to foot pad dermatitis from 1 to 10 weeks of age and foot pad scores were minimized when litter moisture was less than 30%. Poult. Sci. 90, 1170-1178

Youssef I M I, Beineke A, Rohn K, Kamphues J (2010): Experimental study on effects of litter material and its quality on foot pad dermatitis in growing turkeys. Int. J. Poult. Sci. 89, 1125- 1135

Ziegler N, Bergmann S, Hübel J, Bartels T, Schumacher C, Bender A, Casalicchio G, Küchenhoff H, Krautwald-Junghanns M-E, Erhard M (2013): Auswirkungen des Stallklimas auf die Fußballengesundheit von Mastputen der Herkunft B.U.T. 6 in der Aufzuchtphase. Berl Münch Tierarztl Wochenschr 126, 181-188

8. Appendix

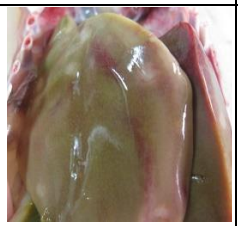
8.1 Foot Pad Dermatitis Score

0	1	2	3	4
No alterations	Minimal alterations; several necrotic scales	Moderate alterations; necrotic lesions < 2cm	High degree of alterations; necrotic lesions > 2cm; deep lesions	Abscess
				

8.2 Breast skin lesion

Breast Button


8.3 Liver alterations

Swollen liver	Green liver	Liver necrosis	Liver abscess	Fatty liver
				

8.4 Joint alteration

Swelling of the hock joint


9. List of own publications

1. Freihold D, Bartels T, Berk J, Deerberg F, Dressel A, Erhard M H, Ermakow O, Huchler M, Krautwald-Junghanns M-E, Müller R, Spindler B, Thieme S, Hafez H M: **Investigation of animal welfare indicators at the processing plant of fattening turkeys reared under organic poultry farming system.**
   11th "Hafez" International Symposium on Turkey Diseases, 26.-28.05.2016, Berlin, Germany

2. Freihold D, Bartels T, Berk J, Deerberg F, Dressel A, Erhard M H, Ermakow O, Huchler M, Krautwald-Junghanns M-E, Müller R, Spindler B, Thieme S, Hafez H M: **Indikatoren einer tiergerechten Mastputenhaltung unter den Bedingungen der ökologischen Geflügelmast.** Diagnostik und Betreuung von Wirtschafts- und Ziergeflügel. 16. Fortbildungsveranstaltung des Landesamtes für Verbraucherschutz, Fachbereich Veterinrmedizin und der Tierärztekammer Sachsen-Anhalt, 28.-29.09.2016, Stendal, Germany

3. Thieme S, Freihold D, Bartels T, Berk J, Deerberg F, Dressel A, Erhard M H, Ermakow O, Spindler B, Huchler M, Krautwald-Junghanns M-E, Hafez H M: **Tierschutzindikatoren im Rahmen der Schlachtkörperuntersuchung bei Mastputen in der ökologischen Haltung.**
   21. Internationale Bioland-Geflügeltagung, 01.-03.03.2017, Bad Boll, Germany

4. Krautwald-Junghanns M-E, Bartels T, Berk J, Deerberg F, Dressel A, Erhard M H, Ermakow O, Freihold D, Hafez H M, Huchler M, Ludewig M, Mitterer-Istyagin H, Spindler B, Thieme S (2017): **Indikatoren einer tiergerechten Mastputenhaltung unter den Bedingungen der ökologischen Geflügelmast**.
   https://fob.uni-leipzig.de/public/details/publikation/www.orgprints.org/34305

5. Thieme S, Freihold D, Bartels T, Bergmann S, Berk J, Deerberg F, Dressel A, Erhard M H, Ermakow O, Huchler M, Ludewig M, Mitterer-Istyagin H, Spindler B, Krautwald-Junghanns M-E, Hafez H M: **Grüne Lebern und schwarze Füße – Schlachtbefunde als retrospektive Tierschutzindikatoren in der Ökoputenhaltung.**
   59. Arbeitstagung des Arbeitsgebietes Lebensmittelsicherheit und Verbraucherschutz, 25.-28.09.2018, Garmisch-Partenkirchen, Germany

6. Bartels T, Huchler M, Freihold D, Thieme S, Bergmann S, Berk J, Cramer K, Deerberg F, Dressel A, Erhard M H, Ermakow O, Pees M, Spindler B, Hafez H M, Krautwald-Junghanns M-E (2020): **Untersuchungen zur Prävalenz von Fußballenveränderungen bei ökologisch gehaltenen Mastputen und zu potenziellen Einflussfaktoren auf den Fußballenzustand**. Berl. Münch. Tierärztl. Wochenschr

10. Acknowledgements

Zuallererst möchte ich mich bei meinem Doktorvater Univ.-Prof. Dr. Hafez Mohamed Hafez bedanken für die Möglichkeit an dieser Studie zu arbeiten und diese Dissertation zu schreiben. Vielen Dank für die stetige Unterstützung, Beratung und das Teilen Ihres unerschöpflichen Wissensschatzes. Ich bin sehr dankbar für Ihre Zeit und Geduld.

Ein großer Dank geht an Dr. Thomas Bartels, für die sehr hilfreichen Anregungen, das Korrekturlesen und Diskutieren über das Thema. Danke, dass du mich auf meinem wissenschaftlichen Weg begleitet hast.

Vielen Dank Susann, für die tollen Ausfahrten und deine unverzichtbare Unterstützung. Es hat mir immer sehr viel Freude bereitet mit dir zu arbeiten und gemeinsam mit dir zu lernen.

Ich möchte mich bei allen Co-Autoren bedanken, für wertvolle Unterstützung durch geballten Wissensschatz: Prof. Dr. Maria-Elisabeth Krautwald-Junghanns, Dr. Shana Bergmann, Dr. Jutta Berk, Friedhelm Deerberg, Dr. Annette Dressel, Prof. Dr. Dr. Michael H. Erhard, Dr. Olga Ermakow, Martin Huchler und Dr. Birgit Spindler.

Herzlichen Dank Gerzon. Danke, dass du immer da warst, wenn ich jemanden brauchte, der mich motiviert und wieder aufbaut. Deine unvergleichlich positive Energie hat nicht nur mir die Arbeit versüßt. Und ohne dich wäre ich das ein oder andere Mal verzweifelt, wenn der Computer mal wieder nicht so wollte wie ich.

Danke Anne, für deine Zeit, dein stets offenes Ohr und deine hilfreichen Tipps. Danke für die schönen Kaffeepausen, die mich stets aufgebaut und mir neue Energie gegeben haben.

Vielen Dank Papa, für deine Unterstützung, das geduldige Korrekturlesen und Korrigieren der englischen Grammatik.

Herzlichen Dank an meine Familie: an meine wunderbaren Eltern, meine Schwester und mein Schwager, die stets an mich geglaubt haben. Danke an meine Freunde, die mich immer unterstützen und für mich da sind. Danke Salim. Ich bin sehr dankbar dafür dich in meinem Leben zu haben und für deinen unvergleichlichen Optimismus.

Ohne euch wäre ich nicht so weit gekommen.

11. Funding Sources

The project was financially supported by the German Federal Ministry of Food and Agriculture (BMEL) through the Federal Scheme for Organic Farming and Other Forms of Sustainable Agriculture (BÖLN).

12. Conflict of Interest (Interessenskonflikt)

Es besteht kein Interessenskonflikt durch finanzielle Unterstützung der Arbeiten.

13. Declaration of academic honesty (Selbstständigkeitserklärung)

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

Berlin, 26.05.2021

Darja Freihold

Druck: **mbv**berlin mensch und buch verlag