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

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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

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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 ($P > 0.05$).

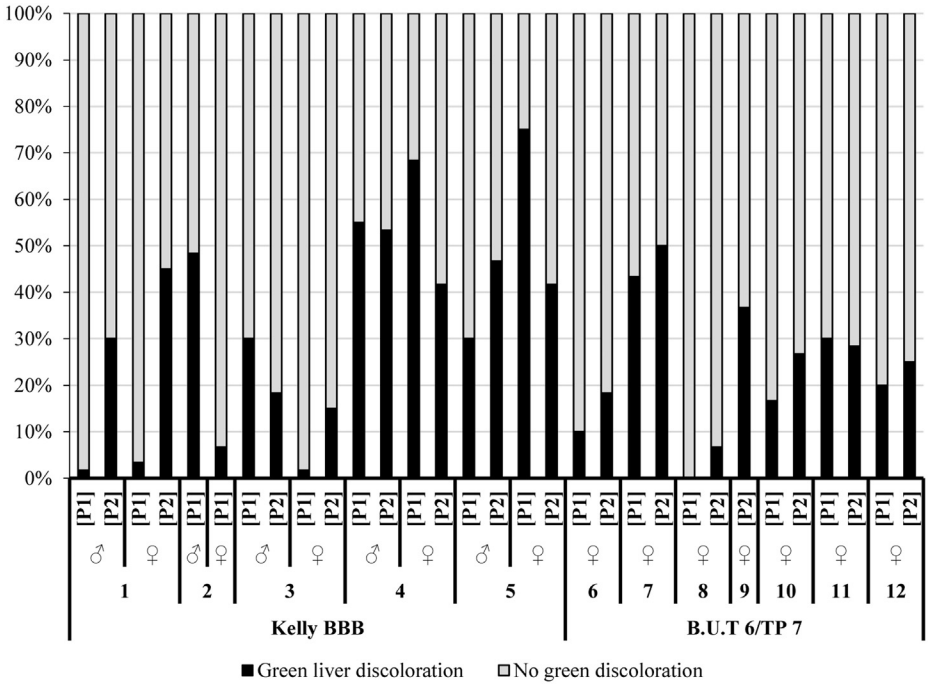

Figure 1. Farm-specific occurrence of green liver discoloration in turkeys reared in organic farms at the slaughterhouses. P: observed fattening period; P1: summer period; P2: winter period. Arabic numerals: examined farms. Abbreviations: B.U.T. 6, British United Turkey 6; Kelly BBB, Kelly Broad Breasted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

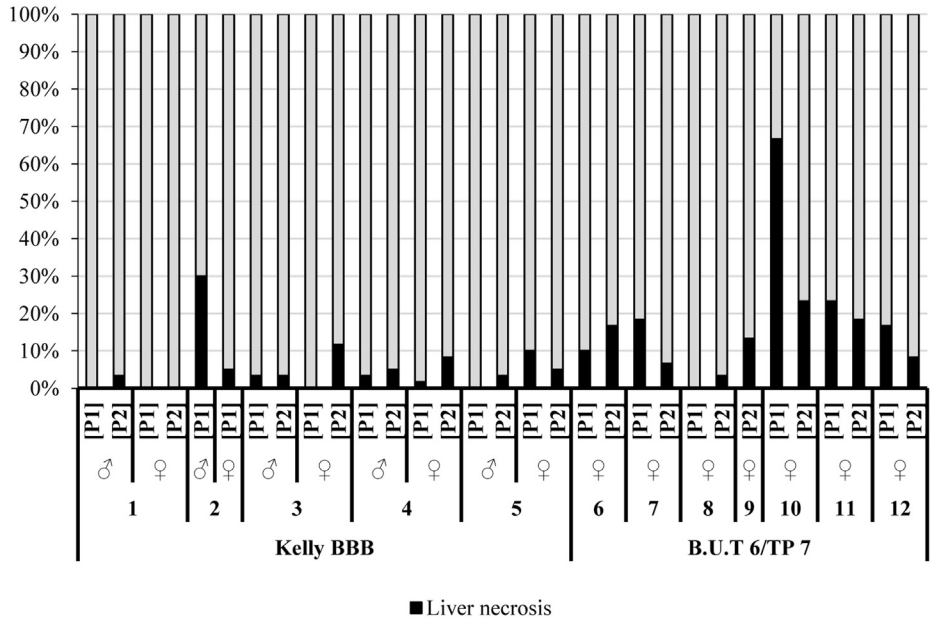

Figure 2. Farm-specific occurrence of liver necrosis in turkeys reared in organic farms. P: observed fattening period; P1: summer period; P2: winter period. Arabic numerals: examined farms. Abbreviations: B.U.T. 6, British United Turkey 6; Kelly BBB, Kelly Broad Breasted Bronze; TP 7, Test Product 7.

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.

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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.