Associations between on-farm welfare measures and slaughterhouse data in commercial flocks of turkey hens (*Meleagris gallopavo*)

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ABSTRACT There is a growing demand for documentation of animal welfare in meat production industry. Research on turkey welfare has mainly focused on toms at the end of production cycle, and information on the relationship between on-farm welfare and slaughterhouse recordings for turkey hens is currently lacking. The aim of this study was to investigate the relationship between routinely collected slaughterhouse data from turkey hens and their on-farm welfare measured by transect walks, to identify potential retrospective welfare indicators. The study was conducted between November 2017 and March 2018 in 20 commercial turkey flocks in Norway. On-farm welfare was evaluated using the transect walk method when the turkey hens were 11 wk old, recording the number of birds that were immobile, lame, small, featherless, dirty, sick, terminal, or dead and had visible head, tail, or wing wounds. Slaughterhouse data was provided for each flock. Univariate and multivariate linear regression models were used to investigate the associations between the variables. The results showed significant associations between several measures on farm and at slaughter. Flocks with more lameness on farm had more birds rejected at the slaughterhouse owing to leg and joint issues (P = 0.03, r = 1.01). Featherlessness and dirtiness on farm were positively associated with airsacculitis (P = 0.005; r = 0.42 and P = 0.0008; r = 0.57, respectively). The results suggest that slaughterhouse registrations may provide both practical and feasible retrospective information on the welfare of turkey hens that potentially could be implemented in future welfare assessment schemes. Further studies are needed to investigate the causal factors behind the identified relationships.

Key words: turkey, hen, animal welfare, on-farm, slaughterhouse

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INTRODUCTION

A modern and sustainable poultry production must encompass acceptable welfare standards for animals. Previous studies have identified several welfare issues in turkey production, including poor leg health and mobility problems (Martrenchar et al., 1999), feather pecking and aggression toward flock mates (Busayi et al., 2006; Dalton et al., 2013), wounds, infections, airsacculitis, and contact dermatitis (Krautwald-Junghanns et al., 2011; Mitterer-Istyagin et al., 2011). In addition to the compromised welfare, these issues can also result in economic losses (Krautwald-Junghanns et al., 2011; Marchewka et al., 2013). Several risk factors for poor turkey welfare related to the physical and social environment as well as management conditions have been identified. High stocking density in turkey flocks has been mentioned as one of the largest welfare challenges in the European Union (Broom, 2017) and can lead to increased aggression and more feather pecking (Buchwalder and Huber-Eicher, 2004), more disturbances (Martrenchar et al., 1999), increased lameness (Martenchar et al., 1999), and more contact dermatitis (Wu and Hocking, 2011). Wet and poor quality of litter is another well-known welfare issue in turkeys and can lead to footpad dermatitis (**FPD**), hock burns, and breast blisters (Krautwald-Junghanns et al., 2011; Freihold et al., 2019).

There is an increasing demand for a continuous documentation of animal welfare status in commercial meat production industry (European Commission, 2005, 2017). Recently, transect walks have been found to be

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a feasible, practical, and validated method for assessing on-farm welfare in broilers (Marchewka et al., 2013; 2019; BenSassi et al., 2019) and turkeys (Marchewka et al., 2015, 2019; Ferrante et al., 2019). This method is based on line transect methodology, a technique routinely used in ecological studies to estimate animal biodiversity and abundance (Butler et al., 2007). In short, an assessor walks the house along the predetermined paths counting the incidences of birds representative of predefined welfare indicator categories: immobile; lame; visible head, vent, or back wounds; small; featherless; dirty; sick; terminally ill; or dead. The method requires no animal handling and allows for the visual assessment of the entire flock. An additional strength of the approach is that it bears similarity to the daily poultry flock checks conducted by the farmers and is therefore easy to adopt.

In standard commercial turkey production systems, hen production cycle is shorter than that of toms. Turkey hens are typically slaughtered at 12 to 16 wk of age, whereas toms are slaughtered at 18 to 22 wk of age, depending on the line (Chartrin et al., 2019), which requires producers to separate the 2 sexes in the barn. The last week before the hens are slaughtered is generally considered a challenging time, when the barn is at its maximum capacity with regard to the number of animals, ventilation capacity, litter quality, and animal care (Martrenchar, 1999). A previous study using the transect walk method to assess welfare in Norwegian flocks of turkeys hens and toms at this time (11 wk of age) found that the most prevalent welfare challenges across sexes were dirty and featherless birds and birds with tail and wing wounds (Marchewka et al., 2019). Another study using the transect walk method in Italian turkey flocks found similar results (Ferrante et al., 2019). Interestingly, both studies found a higher prevalence of welfare challenges such as lameness, wounds, and dirtiness (Ferrante et al., 2019) and more tail wounds and sick birds (Marchewka et al., 2019) in toms than in hens. However, although the transect method is a practical tool, it is not feasible to visit all the turkey flocks before slaughter. To develop a feasible welfare assessment scheme for commercial use, it is necessary to develop assessment methods that reflect welfare challenges on farm without the need for individual farm visits.

A potential strategy for simplification of welfare assessment is to replace time-consuming on-farm scoring in live birds with other animal-based measures that reliably detect impaired welfare after postmortem, that is, based on slaughterhouse data. Indeed, animal welfare in commercial poultry flocks can be monitored using registrations routinely recorded at the slaughterhouse (EFSA, 2012), such as dead on arrival (**DOA**), mortality, and rejections due to infections and wounds. Inspecting the broiler chicken feet for FPD to detect animal welfare faults in the farm of origin is a requirement in Sweden, Denmark, Finland, and the UK, while some slaughter plants in Germany and the Netherlands are also evaluating FPD as animal welfare is of major significance for the increase in the number of customers (Löhren, 2012). Some slaughterhouses record birds' condition in more detail, depending on the local legislation or wholesalers' and consumers' demands, recording, for instance, FPD or other health issues. Slaughterhouse registrations are both practical and feasible when it comes to scoring large numbers of animals. However, slaughterhouse data are retrospective and will not benefit the assessed animals, whereas on-farm welfare assessment, preferably using animal-based welfare indicators, provides a more valid view of how the animals are coping with the environment (Phythian et al., 2013). On-farm recordings also allow farmers to adjust their management routines and potentially improve the welfare for the current flock. Therefore, identifying associations between on-farm measures of welfare in turkey flocks and slaughterhouse data after postmortem from the same flocks could contribute to validation and simplification of welfare recordings for commercial use.

Marchewka et al. (2015) found correlations between the transect walk recordings and slaughterhouse recordings in flocks of toms assessed at 19–20 wk of age in the USA, suggesting that slaughterhouse data indeed have the potential to provide reliable information of animal welfare on farm. In broiler chickens, flocks with high DOA (up to 3.34%) were found to have an increased body temperature, more lesions, and soiled plumage during on-farm checks (Jacobs et al., 2017), and DOA was suggested as a feasible parameter for a quick screening of broiler welfare under commercial conditions. However, information on such retrospective relationships in turkey hens, that is, between on-farm welfare recordings and slaughterhouse recordings, is currently lacking.

Therefore, to gain more knowledge about assessment of welfare in turkeys, the aim of this study was to investigate the relationship between routinely collected slaughterhouse data from turkey hens and animal-based welfare indicators measured on farm by transect walks, to identify potential retrospective welfare indicators. To obtain more insight into the causal relationships of the turkey hen welfare, we also investigated associations between animal-based and environment-based measures on farm.

MATERIALS AND METHODS

The study was conducted between November 2017 and March 2018 on 16 different commercial turkey farms in the southeastern part of Norway. On 4 of the farms, 2 consecutive flocks were visited, resulting in a total of 20 flocks of hens to be included in the study. All flocks consisted of both hens and toms, which were kept separate but in the same barn, with the toms occupying approximately 60% of the area. Both hens and toms were assessed using the transect walk method on the same day, but only data from the hens will be presented here. Results from the transect walks in flocks of hens and toms have been reported previously (Marchewka et al., 2019). The farms were randomly selected from the slaughter lists, and all flocks were visited when the birds were between 76 and 83 D of age. Farmers were contacted few weeks before the visit, and participation in the study was voluntary. None of the contacted farmers declined to participate in the study.

Animals and Housing

All the farms in the study received their birds (BUT 10) from the same hatchery and sent their birds to the same slaughterhouse (Nortura Hærland). The birds were not beak or toe trimmed and housed according to Norwegian legislation. At the time of this study, all commercial turkeys in Norway were of the same hybrid (BUT 10). The hens were slaughtered at an average of 84 D of age and 5.9 kg carcass weight, whereas the toms were slaughtered later at an average of 132 D of age and 14 kg carcass weight. Data on toms are not included in the present study and will be presented elsewhere. All flocks were managed using standard protocols according to the genetic company with regard to ventilation, temperature, litter, and feed. All barns were fully enclosed and insulated, with automatic mechanical ventilation and artificial lighting. The light intensity in the animal area was measured using a lux meter (Digital Mulitimeter EM 61, Biltema, Linköping, Sweden). The lux meter was held sidewise to mimic the position of the birds' eyes, at animal height directly underneath the light source (i.e., the brightest area) and between the 2 light sources (i.e., the darkest area). The animals were fed with standard commercial turkey diet with pelleted feed from one of 2 feed mills, that is, Felleskjøpet (Oslo, Norway) (Kromat Kalkun) or Norgesfôr (Oslo, Norway) (Harmoni Kalkun). All birds had continuous access to water from water nipples or cups. The day-old chicks were housed in smaller pens during the first 10 D. The floors were concrete covered with a layer of wood shavings. At the time of the study, no systematic environmental enrichments were provided to the birds. The houses differed in sizes, from 612 to 2,330 m^2. Information on the flocks examined in the present study is presented in Table 1.

The photoperiod program started with continuous light for the first 48 h (day 0–1), followed by an increased length of the dark period, and from day 7, the birds had 8 h of continuous darkness until the day of slaughter. The temperature was set at 38°C on day 0, was gradually reduced to 20°C at day 40, and was then kept stable at 16°C from day 49 until slaughter. The farmers aimed to keep the relative humidity between 50 and 70% from day 0 until slaughter. All farmers are required to have sensors for temperature and humidity in their barns at all times, and these sensors were located near the head height of the birds. The temperature and humidity in the barn on the day of the visit were thus recorded from the automatic ventilation system. The mean flock density on the day of the visit was 6.2 ± 0.3 birds/m^2. The flocks were inspected twice daily by the farmer, and any terminally ill birds were humanely culled.

Data Collection

Each of the 20 flocks was evaluated on the day of the visit, using the transect walk method described in the study by Marchewka et al. (2015) (Table 2). Data collection was carried out by 2 different observers, both with experience in observing turkeys. Before the data collection started, 2 observers were trained by experts in the transect method, they then together evaluated several turkey flocks using the transect walk method, and the experience from these trials showed good agreement in the scoring.

At the start of each farm visit, general information about the flock, management, and the barn was provided by the farmer. Then, the observer entered the turkey barn. Each transect was kept approximately 2.5-m wide, and the number of transects was based on the width of the barn. The order in which the transects were walked was selected randomly, except that the adjacent transects were avoided to ensure no double counting of birds. The observer moved slowly through the flock to minimize disruptions of the birds during scoring.

The overall litter quality in the area was scored using the description in Welfare Quality (2009) protocol for poultry, ranging from 0 (completely dry and flaky) to 5 (sticks to the boots once the cap or crust is broken) (Table 1). The transect walk data collection in each flock took from 30 min to 1 h, depending on the flock size.

Slaughterhouse Data

Data from the slaughterhouse were sent to us shortly after slaughter and included for each flock: birds delivered to the slaughterhouse (n), mortality (%), DOA (%), birds accepted (n), average carcass weight (g), birds rejected (n), total rejected (%), and percentage of rejected birds in 10 different categories—peritonitis, heart issues, leg or joint issues, liver, airsacculitis, odor, machine or technical processing issues, small, poorly bled, and total FPD (calculated as 100 scored animals on a 4-point scale/flock: $\sum = ([n0*0] + [n1*1] + [n2*2] + [n3*3])$, resulting in a flock score between 0 and 300). Rejection due to fecal contamination or technical injuries was recorded separately. If the flock was slaughtered over several days, the results were merged to one flock.

Statistical Analysis

Animal-based welfare indicators collected on farm during the transect walks were used as dependent variables (Table 2). During the transect walks conducted at each visit in the barn, frequency of birds falling within each category of the animal-based welfare indicators was noted for each of the transects. We calculated all variables as a proportion, where x was the frequency of birds with the particular welfare indicator in each transect divided by N (the total number of birds in the transect). The total frequency of birds falling within the animal-based welfare indicator category was calculated per barn. The data were collected using a handheld computer on farm and transferred to an Excel version 13 (Microsoft, Redmond, WA) spreadsheet and further to SAS version 9.4 (SAS Institute Inc., 2013). Environment-based measures collected on farm, such as litter quality, temperature, RH, minimum and maximum light intensity, water-to-

Table 1. Information on factors related to the barn size, management, and bird numbers in the 20 flocks included in the study.

Flock	Barn size (m)		No. of birds	Stocking density (birds/m^2)	Sick pen	Maximum light (lux)	Minimum light (lux)	Dusk (yes/no)	Litter quality	Water-to-feed ratio	Age at transect (d)
	Length	Width									
1	69	18	3,050	6.14	Yes	-	-	Y	-	1.55	82
2	75	22	4,629	7.01	No	-	-	N	2	1.8	78
3	36	17	1,470	6	Yes	22	1	N	2	-	76
4	85	27.5	5,150	5.51	Yes	12	10	Y	1	-	77
5	60	22	3,200	6.2	No	8	5	N	3	1.6	78
6	101	18	7,200	9.9	No	6	4	Y	3	1.6	79
7	59	20	2,590	5.49	No	5	1	Y	4	1.7	75
8	108	44	5,400	4.5	Yes	6	4	Y	3	1.7	76
9	50	18	1,350	3.75	No	3	1	Y	2	1.4	80
10	69	18	3,100	6.24	No	2	0	N	4	1.67	80
11	70	18	2,880	5.71	Yes	2	0	Y	2	1.71	77
12	50	18	2,357	6.55	Yes	3	1	N	3	1.4	80
13	75	16	2,640	5.5	No	8	5	N	2	1.8	78
14	75	30	5,123	5.69	Yes	8	5	J	2	1.6	76
15	38.5	13	1,300	6.5	No	12	3	N	2	1.8	83
16	87.5	16	4,050	7.23	No	8	2	Y	3	1.45	76
17	69	18	2,893	5.82	Yes	-	-	Y	2	1.6	83
18	36	17	1,470	6	No	8	2	N	2	1.7	83
19	75	22	4,650	7.38	No	10	3	Y	2	2	82
20	60	22	3,200	6.06	No	6	3	Y	2	1.7	80

feed ratio, and stocking density, as well as the slaughterhouse data were considered the independent variables. Inspection of the response variables was performed using graphical tools (box plots, histograms, and scatter diagrams), tabulations, calculations of means, standard deviations and errors, and 95% confidence intervals. The outcome variables were analyzed for the retrospective or actual associations with any of the independent variables. The outcome variables were approximately normally distributed across the sample population; thus, linear univariate regression was used. Residuals were predicted and checked for normality. Two sets of analysis were conducted to investigate relationships between 1) on-farm animal-based welfare indicators and slaughterhouse data and 2) animal-based welfare indicators and environment-based measures on farm. In both sets of analysis, associations with a P-value <0.2 were further analyzed in a multivariate linear regression analysis. Models were obtained by backward exclusion until all the obtained associations reached a P-value <0.05. Interactions between the independent variables were tested in the final models and were not detected. Residuals were predicted and plotted in normal quantile plots. Coefficients of determination (R^2) were calculated and used to test how well the model explained the variability of the response variable. The likelihood-ratio test was used to observe the improvement of the multiple regression models by inclusion and exclusion of independent variables. The Akaike information criterion and Bayesian information criterion were used to compare maximum likelihood of reduced and full models, in which the final models were considered better because of smaller values of the information criterion.

RESULTS

Descriptive Flock Data

The slaughterhouse registrations for the 20 flocks are presented in Table 3. The most common reason for partial rejections of individual birds was fecal contamination, occurring in on average 0.87% of birds, but in some flocks reaching up to 1.38% of birds. The biggest variability (SD = 0.66) was rejections due to airsacculitis, ranging from 0.03 to 2.48%.

Animal-based welfare measures in turkey hens on farm at 11 wk of age are presented in Table 4. The most common findings were featherless birds (0.380% ± 0.056), birds with wing wounds (0.26% ± 0.027), dirty birds (0.15% ± 0.031), and birds with head wounds (0.11% ± 0.021) (Table 4).

Retrospective Associations Between On-Farm Animal-Based Welfare Indicators and Slaughterhouse Data

The univariate and multivariate significant retrospective regression models are presented in Table 5. Flocks with more featherless birds on farm had more rejections owing to heart issues (P = 0.02, r = 2.13) and airsacculitis (P = 0.005, r = 0.42). Increased prevalence of wing wounds on farm was associated with lower slaughter age (P = 0.04, r = −0.04) and higher average carcass weight at slaughter (P = 0.04, r = 0.0003). Flocks with more dirty birds on farm had lower total rejection rate (P = 0.02, r = −0.29), fewer birds rejected owing to heart issues (P = 0.02, r = −1.41), and more birds rejected owing to airsacculitis (P = 0.001, r = 0.57). Flocks with more lameness were characterized by more birds rejected owing to leg and joint issues (P = 0.03, r = 1.01). Increased prevalence of immobility on farm was associated with more birds rejected owing to mechanical and technical issues at slaughter (P = 0.05, r = 0.01). Flocks with more head wounds had a higher percentage of rejections of birds classified as too small for processing (P = 0.007, r = 1.97). Higher mortality in the flock was associated with the higher average carcass weight at slaughter (P = 0.05, r = 0.002) and more birds rejected

Table 2. Description of the birds' behavior and appearance in each of the animal-based welfare indicator categories.

Indicator	Description
Immobile	Bird is not moving when approached or after being gently touched. Birds are only able to move by propping themselves up on their wings.
Lame	Bird walks with obvious difficulty. One or both legs are not placed firmly on the ground. Bird is moving away from the observer, but stopping after 2–3 paces to rest. Bird has shaky leg syndrome.
Head wounds	Bird has visible marks on the head, snood, beak, or neck related to fresh or older wounds.
Wing wounds	Bird has visible fresh or older, including bleeding, wounds on the back or wings.
Tail wounds	Bird has visible wounds around tail, or on its sides, including fresh, older or bleeding wounds.
Dirty	Very clear and dark staining in the back, wing, or tail feathers of the bird, not including light discoloration of feathers from dust, covering at least 50% of the body area.
Featherless	Missing feather on the majority of the back area or back and wings.
Small	Easily distinguishable females (in the male area) or individuals that were approximately half the size of an average bird in the flock.
Sick	Bird showing clear signs of impaired health with red watery eyes and disarranged feathers usually found in resting position. Birds with a pendulous crop hanging in front of the breast or with missing or deformed body parts (excluding birds with leg deformations accounted for as lame), with clearly different (pale or yellowish) body color.
Terminally ill	Bird with enormous wounds or lying on the ground with the head rested on the ground or back, usually with half-closed eyes. Bird has to breathe visibly.
Dead	Dead birds found during the transect

Individual turkeys could be classified as belonging to more than one category (as in Marchewka et al., 2015).

owing to liver issues ($P = 0.001$, r = 19.93) (Table 5). No significant associations were found for tail wounds, small, sick, terminally ill, and dead birds.

Associations Between Animal-Based Welfare Indicators and Environment-Based Measures on Farm

More terminally ill birds were found in flocks with poor litter quality ($P = 0.03$, r = 0.006). No other significant associations between environment- and animal-based measures were identified.

DISCUSSION

The aim of this study was to investigate the relationships of routinely collected slaughterhouse data with selected animal-based welfare measures collected on farm by transect walks and with environment-based measures in flocks of turkey hens. In brief, the results showed several significant associations between measures on farm and at slaughter, suggesting that slaughterhouse data could provide useful and reliable information of turkey hens' welfare on farm. Contrary to our expectations, few associations between animal- and environment-based measures on farm were found.

The most commonly found animal-based welfare issue in the flocks was featherless birds. The underlying causes for featherlessness are not fully understood in turkeys. Previous studies found that featherlessness is a common issue in both turkey hens and toms (Marchewka et al., 2019) and could partly be due to the severe feather pecking, known as a type of injurious pecking in turkeys (Dalton et al., 2013), which often targets subordinate birds (Buchwalder and Huber-Eicher, 2003). Flocks with more featherless birds in the present study were characterized by a higher rejection rate owing to airsacculitis and heart issues. Airsacculitis is one of the more common health issues in turkeys (Russell, 2003) and is caused by bacteria such as *Escherichia coli*, *Mycoplasma gallisepticum*, *Mycoplasma synoviae*, or *Mycoplasma meleagridis* (Ficken et al., 1991). Although birds develop lesions throughout their air sacs, they may not show any outward signs of infection at its first stage (Russell, 2003). Therefore, it could be speculated that featherlessness potentially could serve as an early warning signal of arising airsacculitis and heart issues in the flock. If this is the case, targeted efforts at an early stage may improve both animal welfare and farmer profitability, and this relationship and underlying causal factors warrants further investigation.

Another commonly found welfare issue on farm was related to wing wounds. These wounds could be due to injurious pecking including severe feather pecking and cannibalism (Dalton et al., 2013). Compared with laying hens, relatively few studies have focused on injurious pecking in domestic turkeys (Dalton et al., 2013), and even fewer studies have focused on prevalence and severity of feather pecking in commercial flocks (Duggan et al., 2014). Injurious pecking is considered an important economic issue as denuded birds experience increased heat loss and require additional feed intake to maintain thermoregulation (Appleby et al., 2004), and production efficiency can be dramatically reduced, especially if high rates of pecking and feather loss occur in a flock (Duggan et al., 2014). However, in the present study, increased prevalence of wing wounds was observed in flocks with lower slaughter age and a higher average carcass weight, indicating an increased growth rate. High light intensity is known to allow maximum expression of growth potential in turkeys (Gill and Leighton, 1984), but it is also known to provoke injurious pecking (Martrenchar et al., 2001). The light intensity in the present study was relatively low (2–12 lux), and we did not find any effect of light intensity on the observed welfare indicators. The low light intensity recorded in these farms may be due to the fact that Norwegian regulation prohibits beak trimming and that reduced lights reduce amount of injurious pecking. We suspect that the origin of wing wounds in the present study may be different to injurious pecking, for instance, owing to sudden fright attacks, when turkeys fly violently against walls, hitting feeders and drinkers and thus causing damage to wings.

Table 3. Slaughterhouse routine registrations obtained for the 20 flocks in the study.

Variable	Farms (N)	Mean (SD)	Minimum–maximum
Birds delivered to the slaughterhouse (n)	20	3,137.45 (903.26)	1,659–5396
Mortality (%)	20	3.41 (1.75)	1.17–7.92
DOA (%)	20	0.3 (0.47)	0–1
Birds accepted (n)	20	3,060.15 (876.73)	1,569–5,237
Average carcass weight (g)	10	6419.2 (788)	5,100–7,500
Birds rejected (n)	20	77.3 (42.19)	24–159
Total rejected (%)	20	2.43 (0.85)	1.31–4.51
Partial rejections			
Peritonitis (%)	20	0.02 (0.04)	0–0.16
Heart (%)	20	0.15 (0.1)	0.04–0.37
Legs or joints (%)	20	0.06 (0.04)	0–0.16
Liver (%)	20	0.09 (0.06)	0–0.23
Airsacculitis (%)	20	0.56 (0.66)	0.03–2.48
Odor (%)	20	0.09 (0.07)	0–0.23
Machine or technical (%)	20	0.32 (0.35)	0–1.41
Small (%)	20	0.05 (0.05)	0–0.2
Fecal contamination (%)	20	0.87 (0.26)	0.39–1.38
Badly bled (%)	20	0.02 (0.03)	0–0.09
Total FPD[1] (n)	20	132.7 (49.92)	20–228

Abbreviation: DOA, dead on arrival.

[1]Total footpad dermatitis (FPD): 100 scored animals on a 4-point scale/flock: $\sum = (n0*0) + (n1*1) + (n2*2) + (n3*3)$, resulting in a flock score between 0 and 300.

Flocks with more dirty birds in the present study had fewer birds rejected owing to heart issues and rejected in total, whereas they had more rejections due to airsacculitis. Dirty feathers have been suggested in broilers as an iceberg indicator of welfare (EFSA, 2012) as dirty feathers can be associated with lameness and gastrointestinal issues (de Jong et al., 2013). Furthermore, a dirty environment could increase the risk of infection in birds (NACMCF, 1997; Jacobs et al., 2017). Included in the dust of poultry houses are feather and skin particles, feed components, dried fecal matter, molds, fungi, bacteria and bacterial endotoxins, and viruses (Aarnink et al., 1999). Airborne microorganisms may be directly pathogenic or release toxins, meaning that dust in a poultry house may serve as a pathogen disseminator in addition to making the animals more susceptible to normally nonpathogenic or low-pathogenic microorganisms (David et al., 2015). According to Wolfe et al. (1968), dust increased the number of turkey condemnations at slaughter owing to infections of the air sacs. Dirty plumage may also occur in weak birds that spend larger proportions of their time in the litter owing to various types of weakness (Marchewka et al., 2013). As described previously, weakness may be one of the signs of airsacculitis, and dirtiness could indicate that flock health may be challenged.

Lameness in turkeys is an important and potentially painful welfare issue with the infectious and noninfectious background (Kierończyk et al., 2017). Increased lameness in the present study was associated with more birds rejected owing to leg and joint issues. Turkey carcasses with lesions restricted to the joints are only partly rejected, whereas broiler carcasses with similar lesions would be fully rejected from the production line and classified as totally condemned (Löhren, 2012). Therefore, turkeys rejected owing to leg and joint issues, contrary to broiler chickens or ducks, could represent a potential retrospective indicator of lameness on farm. Nevertheless, because lameness in turkeys can be caused by a variety of infections, developmental or degenerative causes (Kapell et al., 2017), the causes of the observed lameness on farm need in-depth pathological examinations to establish more specific causative relationships with the slaughterhouse parameter.

Table 4. Prevalence of on-farm animal-based welfare indicators measured at 11 wk of age using the transect walk method from the 20 flocks in the study (average percentage of birds recorded with welfare indicators across flocks ± SEM, minimum and maximum values).

Indicator	Farms (N)	Mean (%)	SEM	Minimum (%)	Maximum (%)
Immobile	20	0.002	0.002	0.000	0.031
Lame	20	0.064	0.014	0.000	0.382
Head wounds	20	0.109	0.021	0.000	0.670
Wing wounds	20	0.257	0.027	0.032	0.815
Tail wounds	20	0.088	0.014	0.000	0.369
Dirty	20	0.150	0.031	0.000	1.485
Featherless	20	0.380	0.056	0.000	2.177
Small	20	0.012	0.005	0.000	0.116
Sick	20	0.001	0.001	0.000	0.025
Terminal ill	20	0.002	0.002	0.000	0.039
Dead	20	0.003	0.002	0.000	0.031

Table 5. Significant retrospective associations between on-farm animal-based welfare indicators and routinely collected slaughterhouse parameters.

Response variable	Slaughterhouse parameter	Coefficient (r)	SEM	t value	Pr > |t|	95% confidence limits	
Welfare indicators measured by transect walks							
Immobile	Rejected owing to machine or technical issues	0.010	0.005	2.14	0.046	0.000	0.019
Lame	Rejected owing to leg or joint issues	1.016	0.427	2.38	0.028	0.120	1.912
Head wounds	Small	1.974	0.641	3.08	0.007	0.627	3.321
Wing wounds	Age	−0.036	0.016	−2.17	0.045	−0.070	−0.001
	Average carcass weight	0.000	0.000	2.16	0.045	0.000	0.001
Tail wounds Small	No model selected						
Featherless	Rejected owing to heart issues	2.131	0.805	2.65	0.017	0.433	3.829
	Airsacculitis	0.419	0.131	3.19	0.005	0.142	0.697
Dirty	Total condemnations	−0.290	0.109	−2.65	0.018	−0.522	−0.058
	Rejected owing to heart issues	−1.415	0.540	−2.62	0.019	−2.560	−0.270
	Airsacculitis	0.568	0.138	4.11	0.001	0.275	0.861
Sick Terminal ill Dead	No model selected						
Mortality, %	Average carcass weight	0.002	0.001	2.05	0.056	0.000	0.004
	Rejected owing to liver issues	19.932	5.142	3.88	0.001	9.082	30.782

In the present study, flocks with more head wounds observed on farm also had more birds rejected at slaughter owing to being classified as too small. Until now, only one study described behavioral organization of head pecking, indicating that turkeys engaged in head pecking were more active with shorter lying durations and less frequent standing than turkeys performing severe feather pecking or gentle feather pecking (Dalton et al., 2018). Individual differences, including body weight, play an important role in the establishment and maintenance of the hierarchy in laying hens (Cloutier and Newberry 2000). No studies were found relating head pecking to physical characteristics of turkeys, such as their size. Group variation in body weights of tom turkeys at 1 wk of age was not predictive of being the recipient of skin damage later in life at 21 wk of age (Dalton et al., 2013). In the wild, head pecking is learned by young birds as a fighting technique used by mature birds to determine the "pecking order" (Buchholz, 1997). Head wounds under commercial production conditions are typically caused by aggression owing to stress or social disturbance (Moinard et al., 2001). Head pecking was found to be more frequent in sexually matured toms than in hens (Dalton et al., 2013). On the other hand, Marchewka et al. (2019) found similar levels of head wounds in both sexes at 11 wk of age, but they found a positive association between density and head pecking (Marchewka et al., 2019). Previously, increased stocking density was related to reduced body weight gain, decreased daily feed intake, feed conversion ratio, and skeletal properties between the 57th and 126th day of life (Jankowski et al., 2015). However, relations between head wounds and stocking density were not found in the present study.

The worldwide growing demand for poultry meat puts pressure on breeders, nutritionists, and producers to increase the growth rate of birds, feed efficiency, and size of breast muscle. These changes are mainly due to the high heritability of body weight and body meat composition (Le Bihan-Duval et al., 2008). Simultaneously, this has lowered the capacity of modern growing birds to respond to stressors, such as responses to heat stress in their environment (Soleimani et al., 2011) and potential failure of several organ and body systems because of the increased metabolic demands required for extremely rapid increases in body mass (Julian, 2005). In meat-type chickens, liver damage may be a result of high feed intake, fast growth, and high daily weight gain, leading to high metabolic demand by the liver (Senanayake et al., 2015). Similar results were found in the present study: higher mortality was associated with increased carcass weight, and more birds were rejected owing to liver issues.

We expected to find associations between environmental conditions (resource-based welfare indicators) and on-farm animal-based welfare measures. Indeed, we found more terminally ill birds in the flocks with poor litter condition. It has been reported that poor litter quality can increase the microbiological load in litter, thereby exposing birds to increased challenges from parasites such as coccidia, other protozoa, fungi, enteric viruses, and environmental bacteria (Ritz et al., 2009). It could therefore be speculated that an increased microbiological load due to poor litter quality explains the more terminally ill birds found. However, contrary to previous studies (Mayne et al., 2007; Wu and Hocking, 2011), we did not find associations between FPD and litter quality. Poor litter quality is a challenge to footpad health, and wet litter is the primary cause of ammonia volatilization, which can reduce air quality (Tran et al., 2015). Development FPD is a dynamic process over time (Youssef et al., 2011), whereas in the present study, we recorded the litter quality only once, which may have hindered our ability to find the expected association. Therefore, it may be more informative to record litter quality throughout the production period regularly and relate it to FPD recorded at the slaughterhouse, which in this case will provide a useful retrospective welfare indicator.

In conclusion, several slaughterhouse data were associated with on-farm welfare indicators. Increased lameness gave more rejected birds owing to leg and joint issues and could thus represent a potential retrospective indicator of lameness. More featherlessness and dirtiness resulted in more birds rejected owing to airsacculitis, suggesting they could potentially function not only as early warning signals in the flocks but also as a retrospective indicator of on-farm welfare.

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