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On-Farm Assessment of Broiler Welfare in Tunisia Using Welfare Quality® Broiler Protocol

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Authors' Contribution
All authors contributed to the study conception and design. MBL analyzed the findings and oversaw the manuscript preparation. AA planned and carried out the experiment. MS participeted in data collection and revised the final version of manuscript. NM analysed the data, contributed to interpretation of the results and aided in writing the manuscript. IEAZ, NBB and HM contributed to the data analysis and curation and the results interpretation.

Key words
Arbor Acres, Assessment, Broiler health, Injuries, Scores, Welfare quality, Tunisia, Wealth indicator

ABSTRACT

Broiler chickens have been selected for their rapid growth rate as well as for their high protein quality. They are reared in intensive systems at high stocking density ranging from 30 to 40 kg live weight/ m2. The industry's drive to ever faster growth rates has an impact on broiler health and welfare such as painful leg disorders and heart failure in broiler chickens and hunger due to severe food restriction in the breeding birds. The scientific literature on broiler chicken welfare in Tunisia is scarce. This study aimed to assess broiler welfare conditions in five Arbor Acres commercial flocks at the age of 35 days. Some indicators were observed like hock lesions, lameness, pododermatitis, plumage cleanliness, and breast blister. The scores of welfares ranged between 0 and 100. The results showed higher scores for feeding, housing, and health ($P < 0.001$). The absence of prolonged thirst and hunger, litter quality, breast blister, and touch test had a score exceeding 70, which is why they were considered excellent. Comforting around resting, plumage cleanliness, and dust sheet test had scores ranging between 50 and 70. The scores of thermal comforts, stocking density, absence of injuries, footpad dermatitis, and hock burn were acceptable (ranging between 20 and 50). However, unacceptable scores (below 20) were reported for lameness. Welfare indicators can help farmers avoid the causes of health problems to adopt the appropriate farming practices for excellent welfare and a better expression of production performance.

INTRODUCTION

Poultry production is an essential and vital agriculture sector in Tunisia, which experienced the fastest growth and development. Poultry is one of the most crucial livestock sectors in the country. World poultry meat production reached 133.3 million tonnes in 2021, up 1.3 % year-on-year (FAO, 2021). Nowadays, broiler production is an intensive farming sector with large flocks, which makes it difficult for farmers to monitor birds continuously (De Jong *et al*., 2016; Gocsik *et al*., 2016; Butterworth, 2018). At the same time, consumers are becoming increasingly more concerned about farm animal welfare and how broilers are being raised (Main *et al*., 2007; Heath *et al*., 2014; Silvera, 2017a). Farm animal welfare is assessed through a combination of indicators of its physical and mental components. Principles and criteria for good welfare were good feeding, good housing, good health, and appropriate behavior (Blokhuis *et al*., 2010; Silvera *et al*., 2017b). Many authors (Broom, 2001; Forkman and Keeling, 2009; De Jong *et al*., 2016) developed and established scientific methods to measure broiler welfare. Through the European Welfare Quality® (WQ) project for animal welfare assessment, researchers developed standardized methodologies (Blokhuis *et al*., 2010). These methods and protocols consist of many measurements and the outcomes are used in a three-step multi-criteria evaluation model to assign farms to one of four welfare

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classes (not classified, acceptable, enhanced, excellent) (Blokhuis *et al*., 2010).

Animal-based measures (panting, mobility, emaciated birds, and mortality) have been used to evaluate the health and welfare of broilers (EFSA, 2012). Welfare is a multidimensional concept and is assessed through some measures related to the specific welfare dimension (or to several welfare dimensions) (Bracke *et al*., 1999). The Farm Animal Welfare Council (FAWC, 1992) identified several requirements to ensure prosperity (e.g., the five freedoms). The concept of animal welfare includes three elements; animal biological functioning, (healthy, feeding, drinking, etc.), animal emotional state (fear, pain, etc.), and normal behaviours (Fraser *et al*., 1997).

The present research aimed to evaluate the welfare of free-range broiler chickens reared in Tunisia, using the protocol developed by the Welfare Quality® (2009) for broiler chickens.

MATERIALS AND METHODS

Farms and birds

Five broiler farms were available for the evaluation of welfare through some welfare indicators during the rearing period between March and June 2021. All farms visited were in the governorates of Nabeul (n=1), Sfax (n=2), and Ben Arous (n=2). Each farm had two houses, with flock sizes of 10.000 to 25.000 chickens (Arbor® Acres, mixed-sex) with initial stocking densities ranging from 10-15 birds/m^2 and occupied air space of 0.064 m^2/bird, to ensure not to exceed the threshold of 33 kg/m^2. All farms followed identical management practices. All houses were equipped with automatic drinkers and feeders (Nipples and Chain feeders) to provide *ad libitum* access to feed and water (tap water). All farms used deep wood shavings as litter. The litter was disinfected with the same protocol in all farms for this study (Muniz *et al*., 2014). Birds were subjected to 16 h of natural daylight and extra artificial lighting (5 lux). The artificial lighting was incandescent or fluorescent (the same lighting program). The ventilation systems poultry house fan-powered systems used negative-pressure ventilation. This means that the fans are exhaust fans, pulling air out of the house. A ration (Table I) containing 22% protein was used through the starter period (1-14d) then a grower diet with 19% protein was used for the rest of the growing cycle (15-35d). During the experimental period, a vaccination program was followed according to the manufacturer's recommendation. Farmers checked their flocks twice a day to eliminate dead birds, birds with malformations, or in poor health. Two farms had concrete flooring, and three had earth floors equipped with nipple drinkers and automatic or manual feeders. One housing unit was selected randomly on farms with more than one shed (Table II).

Table I. Ingredient and nutritive values of the basal diet (g/kg).

Ingredients (%)	Starter (d1-14)	Grower-finisher (d15-42)
Corn	64	69
Soybean meal	32	27
Mineral[A] and vitamin[B] mixture	4	4
Anticoccidial	None	None
Total	100	100
Calculated nutrient content		
ME[C](Kcal/Kg)	2900	2970
Crude Protein %	20.5	19.5
Crude fiber %	3	3
Ash %	6.5	6.5
Fat %	3	4
Calcium %	1	0.9
Available Phosphorus %	0.67	0.66
Methionine %	0.5	0.44
Threonine %	0.8	0.78
Tryptophan %	0.3	0.25

A Mineral mixture supplied (mg·kg-1 of diet): CF1: Mn. 80; Fer. 50; Cu. 25; Zn. 65; Co. 0.2; Se. 0.3; I. 1.2/ CF2: Mn. 70; Fer. 40; Cu. 20; Zn. 52; Co. 0.16; Se. 0.24; I. 0.69. B Vitamin mixture supplied per kg of diet: CF1: Vit A. 13000 IU; Vit D3. 3500 IU; Vit E. 40 mg/ CF2: Vit A. 10400 IU; Vit D3. 2800 IU; Vit E. 32 mg. CME: metabolizable energy.

Table II. Characteristics of poultry houses during the assessment.

	Min	Median	Max
Poultry house area (m^2)	500	950	1500
Number of birds/ poultry house	4.570	9.830	12.710
Age of birds (d)	30	35	40
Live weight (g)	1980	2510	2730
Stocking density (kg/m^2)	20	26.5	29.7
Stocking density (birds/m^2)	9.5	10.2	11.3

Measurements

Measurements were executed between March and June 2021 at the last seven days before slaughter according to the broiler assessment protocol (Welfare Quality®, 2009). Two experimented observers visited each flock once and a short questionnaire was elaborated to collect information on the number of birds on site, number of birds in thehouse at placement, number of actual birds in the house,

Table III. The Welfare Quality® broiler assessment protocol, to assess on-farm welfare (Welfare Quality, 2009).

Welfare principle	Welfare criterion	Measure[1 2]
Good feeding	Absence of prolonged hunger	Emaciation (S)
	Absence of prolonged thirst	Drinker space
Good housing	Comfort around resting	Cleanliness, litter quality, dust
	Thermal comfort	Panting, huddling
	Ease of movement	Stocking density
Good health	Absence of injuries	Lameness, hock burn (F+S), footpad dermatitis(F+S), breast blisters (S)
	Absence of disease	Mortality culls on-farm (S), pericarditis (S), septicemia (S), hepatitis (S), dehydration (S), abscesses (S)
	Absence of pain induced by management procedures	-[5]
Appropriate behavior	Expression of social behaviors	-
	Expression of other behaviors	Cover on the range, free-range
	Good human-animal relationship	Touch test[3]
	Positive emotional state	Qualitative Behaviour Assessment[4]

[1]Measures in italics are animal-based measures. Other measures are management- or resource-based measures. [2]Measures indicated with (S) are measured during slaughter; measures indicated with (S+F) can be measured either on-farm or at slaughter. [3]The touch test measures the number of birds within 1 m distance of the observer at various locations in the house (Welfare Quality, 2009). [4]The Qualitative Behaviour Assessment (QBA) scores the behavior of the flock using 23 descriptors (Welfare Quality, 2009). [5]Empty cells indicate that there is yet no measure available for this criterion.

date of placement, age of the birds, average bird weight, dimensions of the house, drinker type(s) and number, and mortality. A brief description of the measures involved is given in Table III. To assess the breast blister, the injury was considered and scored by observing the birds (Welfare Quality, 2009). Birds were clustered into samples of 25 randomly collected birds each in five random locations within the house. The birds were weighed and evaluated for footpad dermatitis, hock burns, and breast dirtiness. Then, each bird was released away to evaluate gait scoring. The human-animal relationship was evaluated through the Touch Test (De Jong *et al*., 2011). This procedure was repeated five times at different locations around the house. Plumage cleanliness was assessed from the ventral side of the bird with a four-class scoring system (clean, slightly dirty, moderately dirty, and extremely dirty). Regarding lameness, the Bristol gait score was used (Kestin *et al*., 1992). A score between zero and five was assigned to a perfect gait and to a bird unable to walk, respectively. Hock burn was assessed by manual scoring the hocks of the birds using a five-point scale to assess the severity of hock burn on-farm (live birds) (Butterworth *et al*., 2015; Welfare Quality, 2009). Good feeding was evaluated from the absence of prolonged hunger and thirst (Welfare Quality, 2009). Prolonged hunger was calculated using the percentage of emaciated birds as follows:

$$\%\ emaciated\ birds = \frac{\text{Number of emaciated birds}}{\text{number of the birds from the house}} \times 100$$

The absence of prolonged thirst is assessed by calculating the number of birds per drinker (Vanderhasselt *et al*., 2014). Mortality was registered by the farmer.

Calculation of scores and statistical analysis

Data were transformed into scores ranging from 0 to 100, with 100 being the best (Welfare Quality, 2009). Finally, each herd was classified into an overall welfare category according to the score obtained. A herd with a score of 80 was classified as excellent, improved with a score between 55 and 80, acceptable with a score between 20 and 55, and unclassified with a score lower than 20 (Federici *et al*., 2016). Statistical analyses were performed using SAS 9.4 (SAS Institute Inc., 2014). Data were presented as mean and percentage and analyzed by independent T-test. Normality was checked (Shapiro Wilk test) and results were analyzed via descriptive statistics and compared using the one-tailed Mann-Whitney U test. For all analyses, significance was assessed at the level of 0.05.

RESULTS AND DISCUSSION

Health indicators

Results were presented as scores ranging from zero to 100 (Table IV). The lameness score was high (78%, 60-98) and agreed with the results of Granquist *et al*. (2019). However, in previous studies like De Jong *et al*. (2011) and Knowles *et al*. (2008), lameness scores ranged between 50 and 30%, respectively. The results of the current study showed the good animal welfare of the appliances. Our results were higher than the finding of Baéza *et al*. (2015) who showed 56 to 100% of birds with lameness.

Table IV. Animal-based measures.

Welfare indicators	Min	Median	Max	Score	Prevalence percentage
Lameness	60	78	98	-	-
Pododermatitis	8	33	73	41	48.5
Hock lesions	80	95	98	93	95
Plumage cleanliness	96	99	100	-	-
Breast blister	73	98	99	91	83
Drinker score	43	95	100	58	58
Mortality (%)	3.1	6.2	7.8	-	-

In this context, EFSA (2010) reported that lameness prevalence is a major welfare issue in broiler chickens. The high median score of hock burns lesions (95%, 80-98) revealed that the incidence of the injuries was low, on the other hand, the low pododermatitis scores on the farm (33%, 8-73) indicated that this was a critical animal welfare issue, some pododermatitis scores presented a median of 35% (Jacob *et al*., 2016; Petek *et al*., 2014; Xie *et al*., 2014). This result was better than those described by Kjaer *et al*. (2006) who reported frequencies of hock burns lesions ranging from 50 to 100%, and 80%, respectively. For plumage cleanliness, a median score of 99% was excellent. This finding differed from previous results reporting that more than 90% of the assessed birds appeared at least slightly dirty (Kaukonen *et al*., 2017). In general, plumage cleanliness in tested flocks appeared to be good in comparison with the study of Li *et al*. (2017). Therefore, cleanliness reflects good litter and floor conditions. The median breast blister score was 91%, and considered high; these results agree with those of Dal Bosco *et al*. (2010). However, Li *et al*. (2017) reported a few breast blister cases. Mortality with other production criteria was an important performance measurement of the broiler. Therefore, it represented a major economic loss in broiler flocks. The median percentage of mortality was 6.2% and ranged between 3.1 and 7.8%. This value was higher than observed by Sans *et al*. (2014) who found a median percentage of 2% and also than those found by De Jong *et al*. (2011) who reported average mortality of about 3%. Assessed farms in our study presented a higher score for the absence of injuries criterion, better than other studies whose scores varied from 20 to 36 (Souza *et al*., 2015). The average scores for welfare principles were significantly higher than in other studies. We can conclude that the welfare level in visited farms was acceptable.

Absence of prolonged hunger and thirst

For proper feeding, the percentage of emaciated birds was calculated (Fig. 1). The lack of an extended hunger count was 80% and this was attributed to the feed availability and free access of birds to feed. So, there was no problem with feeding, and more than 90% of birds had a higher score (>80). Our finding was close to other studies which reported a score of the absence of prolonged hunger ranging between 78.8 and 98% in broiler chicken farms (Sans *et al*., 2014; Federici *et al*., 2016), lower than those found by Souza *et al*. (2015) in broilers, where they reported a score of an absence of prolonged hunger of 98 %, and higher than that described by Tuyttens *et al*. (2015), where good feeding scores in broilers ranging from 54.6 to 78 %. Prolonged hunger was considered an indicator of poor welfare as it tends to develop in an aversive and stressful situation.

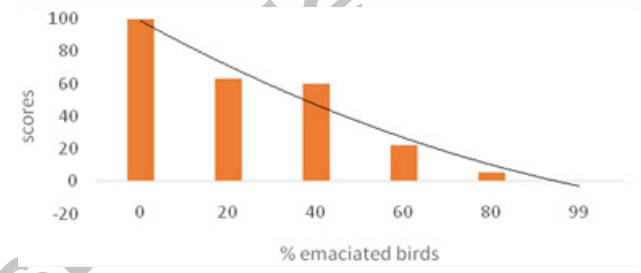

Fig. 1. Scores for absence of hunger according to the proportion of emaciated birds.

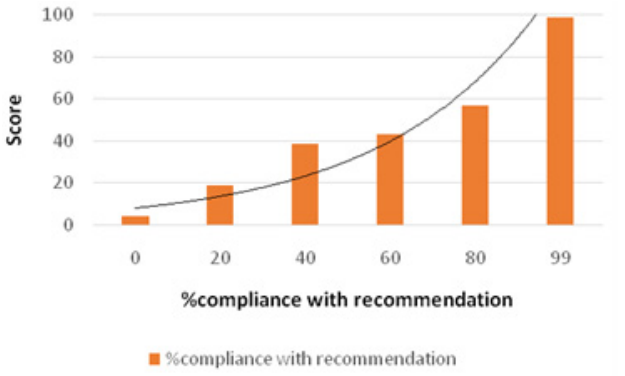

Fig. 2. Scores for absence of thirst according to an index expressing the percentage of compliance of the house with the recommended number of drinking places.

Thirst was considered to have a major impact on animal welfare. For prolonged thirst, it was measured using the number of drinking places and compared to recommendations (Fig. 2). In this study, 20% of birds scored less than 20, and more than 70% had a score of 80, which could be considered excellent, suggesting that access to water was adequate in most farms. The obtained drinker scores (95) showed that the visited farms presented

adequate results. The results of the present study were similar to those of previous studies (Waiblinger *et al*., 2006; Souza *et al*., 2015; Tuyttens *et al*., 2015; Federici *et al*., 2016) who reported scores of absences of prolonged thirst ranged from 70.5 to 80%. In Belgium and Brazil, Vanderhasselt *et al*. (2014) reported a score for the absence of prolonged thirst of 90 indicating a high welfare standard for thirst.

Good human-bird relationship

The relationship between birds and humans can be described as the interaction between them. The relationship of broilers to humans could be considered as one important aspect of welfare on-farm (Tuyttens *et al*., 2010). The good human-bird relationship was measured according to the proportion of birds within 1 m of the observer. A higher score reflects a good relationship. The average touch test scores were high (72%, 30- 100), but low scores (30) were determined on one farm. Figure 3 showed that more than 70% of birds have a high score (85), which explained the good relationship between birds and farmers. Our findings were in line with those of Waiblinger *et al*. (2006). In previous studies in broiler and layer chicks, Jones (1995) and Zulkifli and Siti Nor Azah (2004) pointed out the importance of avoidance of distance on the performance and welfare of broilers. The results of this study were similar to those of Vasdal *et al*. (2018). Blokhuis *et al*. (2010) showed that the human-animal relationship was a key element in assessing the way the farmer handles the animals, which affects productivity.

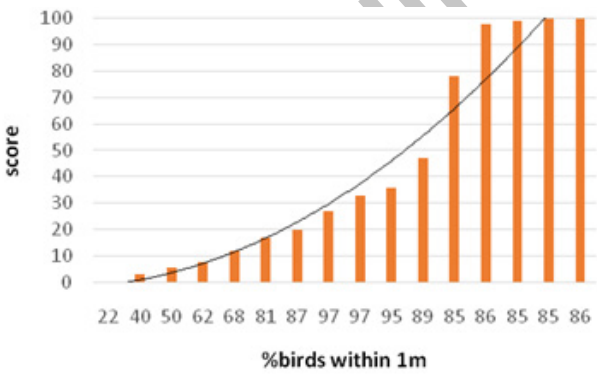

Fig. 3. Scores for good human-animal relationship according to the proportion of birds within 1 m of the observer.

CONCLUSION

Broiler breeds were subjected to a satisfactory level of welfare, including health. Our results suggested that the criterion 'absence of prolonged hunger' can be considered satisfactory in all flocks. We could suggest that the state of welfare of a bird was the result of the integration of the welfare indicators and principles. This study provided useful information to select the most critical welfare indicators to improve and help farmers to avoid the causes of health problems and to adopt the appropriate farming practices for excellent welfare. It is recommended to carry the next level of the study by assessing welfare on a large-scale farm.

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Ethical approval

The handling of the birds was conducted with the approval of the Official Committee of Care and Use of Animals of the Higher School of Agriculture of Mateur (Protocol No. 05/15).

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Baéza, E., Arnould, C., Jlali, M., Chartrin, P., Gigaud, V., Mercerand, F., Durand, C., Meteau, K., Le Bihan-Duval, E. and Berri, C., 2012. Influence of increasing slaughter age of chickens on meat quality welfare and technical and economic results. *Anim. Sci. J*., **90**: 2003-2013. https://doi.org/10.2527/jas.2011-4192

Blokhuis, H.J., Veissier, I., Miele, M. and Jones, B., 2010. The welfare quality® project and beyond safeguarding farm animal well-being. *Acta Agric. Scand. A Anim. Sci*., **60**: 129–140. https://doi.org/10.1080/09064702.2010.523480

Bracke, M.B.M., Spruijt, B.M. and Metz, J.H.M., 1999. Overall animal welfare assessment reviewed, Part 1: Is it possible? *Neth. J. agric. Sci*. **47**: 273– 291. https://doi.org/10.18174/njas.v47i3.466

Broom, D.M., 2001. Assessing the welfare of hens and broilers. *Proc. Aust. Poult. Sci. Symp*., **13**: 61-70.

Butterworth, A., De Jong, I.C., Keppler, C., Stadig, L. and Lambton, S.L., 2015. Facilitation of communication on technical measures amongst competent authorities in the implementation of the broiler directive (2007/43/EC). *Animal*, **10**: 302-

308. https://doi.org/10.1017/S1751731115001615

Butterworth, A., 2018. Welfare assessment of poultry on farming. *Anim. Welf*., pp. 113- 130. https://doi.org/10.1016/B978-0-08-100915-4.00006-3

Dal Bosco, A., Mugnai, C., Sirri, F., Zamparini, C. and Castellini, C., 2010. Assessment of a global positioning system to evaluate activities of organic chickens at pasture. *J. appl. Poult. Res*., **19**: 213-218. https://doi.org/10.3382/japr.2010-00153

De Jong, I., Hindle, V., Butterworth, A., Engel, B., Ferrari, P., Gunnink, H., Perez Moya, T., Tuyttens, F.A.M. and Van Reenen, C., 2016. Simplifying the Welfare Quality® assessment protocol for broiler chicken welfare. *Animal*, **10**: 117-127. https://doi.org/10.1017/S1751731115001706

De Jong, I.C., Perez Moya, T., Gunnink, H., Van den Heuvel, H., Hindle, V., Mul, M. and Van Reenen, C.G., 2011. *Simplifying the welfare quality assessment protocol for broilers*. Report 533. Wageningen UR Livestock Research Lelystad.

EFSA, Panel on Animal Health and Welfare (AHAW), 2010. Scientific Opinion on the use of animal-based measures to assess the welfare of broilers. *Eur. Fd. Saf. Author*., **10**: 2774-2774.

FAO, 2021. *Meat market review: Overview of global meat market developments in 2020, March 2021*. Rome.

FAWC, 1992. The Farm Animal Welfare Council. https://www.gov.uk/government/groups/farm-animal-welfare-committee-fawc

Federici, J.F., Vander Hasselt, R., Sans, E.C.O., Tuyttens, F.A.M., Souza, A.P. and Molento, C.F.M., 2016. Assessment of broiler chicken welfare in southern Brazil. *Braz. J. Poult. Sci*., **18**: 133-140. https://doi.org/10.1590/18069061-2015-0022

Forkman, B. and Keeling, L.J., 2009. Assessment of animal welfare measures for poultry. *Welfare Qual. Rep*., **9**: 176.

Fraser, D., Weary, D.M., Pajor, E.A. and Milligan, B.N., 1997. A scientific conception of animal welfare that reflects ethical concerns. *Anim. Welfare,* **6**: 187-205.

Gocsik, E., Brooshooft, S.D., De Jong, I.C. and De Saatkamp, H.W., 2016. Cost-efficiency of animal welfare in broiler production systems: a pilot study using the welfare quality assessment protocol. *Agric. Syst*., **146**: 55-69. https://doi.org/10.1016/j.agsy.2016.04.001

Granquist, E.G., Vasdal, G., de Jong, I.C. and Moe, R.O., 2019. Lameness and its relationship with health and production measures in broiler chickens. *Anim. Int. J. Anim. Biosci*., **13**: 2365–2372. https://doi.org/10.1017/S1751731119000466

Heath, C.A.E., Lin, Y., Mullan, S., Browne, W.J. and Main, D.C.J., 2014. Implementing welfare quality (R) in UK assurance schemes: Evaluating the challenges. *Anim. Welf*., **23**: 95-107. https://doi.org/10.7120/09627286.23.1.095

Jacob, F.G.I., Baracho, M.S.I., Nääs, I.A.I., Salgado, D.A.I. and Souza, R., 2016. Incidence of pododermatitis in broiler reared under two types of environments. *Braz. J. Poult. Sci*., **18**: 247-254. https://doi.org/10.1590/1806-9061-2015-0047

Jones, R.B., 1995. Ontogeny of response to humans in handled and non-handled female domestic chicks. *Appl. Anim. Behav. Sci*., **42**: 261–269. https://doi.org/10.1016/0168-1591(94)00544-O

Kaukonen, E., Norring, M. and Valros, A., 2017. Evaluating the effects of bedding materials and elevated platforms on contact dermatitis and plumage cleanliness of commercial broilers and litter condition in broiler houses. *Br. Poult. Sci*., **58**: 480–489. https://doi.org/10.1080/00071668.2017.1340588

Kestin, S.C., Knowles, T.G., Tinch, A.E. and Gregory, N.G., 1992. Prevalence of leg weakness in broiler chickens and its relationship with genotype. *Vet. Rec*., **131**: 190-194. https://doi.org/10.1136/vr.131.9.190

Kjaer, J.B., Su, G., Nielsen, B.L. and Sorensen, P., 2006. Foot pad dermatitis and hock burn in broiler chickens and degree of inheritance. *Poult. Sci. J*., **85**: 1342–1348. https://doi.org/10.1093/ps/85.8.1342

Knowles, T.G., Kestin, S.C., Haslam, S.M., Brown, S.N., Green, L.E., Butterworth, A., Pope, S.J., Pfeiffer, D. and Nicol, C.J., 2008. Leg disorders in broiler chickens: Prevalence risk factors and prevention. *PLoS One*, **3**: e1545. https://doi.org/10.1371/journal.pone.0001545

Li, H., Wen, X., Alphin, R., Zhu, Z. and Zhou, Z. 2017. Effects of two different broiler flooring systems on production performance welfare and the environment under commercial production conditions. *Poult. Sci. J*., **96**: 1108–1119. https://doi.org/10.3382/ps/pew440

Main, D.C.J., Whay, H.R., Leeb, C. and Webster, A.J.F., 2007. Formal animal-based welfare assessment in UK certification schemes. *Anim. Welf*., **16**: 233–236. https://doi.org/10.1017/S0962728600031419

Muniz, E., Mesa, D., Cuaspa, R., Souza, A.M. and Santin, E., 2014. Presence of *Salmonella* spp. in reused broiler litter. *Rev. Colomb. De Cienc. Pecu*., **27**: 12-27.

Petek, M., Ustuner, H. and Yesilbag, D., 2014. Effects of stocking density and litter type on litter quality and growth performance of broiler chicken. *Kafkas Univ. Vet. Fak. Derg*., **20**: 743–748. https://doi.org/10.9775/kvfd.2014.11016

SAS Institute Inc., 2014. *Language reference concepts* SAS® 9.4, Cary NC United States.

Sans, E.C.O., Federici, J.F., Dahlke, F. and Molento, C.F.M., 2014. Evaluation of free-range broilers using the welfare quality® protocol Braz. *J. Poult. Sci.,* **16**: Sept 2014 https://doi.org/10.1590/1516-635x1603297-306.

Silvera, A.M., 2017a. *Automatic welfare assessment in broilers with a focus on human-animal relationship and lameness*. Doctoral thesis, Faculty of Veterinary Medicine and Animal Science. The Swedish University of Agricultural Science.

Silvera, A.M., Knowles, T.G., Butterworth, A., Berckmans, D., Vranken, E. and Blokhuis, H.J., 2017b. Lameness assessment with automatic monitoring of activity in commercial broiler flocks. *Poult. Sci*., **96**: 2013-2017. https://doi.org/10.3382/ps/pex023

Souza, A.P.O., Sans, E.C.O., Muller, B.R. and Molento, C.F.M., 2015. Broiler chicken welfare assessment in GLOBALGAP certified and non-certified farms in Brazil. *Anim. Welf*., **24**: 45-54. https://doi.org/10.7120/09627286.24.1.045

Tuyttens, F.A.M., Federici, J.F., Vanderhasselt, R.F., Goethals, K., Duchateau, L., Sans, E.C.O. and Molento, C.F.M., 2015. Assessment of the welfare of Brazilian and Belgian broiler flocks using the welfare quality protocol. *Poult. Sci. J*., **94**: 1758–1766. https://doi.org/10.3382/ps/pev167

Tuyttens, F.A.M., Vanhonacker, F., Van Poucke, E. and Verbeke, W., 2010. Quantitative verification of the correspondence between the welfare quality® operational definition of farm animal welfare and the opinion of Flemish farmer's citizens and vegetarians. *Livest. Sci*., **131**: 108-114. https://doi.org/10.1016/j.livsci.2010.03.008

Vanderhasselt, R.F., Goethals, K., Buijs, S., Federici, J.F., Sans, E.C.O., Molento, C.F.M., Duchateau, L. and Tuyttens, F.A.M., 2014. Performance of an animal-based test of thirst in commercial broiler chicken farms. *Poult. Sci. J*., **93**: 1327-1336. https://doi.org/10.3382/ps.2013-03720

Vasdal, G., Moe, R.O., De Jong, I.C. and Granquist, E.G., 2018. The relationship between measures of fear of humans and lameness in broiler chicken flocks. *Animal*, **12**: 334-339. https://doi.org/10.1017/S1751731117001434

Waiblinger, S., Boivin, X., Pedersen, V., Tosi, M.V., Janczak, A.M., Visser, E.K. and Jones, R.B., 2006. Assessing the human-animal relationship in farmed species: A critical review. *Appl. Anim. Behav. Sci*., **101**: 185-242. https://doi.org/10.1016/j.applanim.2006.02.001

Welfare Quality®, 2009. *Welfare quality® assessment protocol for poultry (broilers laying hens)*. Welfare Quality® Consortium Lelystad Netherlands.

Xie, M., Jiang, Y., Tang, J., Wen, Z.G., Huang, W. and Hou, S.S., 2014. Effects of stocking density on growth performance carcass traits and footpad lesions of White Pekin ducks. *Poult. Sci. J*., **93**: 1644–1648. https://doi.org/10.3382/ps.2013-03741

Zulkifli, I., Siti Nor Azah, A., 2004. Fear and stress reactions and the performance of commercial broiler chickens subjected to regular pleasant and unpleasant contact with a human being. *Appl. Anim. Behav. Sci*., **88**: 77–87. https://doi.org/10.1016/j.applanim.2004.02.014