



ASSESSMENT OF WELFARE OF PEKIN DUCKS REARED IN INTENSIVE PRODUCTION SYSTEM IN POLAND USING TRANSECT METHOD*

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Abstract

The aim of this study was to evaluate the practical application of the Transect Walk (TW) method on a commercial farm, focusing on different ages of Orvia ST5 Pekin ducks. The study was conducted in four flocks of Orvia ST5 ducks, reared in two identical buildings. Flocks 1 and 3 were housed in building 1, while flocks 2 and 4 occupied building 2. A total of 8,000 ducklings were allocated to rearing, with 2,000 in each flock. The welfare of the ducks was assessed at 5, 6, and 7 weeks of age using the TW method, which involved assessing indicators such as immobility, lameness, dirtiness, small size, head wounds, back wounds, tail wounds, feather loss, illness, terminal illness, being flipped, or being deceased. Information regarding factors contributing to reduced carcass quality was gathered from the slaughterhouse. It was observed that all welfare indicators, except for head and tail wounds, were equally effective in assessing duck welfare and accounted for up to 82.13% of the variation in welfare. Lameness emerged as the most prevalent factor associated with reduced welfare, showing a strong correlation with immobility. Both indicators exhibited a significant interaction with age and flock ($P = 0.001$ and $P = 0.029$, respectively). Feather loss emerged as another crucial indicator of reduced welfare in the examined flocks. The percentage of featherless ducks varied from 0.29% to 3.50% and was significantly influenced by both duck age and flock (both $P < 0.001$). Additionally, it showed a significant and positive correlation with immobility ($P < 0.05$). The primary issues identified during duck culling were associated with skin problems and leg and joint issues. Statistically significant variations were noted among flocks concerning the frequency of indicators linked to reduced welfare. This variance was attributed to the specific building where the ducks were raised. The findings of this study suggest the incorporation of the TW method in future welfare assessments, utilizing the 10 welfare indicators employed while excluding head and tail wounds.

Key words: Pekin duck, welfare assessment, commercial farm

The intensification of livestock production witnessed in recent decades is a response to the increasing consumer demand for a plentiful supply of affordable meat. Particularly in poultry production, significant genetic advancements and the adoption of new technologies, notably advanced IT systems, have accelerated this intensification (Zheng et al., 2021; Park et al., 2022). Currently, within a relatively short timeframe, a single farm can yield up to several hundred thousand birds simultaneously. However, while this rapid expansion and high stocking rates per unit area have bolstered profitability, they have also raised welfare concerns related to animal management. As birds mature, welfare deteriorates due to crowding, moisture accumulation, droppings, and subsequent alterations in the microclimate within the enclosed environment (Rodenburg et al., 2005; El Sabry and Almasri,

2023). Naturally, the maintenance of suitable conditions inside the poultry house relies heavily on the performance of ventilation systems (Shin et al., 2023). Ventilation systems are regarded as one of the primary factors affecting the housing conditions of domestic ducks (Lee et al., 2022). Other crucial factors include litter quality (Karcher et al., 2013), stocking density (El Sabry and Almasri, 2023), and external temperature/humidity (Sun et al., 2023). Low welfare indicators not only adversely affect the birds' quality of life but also incur economic losses through slower growth, decreased feed efficiency, and inferior carcass and meat quality. Mechanical injuries such as scratches and feather loss, or aggression within the flock contribute to the downgrading of carcasses in slaughterhouses and consequently diminish production profitability (Benincasa et al., 2020; Baéza et al., 2022).

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However, the question remains as to how to determine the welfare levels on the farm are maintained at an appropriate level. Apart from measuring microclimate indicators and the concentration of harmful gases, primarily CO₂, NH₃, and H₂S (Sousa et al., 2017), the assessment of welfare through examining resource-based indicators still often serves as the benchmark method and the most crucial measurement tool (Dawkins, 1999; Lourenço-Silva et al., 2021).

Determining the welfare level through direct assessment of birds using animal-based welfare indicators can be achieved through two primary methods. Firstly, by introducing a representative group of birds into an enclosure and then observing them according to a predefined protocol. The “catch-and-inspect” (CAI) method is commonly used for this purpose (Butterworth et al., 2011). This method is employed, among other instances, during experimental rearing, where welfare components may involve more detailed observations such as foot pad dermatitis (FPD) (Zhu et al., 2013; Makagon and Riber, 2022). Unfortunately, herding and separating birds from the flock can induce stress and behavioral changes, potentially leading to inaccurate results regarding overall conditions and movement. Furthermore, it is a time-consuming and labor-intensive process (Bright et al., 2006; Marchewka et al., 2013). The second method entails observing the birds inside the poultry house from a distance without disrupting their immediate surroundings. This method is known as the “transect walk” (TW) method, where farm personnel observes birds during routine handling without physically catching them (Marchewka et al., 2015, 2019). In essence, the staff walk along designated corridors (transects) and document birds exhibiting predetermined welfare deviations (Abdelfattah et al., 2020). Animal-based indicators utilized in the TW, or outcome measures, are generally considered more reflective of animal experience than input measures, or resource-based indicators, and have become the preferred approach for assessing welfare (e.g., Welfare Quality protocols, AWIN protocols, etc.). The TW method, with its highly realistic depiction of welfare on the flock level, has a high potential of use on broiler farms (Marchewka et al., 2013; BenSassi et al., 2019) and it has been a reliable approach applied in commercial turkey farms (Marchewka et al., 2015; Ferrante et al., 2018; Marchewka et al., 2019), as described in the AWIN Welfare Assessment Protocol for Turkeys (AWIN, 2015).

The primary focus of producers and researchers on the welfare of broilers and turkeys arises from the fact that these species dominate global poultry meat production. In contrast, relatively less attention has been directed towards assessing the welfare of waterfowl. This limited focus is evident in European Union (EU) legislation, particularly regarding ducks raised for meat, where existing regulations are based on data from 20 years ago. Recognizing this gap, the European Commission tasked the European Food Safety Authority (EFSA) with reviewing available information and publications to

establish a robust scientific foundation for revising proposals on the welfare of this poultry category (EFSA et al., 2023). However, the challenge lies in the scarcity of research on duck welfare, with only a few authors having published welfare-related findings for commercially raised ducks in recent years (Jones and Dawkins, 2010 a; Fraley et al., 2013; Karcher et al., 2013; Colton and Fraley, 2014; Zeng et al., 2015; Byrd et al., 2016; House et al., 2021 a, b). Notably, only one of these studies utilized the TW method (Abdelfattah et al., 2020). Abdelfattah et al. (2020) validated the TW method on commercial duck farms when assessing ducks; however, they did not specify the duck strain, and their observations were conducted only within one age group.

Therefore, the aim of this study was to evaluate the duck welfare on a commercial farm using a noninvasive assessment method that eliminates the need for bird handling. We identified TW as such a method, focusing on Orvia ST5 Pekin ducks of different ages. Given that intensive selection of ducks to increase their body weight has resulted in them now having a similarly fast growth rate as broiler chickens, we tested the hypothesis that the most prevalent welfare issues, escalating with age, would be lameness and immobility.

Material and methods

Duck, housing, and management

The study was conducted on four flocks of Pekin Orvia ST5 ducks (*Anas platyrhynchos domesticus*), encompassing both sexes. These flocks were raised on a commercial farm located in the village of Milkowice-Paszk in Poland (52°28'23"N 22°40'24"E). The rearing process took place in two identical and adjacent buildings: flocks 1 and 3 in November (building 1), and flocks 2 and 4 in February of the following year (building 2). A total of 8,000 ducklings were assigned for rearing, with 2,000 allocated to each building. The ducks had access to an 800 m² floor area covered with triticale straw bedding, which was consistently replenished. Rearing was conducted in a closed system until the ducks reached 49 days of age. During the initial three days, the ducks were provided water through reversible drinkers and an automatic watering line simultaneously. Subsequently, they exclusively utilized nipple drinkers with drip trays. The feeding regimen (comprising maize, wheat, and post extraction soybean meal) consisted of two phases: starter feed from day 1 to 14 (with crude protein at 19.50% and metabolizable energy at 2,850 Kcal/kg, with a feed particle diameter of 1.5 mm) and grower feed from day 15 to 49 (with crude protein at 16.5% and metabolizable energy at 2,900 Kcal/kg). Both water and diet were available *ad libitum*. The temperature at the beginning of rearing was 29°C and gradually decreased, reaching 15–16°C between 4 and 7 weeks of age. Humidity was maintained at 60–70%. All rearing houses were equipped with a uniform mechanical ventilation system. On the side walls

of the buildings, 12 axial exhaust fans were installed (Model EWD 31/0.75; type A, 905 mm × 907 mm, Termotecnica Pericoli, Italy). The construction details and flow intensity were specified by the manufacturer (Termotecnica Pericoli, 2005). The fans were integrated with a system controlling the inlet openings (closed, partially open, fully open), and the fan operating cycle depended on the prevailing temperature in the building. The light was provided round the clock during the first week, followed by gradually shortening the day length so that by week 3, the light program was set at 20 h of light and 4 h of darkness (20L:4D). The light, with an intensity of 20 lux (measured at the height of the duck's head), was emitted by LEDs evenly distributed throughout the building (Agrishift® MLB, Plymouth, USA). Since the buildings were windowless, the ducks did not have access to natural light.

During the entire duck-rearing period in this study, bills and claws were not trimmed.

Transect walk analysis

All four flocks of Pekin ducks underwent assessment at 5, 6, and 7 weeks of age, with the evaluation in week 7 conducted the day before export to the slaughterhouse. The assessment utilized a slightly modified TW method, initially described for turkeys by Marchewka et al. (2015). The modification to the method involved incorporating a welfare indicator specific to ducks: flipped birds, which is not observed in turkeys. Data collection was conducted by two trained duck farm permanent workers who assessed all four flocks independently, without engaging in mutual discussion. These observers possessed similar experience in observing ducks and were trained by the developer of the TW method, including explanation and indicating examples of the welfare indicators on the birds, practicing how to set the limits for birds observation within the transect walks pathways and regarding the pace of movement in the barn to avoid birds disturbance. In summary, data collection occurred along four stripes extending throughout the length of the duck house, delineated by the watering and feeding lines (see Figure 1). Observers utilized predetermined welfare indicators, as outlined in Table 1.

Slaughterhouse data

Data obtained from slaughterhouses were provided for each flock and included the following parameters: the total number of ducks delivered to the slaughterhouse (n), mortality rate (%), death on arrival (DOA) rate (%), ducks accepted (n), average carcass weight (g), ducks rejected (n), and the proportion of rejected ducks for the flock (%). Additionally, this encompassed the proportion of rejected ducks per category (%), such as peritonitis, heart or liver issues, leg problems, skin lesions (scratches, discoloration), mechanical injuries, poor bleeding, very dirty/fecal contamination, and total FPD scored on a 4-point scale according to Butterworth (2009), where:

- 0: complete absence of foot pad skin lesions,
- 1: single lesion with light-colored erythema and mildly enlarged skin scales,
- 2: enlarged dark lesion with brownish exudate,
- 3: visible necrotic skin lesion of the foot pad with loss of epidermis and dark skin around, with small lesions also observed on the pads of individual toes.

The FPD score was calculated for a total of 100 ducks, where all ducks with a score of 0 ($n0$) were multiplied by 0, all ducks with a score of 1 ($n1$) were multiplied by 1, all ducks with a score of 2 ($n2$) were multiplied by 2, and all ducks with a score of 3 ($n3$) were multiplied by 3: $\Sigma = (n00) + (n11) + (n22) + (n33)$, therefore ranging from 0 to 300 points. The division into three carcass quality classes included: carcasses in categories I and II, following the adopted requirements by DEFRA (2011). Briefly, Category I encompasses carcasses with full musculature, well-developed and muscular breasts that are broad and long, muscular legs; in the case of young ducks, a thin, even layer of fat covering the breast, back, and legs, free from damage, bruising, or discoloration. In category I, slight damage, bruising, and discoloration are allowed if they are not on the breast or legs, along with slight reddening of the wing tips and joint capsule. Category II includes duck carcasses that do not meet the requirements of Category I but are fit for processing. This means they are clean, free of foreign matter, dirt, and blood, have no foreign odors, and have no visible bone fractures or extensive hematomas. All other carcasses are placed in category III, i.e. not suitable for processing and rejected.

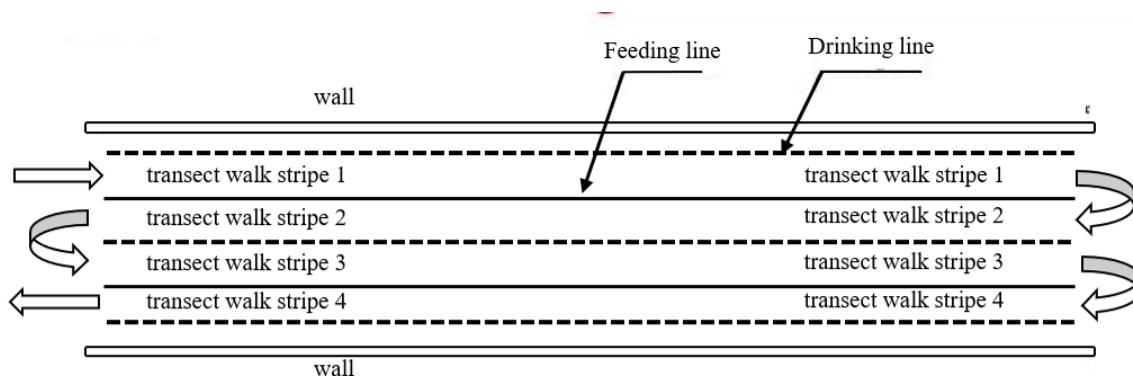


Figure 1. Duck house diagram. The arrows indicate the direction of observers' passage along the transects marked between the drinkers and feeder lines

Table 1. Description of the Pekin duck behavior and appearance in each animal-based welfare indicator category, along with their respective scores

Indicator	Score	Description
Immobile	0	Ducks not moving at all = 0
	1	Ducks moving with great difficulty = 1
	2	Ducks that are able to move, but only with human intervention = 2
Lame	1	Ducks moving incorrectly = 1
Dirty	0	Dirty part of the abdominal and thoracic-dorsal plumage = 0
	1	Dirty thoracic-abdominal area = 1
	2	Dirty abdominal area = 2
Small	0	Ducks are significantly smaller in body size compared to others in the flock
Head wounds	0	Ducks without head injury = 0
	1	Ducks with head injury = 1
Back wounds	0	Ducks with back/rump injury = 0
	1	Ducks without back/rump injury = 1
Tail wounds	0	Ducks with tail injury = 0
	1	Ducks without tail injury = 1
Featherless	0	Missing feather on the majority of the back area = 0
	1	Missing feather on the back and wings only = 1
Sick ¹	0	Ducks with behavior different from the flock = 0
	1	Ducks without behavior different from the flock = 1
Terminally ill	0	Ducks are clearly sick, bad prognosis
Flipped	0	Ducks that do not need to be turned = 0
	1	Ducks that need to be turned = 1
Dead	0	Dead ducks = 0

¹Sick symptoms: ducks showing sluggishness, difficulty breathing, complete lack of reaction to the approaching farm workers, ruffled feathers, greenish-yellow diarrhea (directly on the litter under or behind the duck), general appearance of dehydration, especially wrinkled webbed foot, pale color of the bill and foot compared to other ducks, nervous signs such as tremors and twisting of the neck or swelling of the head and neck.

Statistical analysis

All results obtained in the study exhibited a normal distribution. A generalized linear mixed model (GLM) was employed for welfare traits, incorporating the factors room (house: 1, 2), rearing week (week: 5, 6, 7), and their interactions. Flock was included as a random factor in the model. The experimental unit was the transect formed between the drinking and feeding lines, as delineated in the description of the TW method. We calculated all welfare indicator variables as proportions, where x represented the frequency of ducks with particular animal-based welfare indicators in each transect divided by N , the total number of ducks in the transect. The total number of ducks in the transect (N) was computed by dividing the known flock population size in each particular barn on the day of the transect walks by the number of conducted transects, assuming that ducks were randomly distributed throughout the house. The model was validated using Akaike's information criterion, with Schwarz's Bayesian information criterion used for comparing the maximum likelihood of reduced and full models. The selection of the final models was based on the smaller values of the information criterion. PROC GLIMMIX in SAS v9.4 statistical software (SAS Institute Inc., 2013) was utilized for the analysis, employing Tukey's test. The least squares for all statistically significant effects in the model ($P < 0.05$) were generated using the LSMEANS option. Spearman correlations were calculated using the

PROC CORR script in SAS 9.4 software to examine the relationships between all variables collected during TW. The means and standard deviations were calculated using PROC MEANS. Additionally, principal component analysis (PCA) was conducted for all 12 parameters describing duck welfare to further characterize which parameters best described the welfare of the ducks. The results of mortality and findings obtained from the abattoir were for ducks at 7 weeks of age without transect divisions; thus, only values without statistical calculations are provided.

Results

Out of all 12 welfare indicators, head wounds were only observed in two ducks in flock 1. Consequently, this indicator was excluded from the presented results, except for the PCA analysis.

Effects of age and flock on Pekin duck welfare

The impact of age and flock on the duck welfare indicators is depicted in Tables 2 and 3, and Figures 2 and 3.

Interactions were confirmed for immobility ($P = 0.0299$), lameness ($P = 0.0015$), small size ($P = 0.0136$), and flipped ducks ($P = 0.0002$) (Table 2). In flocks 2 and 4, the proportion of immobile and lame ducks remained relatively stable throughout all weeks of obser-

vation (ranging from 0.17% to 0.35% and from 0.13% to 0.47%, respectively) (Table 3). In contrast, in flocks 1 and 3 (building 1), both indices consistently occurred at a higher frequency (ranging from 0.57% to 0.95% and from 0.63% to 1.47%, respectively) compared to flocks 2 and 4 (building 2) ($P < 0.001$; Tables 2 and 3).

The influence of age on the occurrence of both immobile ducks ($P < 0.001$) and lame ducks ($P < 0.001$) was substantiated (Table 2). In flocks 1 and 2, an escalation in the proportion of immobile ducks was evident after 5 weeks of rearing, while in flock 3, this indicator decreased in the 7th week to the level observed in week 5 (Table 3). Conversely, in flocks 2 and 4, the proportion

of immobile ducks remained consistent throughout the entire rearing period (Table 3). The prevalence of lame ducks remained stable only in flock 1 ($P > 0.05$). In flock 3, a rise in the proportion of lame ducks between the 5th and 6th weeks of rearing ($P = 0.016$) was noted, followed by a reduction in the frequency of this indicator in the 7th week to a level comparable to week 5 (Table 3). In flocks 2 and 4, the proportion of lame ducks increased after the 5th week of rearing and remained steady in weeks 6 and 7 (Table 3). Additionally, the occurrence of small and flipped ducks was also contingent on age (both $P < 0.001$) and flock ($P = 0.0268$ and $P = 0.0293$, respectively) (Table 2).

Table 2. Results of the ANOVA for welfare indicators including F values, P-values, and degrees of freedom across flock, week and their interaction

Welfare indicator	Effect	DF num.	DF den.	F value	P-value
Immobile	flock	3	37	20.17	<.0001
	week	2	37	12.60	<.0001
	flock $\times$ week	6	37	2.67	0.0299
Lame	flock	3	37	57.61	<.0001
	week	2	37	20.90	<.0001
	flock $\times$ week	6	37	4.56	0.0015
Dirty	flock	3	37	43.13	<.0001
	week	2	37	5.63	0.0073
	flock $\times$ week	6	37	1.24	0.3100
Small	flock	3	37	3.43	0.0268
	week	2	37	16.88	<.0001
	flock $\times$ week	6	37	3.13	0.0136
Back wounds	flock	3	37	10.26	<.0001
	week	2	37	4.84	0.0136
	flock $\times$ week	6	37	1.77	0.1319
Tail wounds	flock	3	37	0.24	0.8677
	week	2	37	9.74	0.0004
	flock $\times$ week	6	37	1.99	0.0924
Featherless	flock	3	37	79.15	<.0001
	week	2	37	12.25	<.0001
	flock $\times$ week	6	37	1.49	0.2092
Sick	flock	3	37	13.35	<.0001
	week	2	37	0.40	0.6734
	flock $\times$ week	6	37	1.85	0.1168
Terminally ill	flock	3	37	3.74	0.0192
	week	2	37	0.27	0.7654
	flock $\times$ week	6	37	0.74	0.6171
Flipped	flock	3	37	3.35	0.0293
	week	2	37	32.46	<.0001
	flock $\times$ week	6	37	6.11	0.0002
Dead	flock	3	37	2.02	0.1277
	week	2	37	0.96	0.3914
	flock $\times$ week	6	37	0.73	0.6308

Table 3. Mean values and pooled standard error of the means for the welfare indicators for Pekin ducks across ages and flocks (interaction effect)

Age (wk)	Flock	Welfare indicators										
		immobile	lame	dirty	small	back wounds	tail wounds	featherless	sick	terminally ill	flipped	dead
5	1	0.57 B	1.62 B	3.13	0.68 B	1.30	0.47	3.50	0.26	0.27	1.15 A	0.52
	2	0.17 C	0.39 D	0.82	0.95 B	0.56	0.30	0.99	0.04	0.30	0.21 B	0.04
	3	0.63 B	1.46 B	2.77	1.41 A	1.51	0.21	2.77	0.47	0.42	0.94 A	1.56
	4	0.13 C	0.39 D	0.95	1.12 A	0.51	0.13	0.94	0.04	0.04	0.26 B	0.09
6	1	0.95 A	1.89 B	1.95	0.84 B	0.63	0.00	2.53	0.21	0.31	0.00 B	0.21
	2	0.35 BC	0.83 C	0.66	0.17 C	0.49	0.10	0.62	0.07	0.14	0.10 B	0.03
	3	1.47 A	2.83 A	3.30	0.47 C	1.05	0.21	2.04	0.42	0.47	0.00 B	0.47
	4	0.35 BC	0.61 C	0.65	0.30 CD	0.48	0.34	0.52	0.04	0.17	0.09 B	0.13
7	1	0.95 A	1.89 B	1.95	0.84 B	0.63	0.00	2.53	0.21	0.31	0.00 B	0.21
	2	0.30 BC	0.70 C	0.52	0.26 D	0.48	0.00	0.52	0.13	0.00	0.04 B	0.22
	3	0.63 B	2.21 B	2.15	0.58 B	0.68	0.00	2.47	0.26	0.37	0.00 B	0.31
	4	0.47 BC	0.78 C	0.58	0.44 C	0.48	0.00	0.78	0.17	0.22	0.09 B	0.04
Pooled SEM		0.15	0.20	0.34	0.20	0.19	0.12	0.29	0.08	0.13	0.11	0.38

Means within the columns of the table are followed by letters (A, B, C, D) to indicate significant differences between the means. Means sharing the same letter are not significantly different from each other at the $P < 0.05$ level, according to post-hoc comparisons following an ANOVA analysis. In case of indicators for which means are not followed by any letters the effect of interaction in the model was insignificant, $P > 0.05$, as stated in the Table 1.

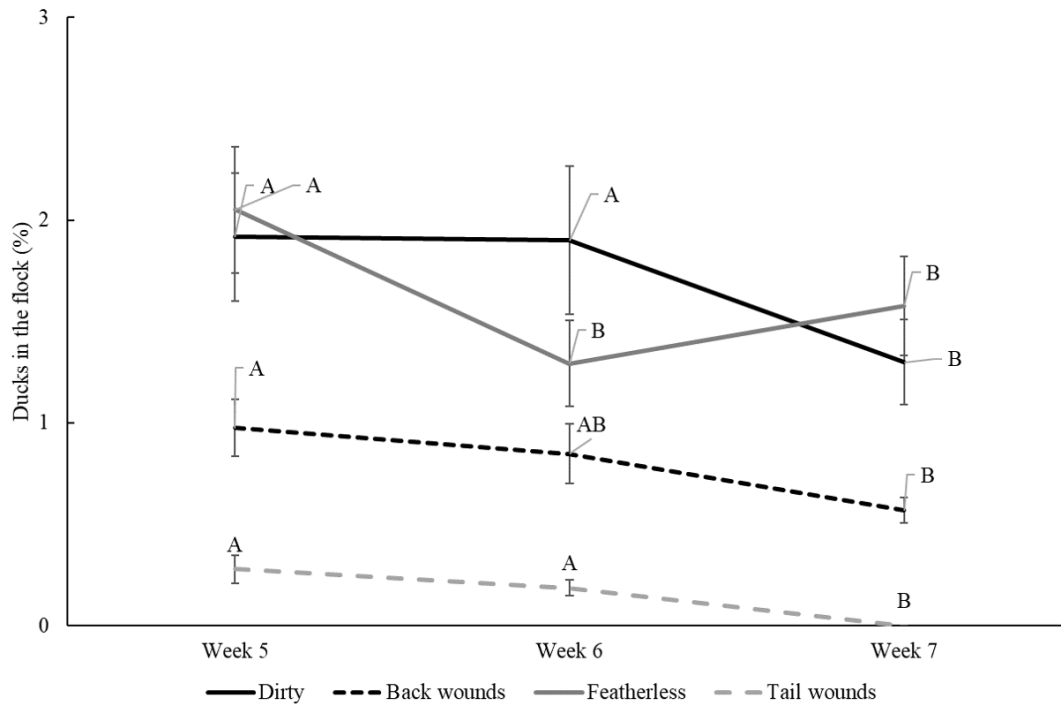


Figure 2. The effect of age on the mean values of welfare indicators in Pekin ducks reared in intensive system evaluated during production cycle at weeks 5, 6 and 7

A, B – different letters for one welfare indicator in subsequent weeks indicate significant differences at $P < 0.05$.

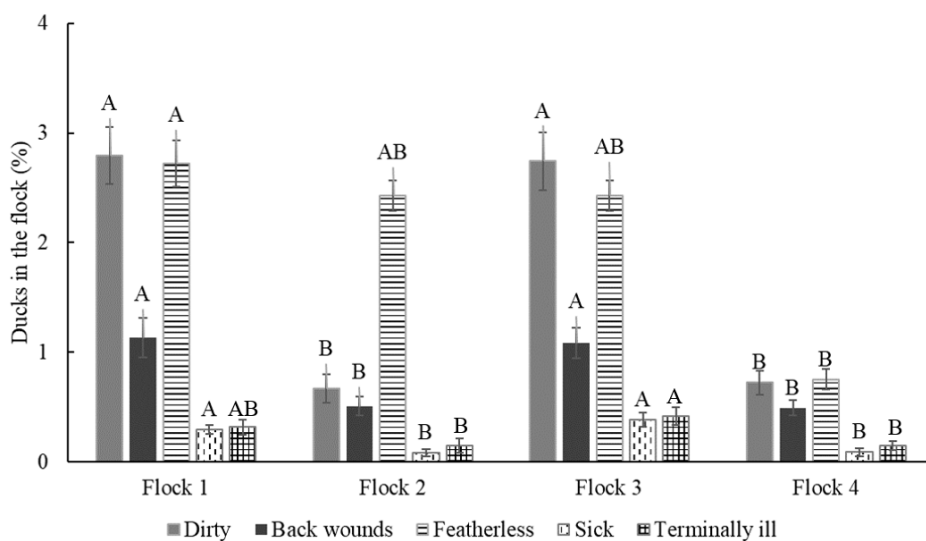


Figure 3. The effect of flock on the mean values of welfare indicators in Pekin ducks reared in intensive system

A, B – different letters for one welfare indicator between flocks indicate significant differences at $P < 0.05$.

In flocks 2, 3, and 4, the highest proportion of small ducks was noted in week 5, with significantly fewer observed in weeks 6 and 7 ($P < 0.05$). Conversely, in flock 1, the proportion of small ducks remained relatively constant throughout the rearing period (Table 3). The proportion of flipped ducks remained consistently low in all flocks during the rearing period, not exceeding 0.3%. However, in flocks 1 and 3, a significantly higher number of flipped ducks, close to 1%, was observed in week 5 (Table 3).

For welfare indicators where no interaction was confirmed, the effect of age was significant on the prevalence of ducks exhibiting dirtiness ($P = 0.0073$), back wounds ($P = 0.0136$), feather loss ($P < 0.001$), and tail wounds ($P = 0.0004$) (Tables 2, 3 and Figure 2). The proportion of dirty ducks, those with back wounds, and ducks with tail wounds remained consistent at weeks 5 and 6 of rearing, followed by a significant decrease in these indicators by week 7 (Table 3). Additionally, ducks had significantly lower rates of feather loss in weeks 6 and 7 compared to week 5 (Table 3 and Figure 2).

Table 4. Correlation coefficients between Pekin duck welfare indicators

Welfare indicator	Welfare indicator										
	Immobile	Lame	Dirty	Small	Back wounds	Tail wounds	Featherless	Sick	Terminally ill	Flipped	Dead
Immobile		0.876*	0.567*	-0.424	0.071	-0.165	0.560*	0.876*	0.567*	1.000*	-0.424
Lame			0.574*	-0.456	0.130	-0.228	0.473	1.000*	0.574*	0.875*	-0.456
Dirty				-0.355	0.698*	0.630*	0.018	0.574	1.000*	0.567*	-0.355
Small					0.384	-0.141	-0.111	-0.456	-0.355	-0.424	1.000*
Back wounds						0.580*	0.032	0.130	0.698*	0.071	0.384
Tail wounds							0.664*	-0.228	0.630*	-0.165	-0.141
Featherless								-0.473	0.018	-0.560*	-0.110
Sick									0.258	0.623*	-0.319
Terminally ill										-0.685*	0.395
Flipped											0.199

*significant effect, $P < 0.05$.

Table 5. Loadings of each of the welfare indicator of the transect walks method in each of the two identified principal components

Welfare indicator	Principal component 1 (82.13%) <i>overall welfare</i>	Principal component 2 (15.77%) <i>head and tail wounds</i>
Immobile	0.318170	0.006962
Lame	0.316857	0.012513
Dirty	0.318029	-0.022983
Small	0.294903	-0.035915
Head wounds	0.193818	0.561518
Back wounds	0.317229	0.003366
Tail wounds	0.155502	0.613469
Featherless	0.317252	0.044932
Sick	0.306076	-0.201284
Terminally ill	0.296888	-0.263365
Flipped	0.313191	0.131448
Dead	0.259453	-0.420885

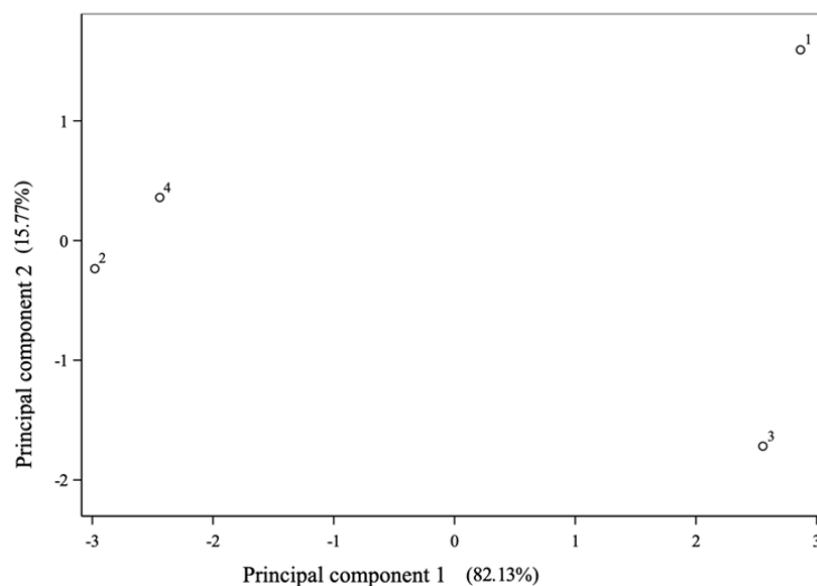


Figure 4. A two-dimensional scatter plot illustrating the distribution of data points with two principal components: all welfare indicators and head and tail wounds

For welfare indicators where no interaction was confirmed, flock influence was significant on the prevalence of ducks exhibiting dirtiness ($P < 0.0001$), back wounds ($P < 0.0001$), feather loss ($P < 0.0001$), sickness ($P < 0.0001$), and terminally ill status ($P = 0.0192$) (Table 2 and Figure 3). The frequency of all these indicators was similar between flocks 1 and 3 and flocks 2 and 4 (Table 3). A notably higher proportion of dirty, back wounds, and sick ducks was confirmed in flocks 1 and 3 compared to flocks 2 and 4 (Table 3 and Figure 3). Featherless ducks were observed in approximately 3% of ducks in flocks 1, 2, and 3. In contrast, in flock 4, there were significantly fewer featherless ducks (Table 3 and Figure 3). The highest proportion of terminally ill ducks was observed in flock 3, with slightly fewer found in flock 1. In flocks 2 and 4, the proportion of terminally ill ducks was comparable and akin to that observed in flock 1 but significantly lower compared to flock 3 (Table 3).

Correlation between welfare indicators and PCA

Table 4 illustrates the correlations between the occurrence of the analyzed duck welfare indicators. Firstly, significant positive correlations were observed between lameness disorders and plumage quality. Flocks with a higher occurrence of immobile ducks also exhibited more lame and flipped ducks ($P < 0.05$). Approximately 50% of immobile ducks were observed to be dirty. Back and tail wounds showed no association with lameness ($P > 0.05$), but they were significantly linked to being featherless ($P < 0.05$). Additionally, most ducks found dead at the time of observation were also small ($P = 0.001$).

Table 5 and Figure 4 present the results of the PCA. All 12 parameters, including head wounds (omitted from previous calculations), were utilized for the analysis. The first two principal components of PCA accounted for 97.9% of the variance in all the measured variables. PC1

explained approximately 82.13% of the variation and encompassed all welfare indicators fairly evenly, excluding head and tail wounds. PC2 was predominantly influenced by these two welfare indicators and could only account for 15.77% of the variability. Additionally, the PCA analysis highlighted similarities between the study flocks. As depicted in Figure 4, clear clustering is evident between flocks 2 and 4 (building 2) and 1 and 3 (building 1) concerning PC1 and PC2. Flocks reared in the same buildings were positioned on opposite sides of the diagram.

Slaughterhouse results

Table 6 presents the data obtained from the slaughterhouse, including the mortality (%) of the ducks for the entire rearing period (data not statistically analyzed). The highest mortality was recorded in flock 3 (5.1%), while the lowest was in flock 2 (3.7%). Flocks 1 and 4 had mortality rates of 4.8% and 4.2%, respectively. During transport, more than 2% of the ducks died, but this was only observed in flock 1; in the other flocks, the rate was similar and below 2%. As a result, flocks 2 and 4 delivered more live ducks accepted by the slaughterhouse compared to flocks 1 and 3. The most common defects observed after duck slaughter were skin issues, affecting about 1% of the birds, except for flock 3, where only 0.39% of the ducks were affected. The second most predominant category of defects was leg and joint issues, occurring in more than 1% of ducks in flocks 1 and 3, and much less frequently at 0.49% and 0.66% in flocks 2 and 4, respectively. The remaining defects occurred only in individual ducks, regardless of the flock, without a single case of heart defects observed in any of the flocks analyzed. Ducks in flock 1 had the highest FPD rate, followed by flock 3. FPD was better in flocks 2 and 4, with a particularly significant difference between flocks 1 and 2, where the FPD score in flock 2 was 46 points lower.

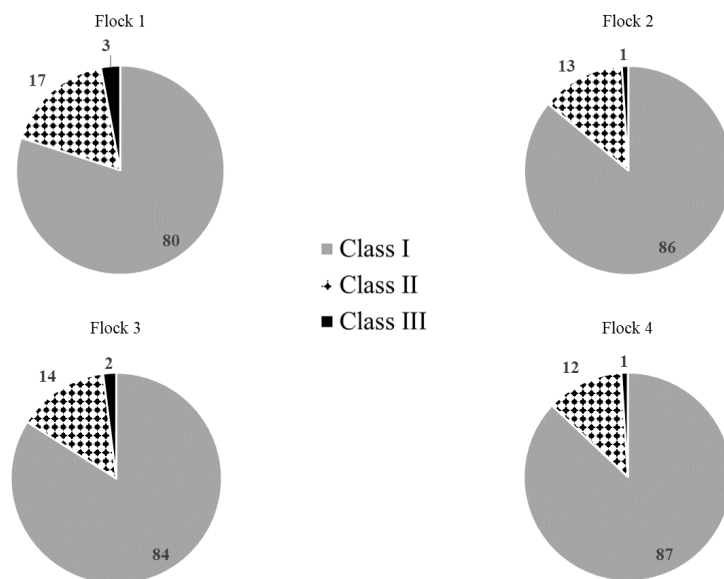


Figure 5. Distribution of birds into three classes of carcass, represented as percentages for each class (%)

Table 6. Data obtained from the slaughterhouse for 4 flocks of ducks

Parameter	Flock 1	Flock 2	Flock 3	Flock 4
Ducks delivered to slaughterhouse (n)	1904	1926	1898	1916
Mortality (%) ¹	4.8	3.7	5.1	4.2
DOA (%) ²	2.2	1.5	1.9	1.8
Ducks accepted (n)	1791	1836	1786	1818
Average carcass weight (g)	2168 (±11.8)	2199 (±10.6)	2204 (±11.8)	2147 (±12.01)
Ducks rejected (n)	71	61	76	64
Partial rejection:				
peritonitis (%)	0.06	0.00	0.00	0.17
heart (%)	0.00	0.00	0.00	0.00
liver (%)	0.11	0.16	0.22	0.06
skin issues (%)	1.28	1.20	0.39	0.99
leg/joint problems (%)	1.17	0.49	1.06	0.66
mechanical/technical injuries (%)	0.45	0.27	0.56	0.55
poorly bled (%)	0.11	0.05	0.00	0.06
fecal contamination (%)	0.73	0.33	0.78	0.22
total FPD (n) ³	164	118	159	143

¹Total duck mortality for the rearing period.

²Dead on arrival.

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

The categorization of duck carcasses into quality classes is depicted in Figure 5. Across all flocks, the percentage of ducks classified in class I ranged from 80% to 90%. Flock 4 exhibited the highest proportion of carcasses classified in class I (87%), whereas flock 1 had the lowest (80%). The highest proportion of duck carcasses classified as class II, suitable for processing but not meeting class I criteria, was observed in flock 1 (17%). In contrast, this proportion was lower in the other flocks, with 13% for flock 2, 14% for flock 3, and 12% for flock 4, respectively. Flocks 2 and 4 had only 1% of carcasses categorized in class III, indicating they were not suitable for processing, while in flocks 1 and 3, this figure was 3% and 2%, respectively.

Discussion

The aim of the study was to analyze the welfare of intensively raised ducks in Poland using the noninvasive TW method. The findings shed light on which indicators are most effective for evaluating duck welfare while identifying prevalent issues in intensively reared duck flocks in Poland. Among the 12 welfare indicators examined, only two – head wounds and tail wounds – were found to be statistically insignificant, as confirmed by PCA analysis. While head wounds are a significant concern in turkey flocks due to inter-bird aggression (Marchewka et al., 2020), they are rare or nonexistent in ducks. This disparity could be attributed to the longer rearing period in turkeys, allowing more time for aggressive behaviors

to develop and establish a hierarchy. In contrast, in broilers and ducks, pecking issues, if present, are more likely associated with cannibalism and often involve the wing and tail regions (Dong et al., 2021).

The prevailing welfare issues noted in ducks was lameness. Lameness is a common occurrence across poultry species, primarily stemming from rapid growth and high body weight due to intensive selection pressure on these traits (Paxton et al., 2013). Regarding Pekin ducks specifically, the walking difficulties were reported to be correlated with alterations in the hip joint angle (Robinson et al., 2015), while Makagon et al. (2015) identified increased disparities in pressure application between the left and right legs, which both could be reasons for the lameness observed in the current study. Further investigations on the lameness etiology in ducks are required.

In our study, the prevalence of lame ducks was impacted by both age and flock, varying from 0.20% to 2.83%. Comparable findings for intensively reared Pekin ducks on litter were documented by Karcher et al. (2013), who noted a 1.1% proportion of ducks with limping or impaired walking due to crossed feet by the 32nd day of life. Conversely, Byrd et al. (2016) reported a higher occurrence, with over 3% of ducks displaying stumbling issues. Also high rates of gait abnormalities have been reported in Pekin ducks: 14% of 23-day-old and 21% of 41-day-old Pekin ducks across 46 commercial flocks (Duggan et al., 2016). According to Duggan et al. (2016) ducks have adapted their gait in similar ways to broilers due to high growth rate.

Compared to other poultry species, these results can be considered low, even when combining lame and immobile ducks (0.17–1.47%) as a single indicator of movement defects. For example, lameness in broilers (Ross 308) can reach up to 50% (Granquist et al., 2019), while in commercial turkeys, it can exceed 15% (Hahn et al., 2020). This contrast is intriguing because one might assume that ducks, with their natural aquatic lifestyle, would face more mobility challenges in non-waterfowl rearing than land-based poultry. However, duck leg development reaches adult levels as early as 4 weeks of age, while wing development does not commence until 3 weeks after hatching. This stands in contrast to chickens, where leg bone and muscle development continue intensively up to 7 weeks of age (Duggan et al., 2015). As a result, ducks complete leg development when their body weight does not impose excessive stress on the bones, which are yet to be fully mineralized (Van Wyhe et al., 2012). Another factor which likely affects gait in ducks is that in most commercial systems the litter topped up very regularly whereas this is not typically the case of meat chickens (at least in Australia) where litter is turned over but rarely topped up. Although the findings of Duggan et al. (2015) specifically concern Cherry Valley ducks, it can be inferred that these results are equally applicable to Orvia ducks. Biesek et al. (2021) conducted comparative studies for Cherry Valley and Orvia ducks and did not identify any differences between the breeds in body weight, body tissue composition, meat quality, bone-breaking strength, and jejunum tensile strength.

In addition to issues related to bone mineralization or overall leg development, lameness can also stem from FPD. Generally, foot pain induced by lesions in the sole tissues can hinder movement, with the severity correlating with the infected surface area, and the FPD scores for the studied duck flocks were unfavorable. FPD exceeded 100 points in all flocks, with the most favorable FPD score observed in flock 2 (118 points), where the fewest lame and immobile ducks were observed. Therefore, FPD likely contributed significantly to lameness. Previous studies on duck and goose welfare also emphasize the importance of preventing FPD through modifications in rearing systems, feeding, and microclimate control (Jones et al., 2009; Jones and Dawkins, 2010 a; Zhu et al., 2013; Liao et al., 2021). In the study of Xie et al. (2014), changes in foot pads in Pekin ducks (rated on a 3-point scale) ranged from 0.8 to 1.2 and were not dependent on stocking density, which was previously observed in chickens (Zuowei et al., 2011). Karcher et al. (2013) observed the influence of the age of ducks on the quality of paw irrespective of flooring type, the proportion of ducks with 2 scores increased from 7 to 21 days old and then decreased from 21 to 32 days old. According to Karcher et al (2013) this could be related to the sticky nature of excreta in young ducks. Campbell et al. (2022) also observed worse results for FPD in younger ducks (26-day-old) compared to older ones (33-day-old). In the study by Campbell et al. (2022), younger ducks

were more susceptible to changes in FPD if misting was used in the poultry house.

The flocks observed in this study were maintained in a closed litter system, as is typical for most slaughtered duck flocks in Poland. The finding of poor FPD results in this study, highlighting lameness as a dominant welfare concern, should underscore the necessity of implementing measures such as better-balancing feed, for example, in terms of biotin content (Zhu et al., 2013), and enhancing ventilation systems to reduce humidity and improve litter quality (Ghanima et al., 2020; Eratalar, 2021). Poor-quality litter is considered one of the primary factors contributing to the occurrence of FPD (Shepherd et al., 2017). Although straw was utilized in this study, it has been demonstrated on multiple occasions that superior litter materials for ducks include rice husks (Oketch et al., 2023), wood shavings, or slatted plastic, all of which aid in decreasing FPD (Mohammed et al., 2019; Eratalar, 2021). Nevertheless, the selection of litter material largely depends on its availability in a given region and, consequently, its cost. In Central Eastern Europe, straw is the most commonly used because of its widespread availability. In the future, an alternative might be the use of straw pellets instead of straw chaff, which has proven to be an effective solution for improving litter quality (high water absorption capacity and the low microbial contamination) in broiler chickens (Gontar et al., 2022). Currently, such an impact has not been proven in the case of Pekin ducks. A limitation might be the structure of their feet (webbed foot) and the risk of foot injuries from the sharp edges of the pellet and its hard structure, especially in the initial days of ducklings' life, necessitating further investigations in the future.

Plumage quality emerged as the second most prevalent indicator of reduced welfare in the studied duck flocks. The presence of dirty feathers showed a positive correlation with lameness and immobility, indicating that these issues predominantly affect ducks experiencing mobility challenges. Other studies have also highlighted feather degradation as a commonly observed sign of reduced welfare in ducks (Colton and Fraley, 2014; Abdelfattah et al., 2020). According to O'Driscoll and Broom (2011), mitigating feather fouling can be achieved by transitioning from drip to trough watering systems, facilitating easier cleaning of feathers by birds. Additionally, offering access to water in a manner that allows ducks to immerse their heads can enhance vision and prevent nostril fouling (Jones et al., 2009; Jones and Dawkins, 2010 b). However, providing open water sources must be coupled with appropriate drinker designs to minimize water spillage and subsequent litter dampness. While dirty feathers may signify increased lameness, immobility, and suboptimal microclimate and litter conditions, a more severe welfare concern is feather loss. Downing (2022) delineated four categories of duck behaviors contributing to feather loss, including feather pecking, feather picking, cannibalism, and aggressive pecking, highlighting that feather damage behavior peaks around mid-rearing

before diminishing. Our study aligns with this observation, as the highest proportion of featherless ducks was noted at 5 weeks, declining in older ducks. This pattern likely relates to the rapid growth of long wing and tail feathers, which, in ducks, are rich in blood and soft, with their quills becoming visible between 21 and 35 days of age (Deschutter and Leeson, 1986). Additionally, keeping ducks on litter allows foraging, significantly reducing feather pecking, as noted by Rodenburg et al. (2005). Although featherlessness emerged as a prominent welfare indicator in this study, the highest observed percentage did not exceed 3.5%, which could be deemed satisfactory.

Fraley et al. (2013) and Karcher et al. (2013) also noted that instances of feather pecking in ducks occur in approximately 3% of the flock. More significant issues are documented in the rearing of Pekin ducks without a fixed light program (24L:0D), which is sometimes used in practice (Erdem et al., 2015; Hua et al., 2021). In our study, a light program of 20L:4D was employed (House et al., 2021 a; Duan et al., 2023). This lighting schedule can notably reduce aggressive duck behavior, as observed in the study by House et al. (2021 a), and likely helped prevent feather damage in the analyzed flocks. Beak or bill trimming is a common method used to deter pecking among ducks, hens, and turkeys (Gustafson et al., 2007). However, this practice is ethically controversial due to the pain it inflicts (Hester and Shea-Moore, 2003; Gustafson et al., 2007). Claw-shortening treatment in ducks, though frequently administered, has received less attention in the literature. This treatment aims to prevent skin scratches and scarring on carcasses. In our study, we did not apply this treatment, resulting in skin issues being the primary cause for the partial rejection of carcasses at the slaughterhouse.

The utilization of Principal Component Analysis enabled a deeper examination of 12 welfare parameters. Notably, PC1, which accounted for a substantial portion of the variance at 82.13%, encompassed a wide range of welfare aspects but excluded head and tail wounds. In contrast, PC2, explaining 15.77% of the variability, was mainly influenced by these two specific welfare indicators. This suggests that head and tail wounds do not play a crucial role in distinguishing between different welfare conditions among the ducks. Additionally, the clustering depicted in Figure 4 indicates that ducks in the same buildings, particularly flocks 2 and 4 versus 1 and 3, displayed distinct patterns concerning PC1 and PC2. This spatial differentiation underscores the significance of considering the rearing environment, as it seems to impact the overall welfare of the ducks. Further investigation of these findings could contribute to more precise interventions aimed at enhancing duck welfare.

An important finding from this study is the notable impact of the flock on the frequency of welfare-related indicators. However, this influence was predominantly affected by the specific building in which the flocks were housed. Flocks 1 and 3, accommodated in building 1,

showed signs of reduced welfare more frequently than flocks 2 and 4, which were housed in building 2. Notably, these two buildings were adjacent, constructed simultaneously, had identical dimensions, and were equipped with the same facilities. The raising of flocks 1 and 2, as well as 3 and 4, occurred concurrently, with ducklings from the same brood randomly assigned to the flocks. Consequently, pinpointing the exact reasons for this difference is challenging, yet it provides crucial insights for future research. Marchewka et al. (2013), despite striving to ensure uniformity in their study by selecting broiler flocks with consistent genetic material, management practices, geographic location, and bird age, also observed variations in the frequency of welfare indicators (primarily lameness and dirtiness), predominantly influenced by the specific flock. The precise causes of this phenomenon remain unclear, but it could stem from the cumulative impact of various simultaneous environmental factors. Even seemingly identical neighboring buildings may be situated on soil with differing moisture levels, exposure to sunlight, or proximity to noise sources. The quality of supplied materials such as litter or feed, which ideally should be uniform, also significantly impacts welfare but may vary due to sourcing from different batches. Hence, it appears that poultry can be sensitive to minor environmental changes that may go unnoticed by humans, yet still affect the welfare indicators of the entire flock.

Observations on poultry welfare under commercial production conditions typically offer more robust factual insights into how birds react to different environmental stimuli compared to maintaining small experimental groups. However, commercial settings may not always permit the identification of all factors contributing to welfare differences between flocks or successive batches. Hence, further research is warranted to assess the welfare of intensively raised ducks in Poland, encompassing as many flocks as possible under diverse rearing conditions and systems. Multiple studies, even conducted by distinct research teams employing similar methodologies, are essential for gaining a comprehensive understanding of duck welfare and pinpointing specific measures necessary for its enhancement.

Conclusion

In summary, this study, employing the TW method, illustrates that the diminished welfare of Orvia ST5 Pekin ducks raised commercially on litter primarily stems from the increasing age-related proportion of immobile and lame ducks in flocks, followed by dirty ducks. The prevalence of locomotor issues (such as lameness and immobility) and featherless conditions underscores the urgency to enhance duck-rearing conditions. Future work should build upon these results to further learn more about the most important causes of immobility and lameness in Pekin ducks. This will allow for a more accurate assessment of how changes in commercial technology may improve their welfare.

The significant finding of the current study was the variation in welfare levels among flocks of ducks housed in seemingly identical buildings. The study did not specifically focus on the effect of building design, and due to the limited number of flocks observed, such parameters were not analyzed. For future investigations into duck welfare using the TW method, increasing the number of observed flocks across different farms and under various intensive rearing conditions could be crucial. Additionally, conducting a meta-analysis on a large dataset of intensively kept duck flocks could yield valuable insights. Furthermore, evaluating welfare indicators collected through a standardized TW method could yield reliable results and aid in identifying the most effective measures to enhance the living conditions of ducks.

Conflict of interest statement

The authors declare no conflict of interest.

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