Layers in aviary system: Effects of beak trimming and alternative feed formulation on technical results and egg quality

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Primary Audience: Geneticists, Housing System Developers, Feed Experts

SUMMARY

Although the transition from cage housing to alternative systems commenced more than 20 yr ago, there is still an ongoing need for information supporting system understanding, system development, and genetic selection. Cannibalism remains one of the largest problems in these housing systems. Furthermore, recent developments in feed prices have increased the price of animal feed, raising production costs of eggs. Replacing feedstuffs with cheaper self-grown crops might be a possible solution to lower feed costs. In Belgium, and more specifically, in the Kempen region, corn is a widely grown crop that is usually used for feeding dairy cows, yet a ground mix of dry corn grains and a small part of the cob, known as corn cob mix (CCM), can also be used as poultry feed. In this paper the effect of the fibrous feed CCM on the prevalence of cannibalism on hens with trimmed and untrimmed beaks is investigated. The results show a positive effect of CCM on mortality; nevertheless, the mortality in the groups of untrimmed hens was very high, indicating the importance of beak trimming. Furthermore, a positive effect of CCM on egg weight was observed.

Key words: aviary, beak trimming, egg quality, corn cob mix

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DESCRIPTION OF PROBLEM

In the past 10 to 15 yr, the production of eggs has been subjected to many changes. Taking into consideration current developments, it is believed that further changes are imminent in the near future. The most radical change was caused by the European Union directive in 1999 [1] that bans cage housing. This has forced developers of housing systems and layer selection objectives to change their direction. Although this shift already started in the late 1980s and early 1990s, there is still a large and ongoing need for improvement of these systems and for evaluating the actual welfare of the hens. Proof of repeatable positive results for a certain gen-

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otype-rearing housing combination on a longer term basis is especially needed [2]. This statement was confirmed by a recent comparative study on housing systems performed by Van Der Zijpp et al. [3], who showed a high variation in mortality rates and performance of hens in alternative housing, and by a welfare study of the alternative production systems by Blokhuis et al. [4]. The absence of persistent production predictability is often due to irregular outbreaks of flock cannibalism [5], to which these systems are still very susceptible [6, 7]. Besides the main issue of higher mortality, aviary systems also tend to lower production levels and increase feed consumption owing to higher body movement [2]. Aerni et al. [8] declared genotype and rearing conditions to be the most important factors for production results and mortality. Moreover, the report from European Food Safety Agency (EFSA) [9] indicates that beak trimming and management play important additional roles in minimizing mortality.

Another concern, and not only in poultry production, is the increasing price for grain and consequently the rising feed cost. Most poultry feeds in Belgium are based on wheat, corn, and soy. A possible way to reduce feed cost for farmers is to mix in or increase the amount of self-produced crops. In Belgium, and more specifically in the Kempen region situated in the north to northeast of Belgium with mainly sandy soil, corn is a regularly grown crop. Therefore, corn would be an interesting option as an alternative, fairly low cost, layer feed composite. Besides using whole corn grains, a crushed mix of corn grains and a part of the cob, named corn cob mix (**CCM**), is often used as a feed. For the production of CCM, corn is usually harvested with a grain DM content of 65 to 70% and stored as silage. The resulting CCM silage is a semi-moist product with lower DM content and unbalanced protein to energy ratio when compared with commercial layer mashes [10]. Because of the moist quality of CCM, it has a slight acidifying effect on the pH of the hen's gut and therefore has a positive influence on the microflora. This would result in an improvement of feed intake and overall technical results of the hens [11]. Furthermore, in relation to the effect of feed on pecking behavior, Millet et al. [10] suggested a bulk effect of CCM in pigs that might increase satiation of animals, keeping them calmer. This assumption is confirmed in the review on feeding management to prevent feather pecking of Van Krimpen et al. [12], who declared that feeding diets with high amounts of fibers and roughages reduced feather pecking mainly because of the higher time spent on feed intake and foraging.

Indeed, in results of Zoons [13], who performed an experiment on 4 groups of 500 beak-trimmed (at 13 d of age) laying hens and fed a standard layer mash to 2 groups and a CCM-based feed to the other 2 groups, the hens that were fed a CCM-based diet showed a mortality attributable to cannibalism of 8.8 and 13%, and in the groups with the standard diet 24.8 and 22.6% birds perished because of cannibalism.

Based on the latter study, the presented research investigated the possible effect of CCM on feather pecking and cannibalism in both beak-trimmed and untrimmed hens in an aviary housing system. The effect on overall performance and egg quality was also studied.

MATERIALS AND METHODS

Hens and Housing

A group of 2,000 ISA Warren hens [14] were housed in a small experimental aviary system. The henhouse was part of a larger building, as can be seen in Figure 1. The henhouse was 6.1 × 28.8 m in size and was subdivided into 4 pens of 6.1 × 7.2 m for housing 500 hens each, giving the birds a usable space of 1,165 cm^2 per hen (8.57 hens per m^2). The facilities of the housing system all conformed to the minimum standards of the European Union [1]. The henhouse contained 2 rows of Specht [15] nesting areas, on the left and on the right side of the house, altogether providing 120 cm^2 nesting area per hen. All nests were equipped with Astroturf XPNP [16] nest material. In the middle of the house a scaffold 2 m wide with a grid floor and perches on each level was available (see Figure 1). Drinking and eating facilities were available at each level. The floor of the house served as a scratching area and was furnished with a small layer of white sand (25 kg per experimental group). Once a week, all manure was removed from the scaffold. Manure and litter on the floor

Table 1. Overview of the experimental design of the experiments performed[1]

Group	Beak trimming	Feed
A	6 wk	Standard
B	6 wk	CCM + supplementary feed
C	None	CCM + supplementary feed
D	None	Standard

[1]Beak trimming at 6 wk of age or no beak trimming—standard feed or feed on the basis of corn cob mix (CCM).

were not removed during the laying period, only after removal of the hens at the end of the experiment.

The birds arrived in the house at an age of 16 wk and were subjected to a step-up light schedule (from 17 to 21 wk of age) coming from 8 to 16 h of light at an age of 21 wk. During the complete laying period, they were kept at an average temperature of 21°C.

Experimental Setup and Data Collection

A 2 × 2 full factorial design was used to examine the effect of beak treatment and the effect of feeding an alternative feed. The experimental setup is given in Table 1. In this study, the age effect was not investigated.

For the beak treatment, 2 extreme settings were chosen: the trimmed hens were subjected to a beak treatment at 6 wk of age and the other hens were untrimmed. The beak treatment was done by cutting off two-thirds of the beak using a heated knife in such a way that the lower part of the beak was a bit longer than the upper part. This method of beak trimming was still common practice at the time of the experiment. Two feeding strategies were investigated: a standard commercial layer mash and an alternative feed. The latter feed consisted of a mixture of CCM and a supplementary feed. For the preparation of the CCM feed, corn was harvested at 34% moisture

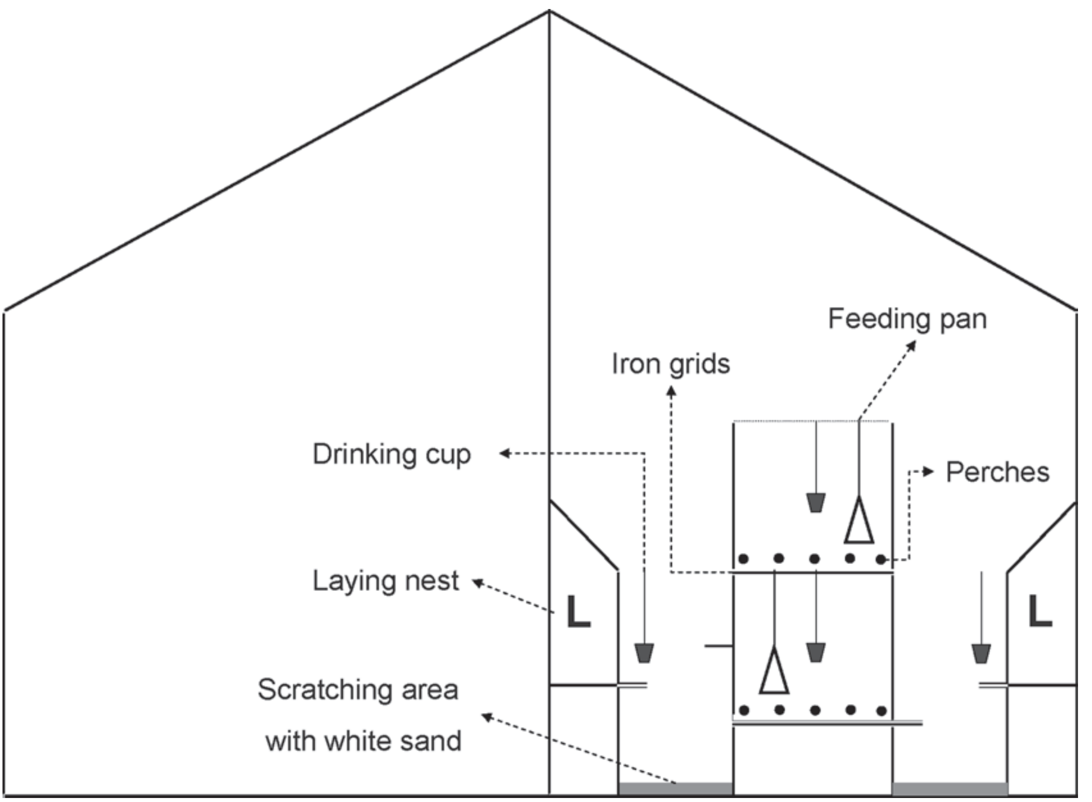

Figure 1. Cross-section of the experimental aviary hen house with 2 rows of laying nests (L) at each side of the house and a 2-level perching rack in the middle.

Table 2. Basic composition and energetic formulation of the different feeds used: the formulation of the commercial feed and the supplementary feed changed in function with hen's age, namely, a first phase feed was given until 50 wk of age, and from 51 wk on a second phase feed was fed[1]

Feedstuff	Commercial feed		Supplementary feed	
Wheat (%)	22.5		31	
Wheat by-products (%)	15		15	
Corn (%)	21		—	
Soy (%)	11		18.2	
Soy-oil (%)	1.6		2.9	
Peas (%)	13		11.8	
	Commercial feed		Mixture CCM + supplementary feed	
Nutrient	Phase 1	Phase 2	Phase 1	Phase 2
CP (%)	15.5	15.0	15.57	15.0
Crude fat (%)	6.61	6.24	6.04	6.24
Raw ash (%)	13.04	13.42	11.64	13.42
Crude fiber (%)	4.28	3.8	3.32	3.8
Moist content (%)	11.22	11.2	18.35	18.35
Ca	3.903	4.102	3.412	4.102
P total	0.544	0.521	0.52	0.521
P	0.311	0.300	0.296	0.300
Energy (kcal of ME)	2,765	2,760	2,682	2,705
Total amino acids				
Lys	0.797	0.766	0.768	0.766
Met	0.386	0.368	0.366	0.368
M+C	0.654	0.631	0.632	0.631
Thr	0.570	0.549	0.572	0.549
Trp	0.180	0.175	0.173	0.175
Digestible amino acids				
Lys	0.640	0.610	0.607	0.61
Met	0.324	0.308	0.306	0.308
M+C	0.540	0.520	0.518	0.52
Thr	0.438	0.418	0.437	0.418
Trp	0.152	0.148	0.149	0.148

[1]Both feeds contained equal amounts of vitamins and minerals: in the experimental feed, vitamins and minerals were provided by adding commercial feed additives. CCM = corn cob mix.

content, and a crushed mix of the corn grains and approximately 1% of the cob was kept in silage. In the final formulation of the alternative feed, 25% of CCM (on a DM basis) was added to a supplementary feed. The formulation of this supplementary feed was such that the nutritional composition of the mixture of 75% of this feed with 25% of the CCM was comparable with the standard layer mash. The hens were fed in 2 phases with adjustment of mainly calcium from 51 wk of age. Formulation of the commercial feed and the final mixture of the alternative feed with CCM, both for each phase, can be found in Table 2.

From 18 until 73 wk of age all hens were monitored daily for the following parameters: consumption: 1) feed and water; 2) mortality; 3) production: floor eggs including eggs on the perch rack, second-grade eggs (dirty eggs and eggs with closed fractures) and total eggs (including floor eggs); and 4) egg quality: total and average egg weight, number of broken eggs, number of dirty eggs, number of leaking eggs.

Dead or dying and sick birds were removed once a day as it is routinely done in practice. Dying and sick birds were killed by cervical dislocation, and necropsies were performed by the responsible animal caretaker. For this investigation, only 2 possible causes of death were taken into account: death attributable to cannibalism and other death causes. To obtain an estimation of the degree of feather pecking, plumage condition scores were determined at 3 different ages (36, 53, and 69 wk) on a sample of 30 birds per

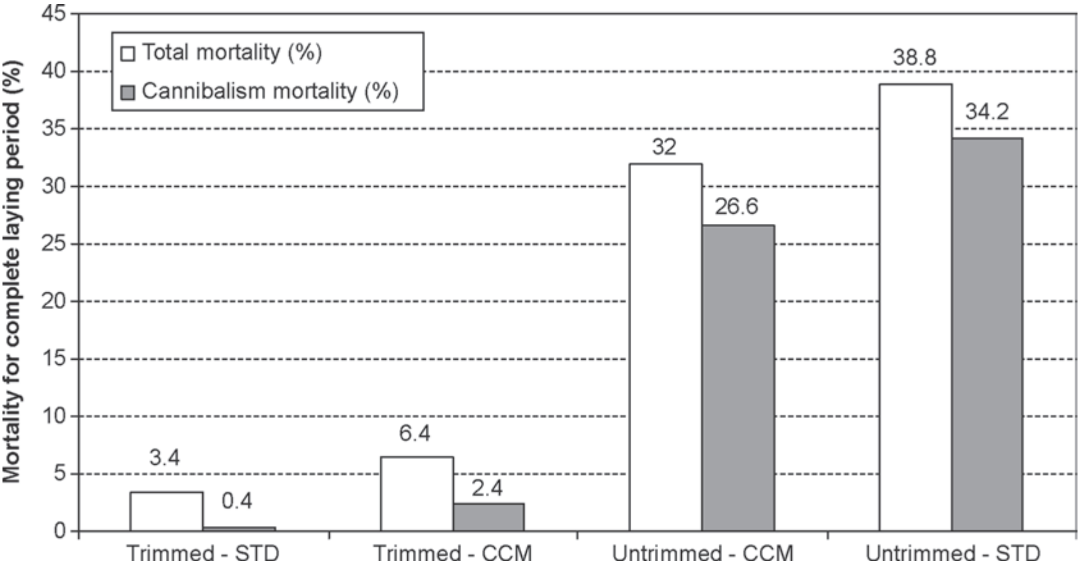

Figure 2. Indication of the percentage of cannibalistic mortality compared with the total mortality in each experimental group. STD = standard; CCM = corn cob mix.

experimental group using the method of Tauson et al. [17]. This method gives a score of 1 to 4, with 1 being the worst condition and 4 the best, for plumage condition on neck, breast, back, wings, tail, and vent. These 6 scores were added and resulted in a total score ranging from 6 to 24 points.

Furthermore, detailed egg quality assessment was performed at 3 different ages, namely, at 27, 40, and 60 wk of age. For this quality check, 60 eggs per experimental group were evaluated for individual egg weight, eggshell thickness, dynamic stiffness (**K_{dyn}**), Haugh unit, yolk color, and percentage of cracks. First, the eggs were all checked on cracks (hair cracks, open cracks, etc.) using the acoustic resonance technique as described by Coucke et al. [18]. Next, egg weight was measured using an electronic balance with an accuracy of 0.1 g. For the eggs evaluated as intact by the first test, eggshell strength as defined by K_{dyn} was calculated as described by De Ketelaere et al. [19]. Then internal quality of the eggs was assessed by measuring albumen height and calculating Haugh units using Futura [20] equipment and by defining the yolk color using the Roche color scale. After the eggs had been emptied, finally eggshell thickness was determined with a digital micrometer [21] (accuracy of 0.01 mm). Eggshell thickness was measured as an average of 3 measurements: 1 taken at the equator, 1 at the blunt egg, and 1 at the sharp end of the egg.

Table 3. General technical results of the different experimental groups until an age of 58 wk and (in parentheses) until 73 wk[1]

Item	A		B		C		D	
Cumulative mortality (%)	1.6	(3.4)	2.6	(6.4)	21.5	(32.0)	25.8	(38.8)
Egg production/Hd (%)	77.8	(76.9)	76.1	(75.7)	73.9	(70.1)	74.7	(72.6)
Average egg weight (g)	61.6	(62.5)	61.7	(62.7)	62.6	(63.5)	62.0	(63.0)
Cumulative egg mass/Hd (kg)	13.7	(18.78)	13.4	(18.51)	13.2	(17.14)	13.3	(17.86)
Average feed consumption (g/d per Hd)	112.8	(114.5)	114.2	(116.5)	124.2	(126.3)	123.5	(128.8)
Feed conversion 21 (kg/kg)	2.2	(2.3)	2.3	(2.38)	2.5	(2.74)	2.6	(2.71)

[1]A: trimmed-standard; B: trimmed-corn cob mix; C: untrimmed-corn cob mix; D: untrimmed-standard. Hd = hen day (number of hens present in the henhouse). Feed conversion 21 = from 21 wk of age on.

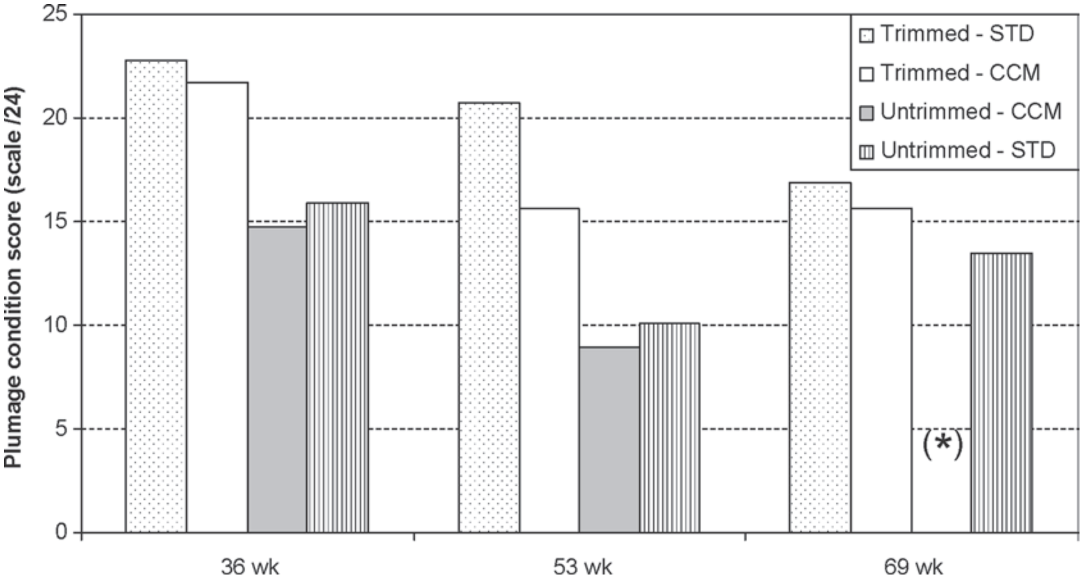

Figure 3. Results of the plumage condition scores using the method of Tauson et al. [16] at 3 different ages of the hens (36, 53, and 69 wk) for each experimental group. *Because of a technical problem at 58 wk of age, the hens went into a forced molt and as a result new feathers were formed. Therefore, no plumage scoring was performed on this group at 69 wk of age. STD = standard; CCM = corn cob mix.

Data Analysis

For evaluation of the technical results of the hens of the whole laying period, the following parameters were calculated: cumulative mortality, egg production per hen day (**Hd**), average egg weight, cumulative egg mass per Hd, average daily feed consumption per Hd, and feed conversion starting from 21 wk of age. For analysis of the daily evolution of cumulative mortality and daily egg quality (percentage of second-grade eggs, percentage of floor eggs, percentage of broken eggs, and percentage of dirty eggs), the whole laying period was divided into 14 subperiods of 4 wk each. All the named parameters were calculated for each subperiod, and analysis was done both between treatments and in time.

The goal of the presented experiment was to do investigations in a practice-related setup with larger groups of laying hens to mimic group behavior in larger flocks within the limitations of the experimental farm. Therefore, no replications of the experimental groups could be established. Because most of the obtained data were not suitable for proper statistical analysis and model development, the results will be presented only in a descriptive way. Only the detailed quality data on a sample of eggs per experimental group were analyzed statistically for the effect of treatments. For this purpose, a GLM treating beak trimming, feed, and their interaction as explanatory variables was developed for all normally distributed variables (egg weight, shell thickness, K_{dyn}, and Haugh unit). For nonnormal data (yolk color), a GLM was used. A Tukey-Kramer procedure for multiple comparisons was used for cases in which the interaction was significant [22]. For comparing multiple proportions, the Marascuillo test was used [23].

RESULTS

In the following paragraph, the results of the complete laying period are given. Nevertheless, it has to be mentioned that because of a technical problem at an age of 58 wk, the birds of group C (untrimmed and CCM) did not receive any feed for 2.5 d. As a result, the birds slid into a forced molting condition, having a higher mortality rate, a drop in egg production, and afterward lower egg weight and partially renewed feathers. Although production was reinitialized and all data could further be collected, results of this

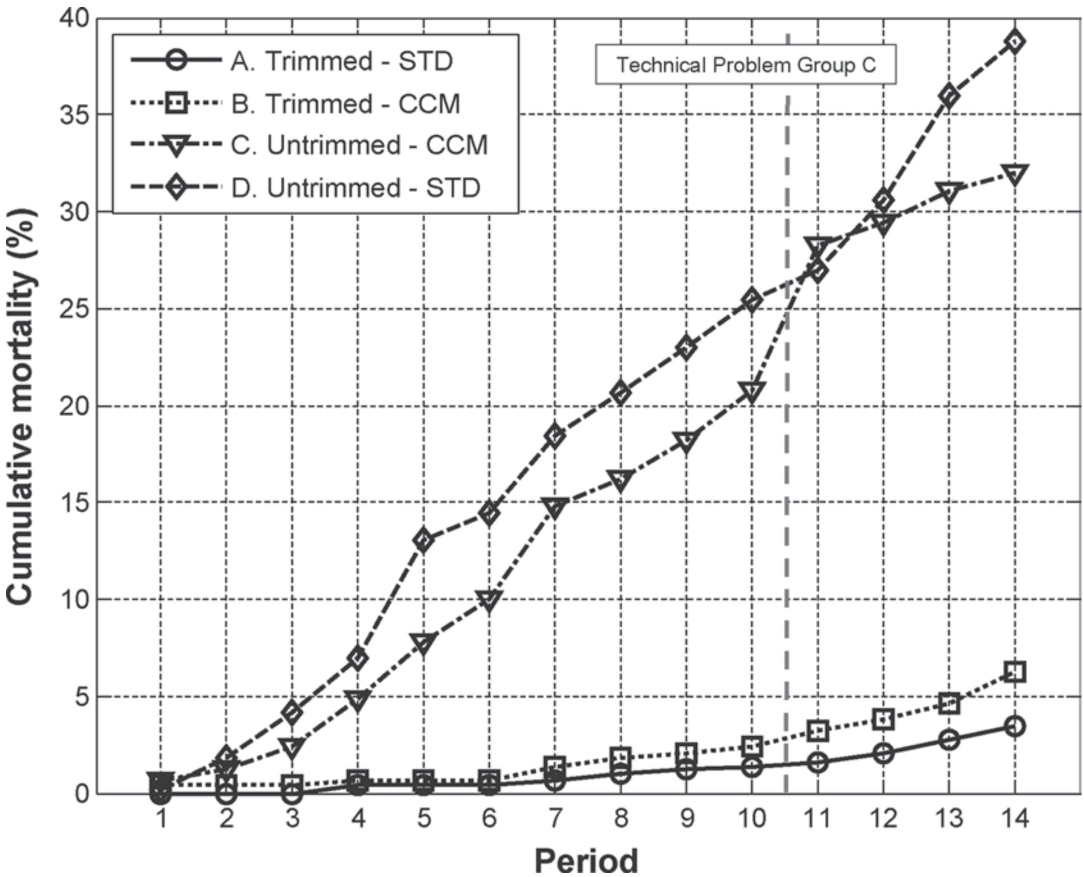

Figure 4. Graphical representation of the evolution of the cumulative mortality per experimental group for the 14 periods of the laying period. STD = standard; CCM = corn cob mix.

group after this event are no longer representative. Therefore, data are represented in 2 parts, the results until wk 58 and the results until the end of the laying period, keeping this event in mind. Furthermore, description and discussion of the results is mainly be based on the results until wk 58.

Overall Technical Results

Table 3 displays the overall technical results per experimental group for the whole laying period. Mortality until 73 wk in the untrimmed groups (C and D) is very conspicuous: 32 and 38.8% total mortality compared with 3.4 and 6.4% for the beak-trimmed groups (A and B; Table 3). The results in Figure 2 clarify that in the untrimmed groups the largest part of the mortality was due to cannibalism: 26.2% (on a total of 32%) and 34.2% (on a total of 38.8%) compared with 0.4% (on a total of 3.4%) and 2.4% (on a total of 6.4%) in the trimmed groups. Comparing feed treatments, CCM fed untrimmed hens showed lower cannibalistic mortality (26.2%) than the standard group of untrimmed hens (34.2%), yet this observation was not found in the trimmed hens (0.4% cannibalistic mortality for the standard group and 2.4% for the CCM group). The egg production at 58 wk of the untrimmed groups is lower compared with the trimmed hens: 73.9 and 74.7% for C and D vs. 77.8 and 76.1% for A and B; and for the trimmed and the untrimmed groups, CCM-fed hens (groups B and C) showed lower production.

The average egg weight at 58 wk was slightly higher (62.6 and 62.0 g vs. 61.6 and 61.7 g) for the untrimmed groups. Comparing CCM vs. standard feed, CCM-fed groups (B and C) showed higher egg weight than the groups with standard feed (A and D). Cumulative egg mass

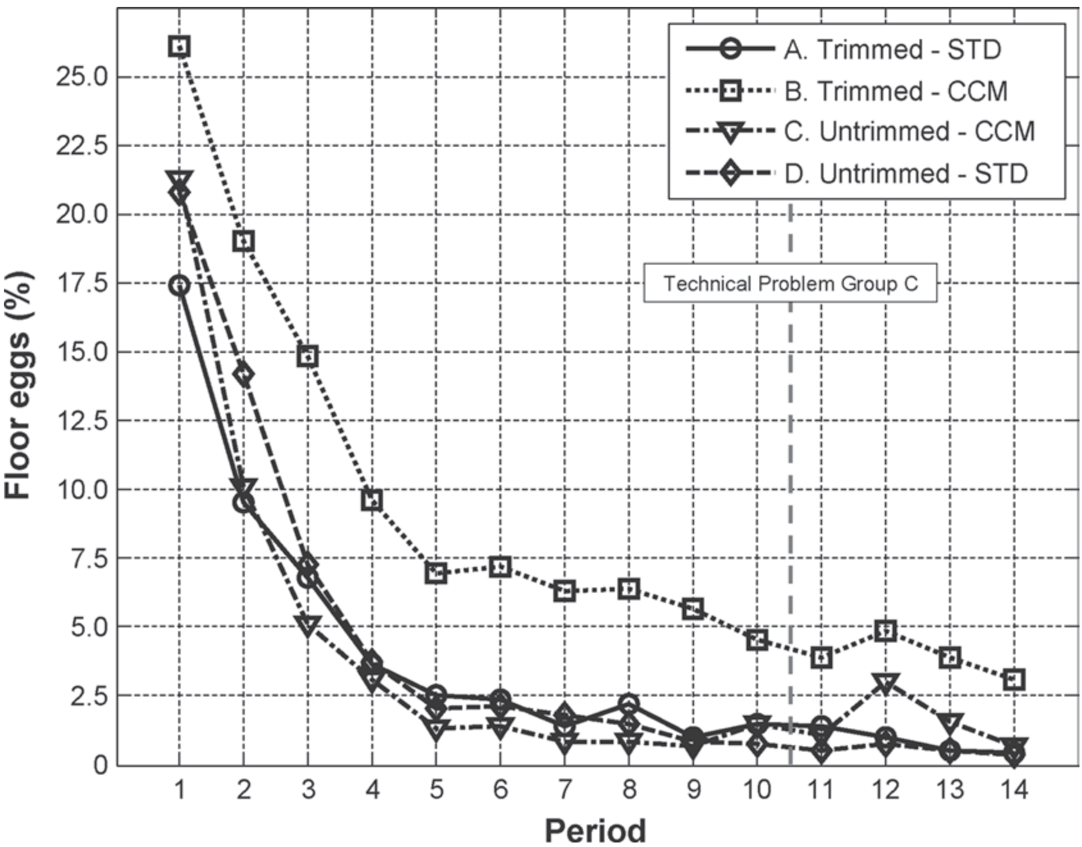

Figure 5. Graphical representation of the evolution of the percentage of floor eggs per experimental group for the 14 periods of the laying period. STD = standard; CCM = corn cob mix.

at 58 wk was lower for the untrimmed groups: 13.2 and 13.3 kg/Hd vs. 13.7 and 13.4 kg/Hd; similar to the lower egg production, the CCM-fed groups showed a lower egg mass. The untrimmed hens clearly consumed more than the trimmed hens (124.2 and 123.5 g/Hd vs. 112.8 and 114.2 g/Hd), which resulted in a higher FCR (2.5 and 2.6 kg of feed/kg of egg mass vs. 2.2 and 2.3 kg of feed/kg of egg mass). Comparing CCM to standard feed at 58 wk, the latter hens consumed less feed, resulting in a lower FCR.

Plumage Condition

Figure 3 gives the results of the scores on the plumage condition of a sample of 30 hens per experimental group at an age of 36, 53, and 69 wk. From this graph, it becomes clear that the condition of the plumage of the groups of birds that were untrimmed was worse for all sample times than for the groups with trimmed birds. From this figure, it can also be derived that the hens that were fed CCM had a slightly lower plumage score than the corresponding group with standard feed.

Daily Mortality and Egg Quality

The data on mortality and egg quality in the 14 subperiods are presented as graphs (Figures 4 to 8). Figure 4 gives a graphical representation of the evolution of the cumulative mortality. In this chart the technical problem that occurred in group C can clearly be seen by the higher mortality increase from subperiod 10 to subperiod 11. As mentioned in the previous section, the mortality rate for the untrimmed hens in general was extremely high. Because Figure 2 clarified that most of the mortality in the untrimmed groups was due to cannibalism, it can be seen in Figure 4 that there was a seemingly positive effect of CCM on cannibalistic mortal-

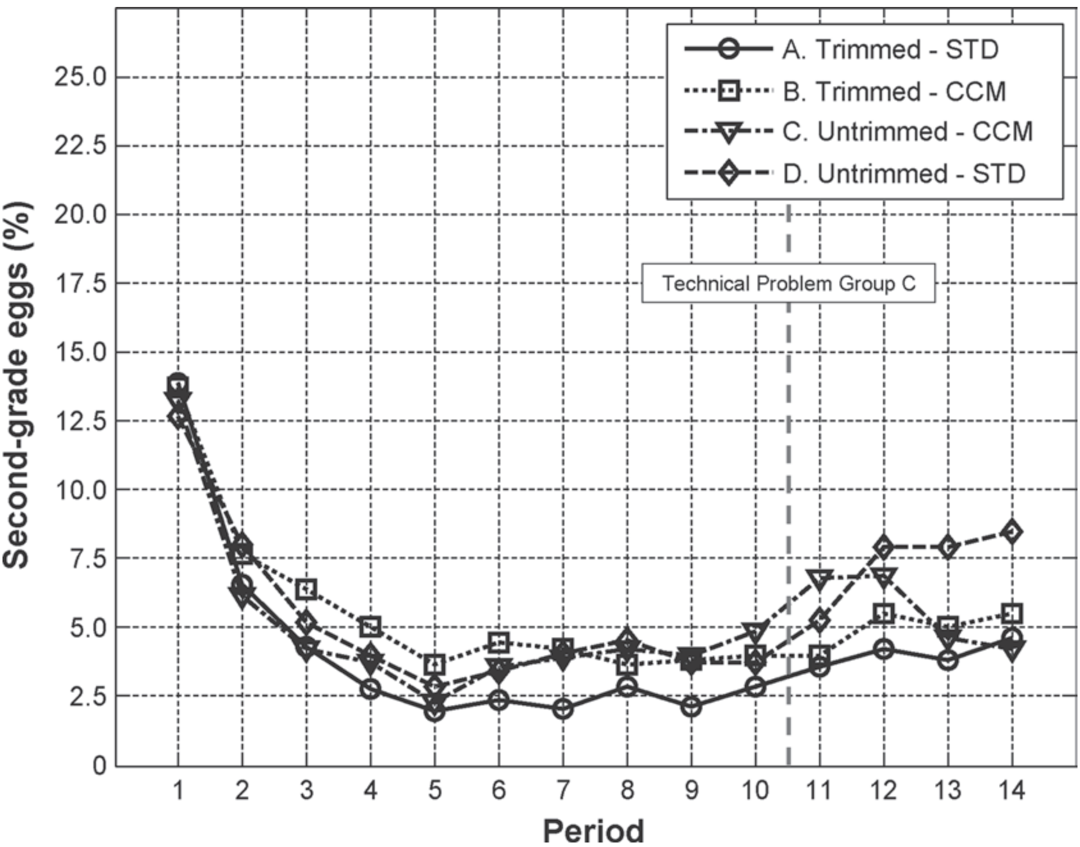

Figure 6. Graphical representation of the evolution of the percentage of second-grade eggs per experimental group for the 14 periods of the laying period. STD = standard; CCM = corn cob mix.

ity in the untrimmed groups, except for the 11th period (technical problem). For the trimmed hens, no positive effect of CCM was noticeable: the CCM group had a slightly higher (not significant) mortality for all periods.

For the egg quality, results are displayed in Figures 5 to 8. In the first 4 subperiods of the laying cycle (4 mo), there were many floor eggs (up to 25%; Figure 5). For all treatments, from period 5 on significantly fewer floor eggs were found, yet the problem remained relatively large, especially in group B, where there was a persistent high percentage of floor eggs. Looking at the percentage of second-grade eggs (Figure 6), it was high during the first 4 periods, followed by a decrease during 6 periods and a new rise at the end of lay (period 11 to 14). The high amount of floor eggs resulted in a high percentage of dirty eggs at the beginning of lay (Figure 7). At the end of lay, the percentage of broken eggs began rising again (Figure 8).

DISCUSSION

This paper presents the results of 4 experimental groups of laying hens in an aviary housing system. In the study, the effect of beak trimming and alternative feed formulation with addition of the low-cost CCM was investigated. The analysis of the data focused on the effect of CCM addition on mortality and on the general performance of all groups. Because of the lack of replications of the experimental groups, the authors do acknowledge the fact that the obtained results cannot statistically prove the hypothesis of the study. Nevertheless, the results provide an interesting basis for more basic research on the effect of the CCM diet on cannibalistic mortality.

As proven by the lower plumage condition of the untrimmed groups (Figure 3), there was a high incidence of feather pecking. As a result, cannibalistic mortality reached 26.6 and 34.2%,

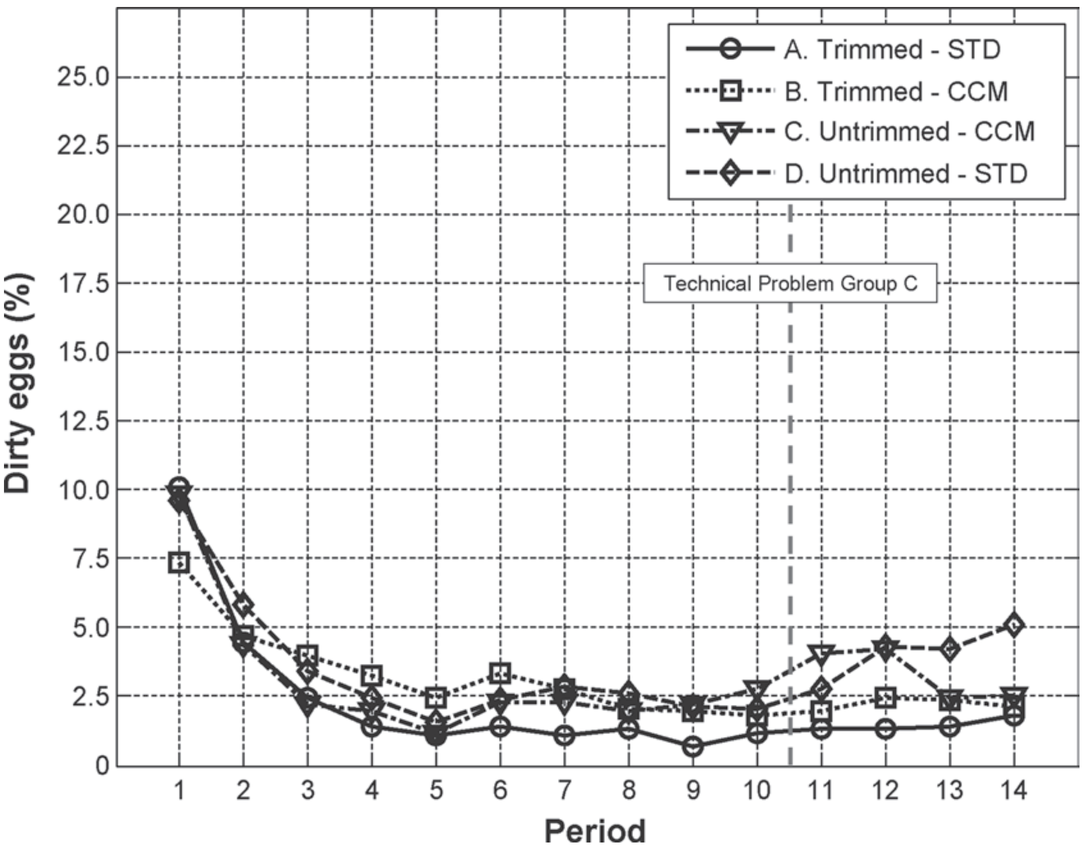

Figure 7. Graphical representation of the evolution of the percentage of dirty eggs per experimental group for the 14 periods of the laying period. STD = standard; CCM = corn cob mix.

causing total mortality of 32.0 and 38.8%. This number is higher than the numbers that can be found in the review of Tauson [5], who reported mortality up to 28%. For the trimmed hens, the mortality of 3.4 and 6.2% is in accordance with the numbers of Tauson [5]. Tauson [2] indicated that keeping down mortality as result of cannibalism will be the main goal for getting good results. Although more knowledge is available, farm-specific situations can still lead to bad results because of high cannibalistic mortality [6, 7]. Jones et al. [24] and Rodenburg et al. [25] proved that high incidence of feather pecking leads to more fearful and stressed hens in a flock [12] and reduced production [26]. Eventually, feather pecking will lead to cannibalism, causing reduced production in wounded hens and finally mortality [12]. The latter finding is supported by our findings: the untrimmed hens showed a lower egg production and egg mass per Hd.

Besides being affected by genetic predisposition, pecking can be affected by housing conditions and feed composition or feed strategy. When hens spend more time eating and foraging and if they are satiated longer, they will pay less attention to each other [12]. This gut-acidifying fibrous feed CCM would not only improve feed nutrient intake but would also give a longer satiation afterward [10, 11]. Our results showed a possible positive suppressive effect on mortality of feeding CCM in the groups without beak trimming (6% less). The CCM feed was more voluminous (more moisture and wet fibers) and had a lower energy level, so as indicated by Van Krimpen et al. [12], the hens probably spent more time eating. Furthermore, there was a higher CCM feed consumption in both the trimmed and untrimmed hens (114.2 vs. 112.8 g/Hd and 124.2 vs. 123.5 g/Hd). From our experimental data, it was not possible to check if there was an

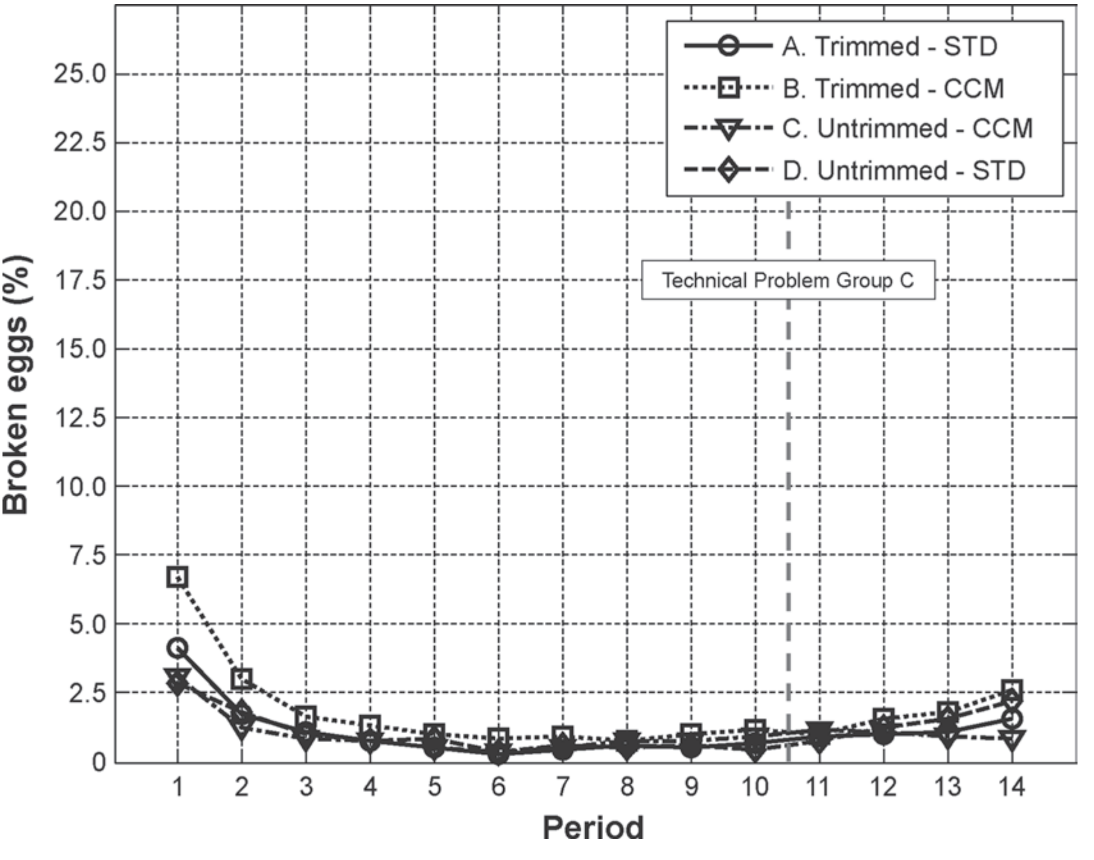

Figure 8. Graphical representation of the evolution of the percentage of broken eggs per experimental group for the 14 periods of the laying period. STD = standard; CCM = corn cob mix.

added effect of the gut acidification leading to a lower feed intake than what one would expect purely based on the lower energy content of the CCM feed. The fact that there was no effect of the CCM feed on cannibalistic mortality in the untrimmed hens could point to the assumption that beak trimming is a primary factor, besides genotype, for preventing cannibalism and that feed strategies and other management-related factors act more as secondary factors that gain importance when no beak trimming is performed. From this we could state that the genotype of hens used in this study was not suitable for good performance without the precaution of beak trimming and under the given conditions (density, system design, etc.).

Although the egg production of the trimmed hens is better than the untrimmed, the flock result at 73 wk of the trimmed hens (17.14 to 18.78 kg/Hd) is rather low as well, compared with figures of 18.6 to 22.5 kg/Hd mentioned by Tauson [5]. This supports the statement of the variability and unpredictability of production performance in alternative housing systems [2–5]. The slightly increased egg weight of the untrimmed hens could be explained by the lower egg production. The higher feed consumption by the untrimmed hens could have been caused by the combination of a higher metabolic energy requirement, as a result of more body movement (from disturbance), and of the poorer plumage condition caused by the high pecking incidence, and the higher feed spillage, and hence wastage, of the untrimmed hens that was observed by the animal caretakers. The combination of feed intake and egg mass gives a worse result on FCR for the untrimmed hens vs. trimmed (2.5 and 2.6 kg of feed/kg of egg mass at 58 wk and 2.74 and 2.71 kg of feed/kg of egg mass at 73 wk vs. 2.3 and 2.6 kg of feed/kg of egg mass at 58 wk and 2.2 and 2.3 kg of feed/kg of egg mass at 73 wk). Nevertheless, these results are within the litera-

Table 4. Review of the evolution of the different egg quality parameters, assessed during the detailed quality measurements, per treatment and per age[1]

Variable	Age (wk)	Group A	Group B	Group C	Group D
EW, g	27	59.7 ± 4.2[a]	59.8 ± 3.9[a]	60.8 ± 4.4[a]	60.4 ± 4.9[a]
	40	61.8 ± 4.1[a]	61.5 ± 4.2[a]	62.9 ± 4.7[a]	61.8 ± 4.4[a]
	60	65.4 ± 5.9[a]	65.5 ± 4.9[a]	—	66.2 ± 5.3[a]
ET, mm	27	0.414 ± 0.024[a]	0.416 ± 0.024[a]	0.418 ± 0.024[a]	0.411 ± 0.022[a]
	40	0.390 ± 0.031[b]	0.395 ± 0.026[ab]	0.401 ± 0.028[ab]	0.404 ± 0.021[a]
	60	0.391 ± 0.031[a]	0.395 ± 0.034[a]	—[a]	0.406 ± 0.040[a]
K_{dyn}, × 100 N/m	27	12,414 ± 1,739[a]	13,279 ± 3,306[a]	12,616 ± 1,760[a]	12,923 ± 3,510[a]
	40	—	—	—	—
	60	13,570 ± 3,375[a]	14,944 ± 2,066[a]	—	14,298 ± 2,838[a]
HU	27	84.3 ± 25.2[a]	88.5 ± 5.4[a]	85.0 ± 7.0[a]	83.4 ± 8.2[a]
	40	83.8 ± 7.9[a]	83.4 ± 9.1[a]	80.4 ± 7.5[a]	81.0 ± 8.3[a]
	60	71.1 ± 11.7[a]	73.5 ± 9.0[a]	—	72.8 ± 13.1[a]
YC, Roche	27	12.0 ± 0.6[a]	11.6 ± 0.9[a]	12.0 ± 0.7[a]	11.9 ± 1.0[a]
	40	11.1 ± 1.5[a]	12.2 ± 1.2[a]	11.2 ± 1.8[a]	11.2 ± 1.3[a]
	60	11.5 ± 1.2[a]	11.6 ± 1.1[a]	—	12.2 ± 1.2[a]

[a,b]Letters indicate significant differences ($P < 0.05$) between experimental groups: numbers with the same letter are not different.

[1]EW = egg weight; ET = eggshell thickness; K_{dyn} = dynamical stiffness; HU = Haugh unit; YC = yolk color (Roche scale); ED = eggshell defects (including hair cracks). A: trimmed-standard; B: trimmed-corn cob mix; C: untrimmed-corn cob mix; D: untrimmed-standard.

ture range, which reports FCR of 1.9 to 2.9 kg of feed/kg of egg mass [2, 5].

Concerning egg quality, there is an indication that the CCM feed had a positive effect on egg weight, with higher values at 58 wk for the CCM-fed hens (62.6 vs. 62.0 g and 61.7 vs. 61.6 g). This might be partly explained by a possible positive effect of CCM on feed nutrient intake attributable to gut acidification as was reported by Jeroch et al. [11]. Yet this observation was not confirmed by the detailed egg quality assessment on a sample of eggs (Table 4). Furthermore, no effects were observed in the detailed data of the internal egg quality.

The present results, up to 25% of misplaced eggs (Figure 5), are in accordance with the worst numbers reported (1 to 40% for different systems setups) in previous studies [2, 5]. Misplaced eggs cause losses through the increased labor for picking up floor eggs; they might get eaten by the hens and they cause higher amounts of second-grade eggs (dirty, broken), which results in an increased food safety risk [2]. This was indeed observed in our study with a very high percentage of second-grade eggs, with a maximum of 14% (Figure 6), in the first 4 mo of the production period, mainly caused by the high proportion of dirty floor eggs (up to 10%; Figure 7). Tauson [5] stated that if the proportion of misplaced eggs can be minimized to less than 1%, it is possible to achieve good egg quality and especially fewer broken eggs compared with cage housing.

In conclusion, this study showed the importance of beak trimming when hens with a genotype sensitive to feather pecking and cannibalism is used in high-density alternative housing systems. Furthermore, feeding a more fibrous feed (CCM) may somewhat reduce the incidence of pecking attacks. Moreover, CCM could be an interesting feed ingredient, being cheaper to produce in Belgium and tending to improve egg weight.

The unpredictability and high variation of egg production in aviary systems that many researchers observe was corroborated. Ongoing research in the different involved fields (genetics, housing construction, feed production) has to contribute to finding a good genotype-rearing housing combination for long-term positive results in aviary housing systems.

CONCLUSIONS AND APPLICATIONS

1. Beak trimming remains a very effective way for preventing high prevalence of mortality caused by cannibalism.

2. Corn cob mix seems to have a positive effect on preventing feather pecking and cannibalism, and through improvement of feed intake, also on egg weight.

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