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Effects of Group Sizing on Behavior, Welfare, and Productivity of Poultry

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ABSTRACT

The excessive intensive production of poultry meat and egg caused significant changes in poultry husbandry, behavior, and welfare. Therefore, animal welfare and behavior have become an important issue in poultry production and arises the necessity to reconsider all husbandry practices including group size and density. This review aims to investigate the association of group size with growth performance, detrimental behaviors, and welfare by reviewing current norms and regulations, as well as scientific literature in industrial poultry farms, including chicken, turkey, and quail. It has been found that group size can affect production performance, especially growth rates, feed efficiency, and number of competitors, which can lead to damaging behavior and consequently injuries in poultry. Due to the intensification of the poultry production systems, many natural behaviors of domesticated poultry, including food search strategies, hierarchy formation, and aggressiveness, are changed or modified, compared to their ancestors. Therefore, challenging behaviors in commercialized conditions and large groups of poultry must be investigated. The current recommendations and regulations of the industry for commercial poultry on group size and space requirements differ from scientifically investigated trials. On the other hand, available scientific research about the impact of flock size on poultry welfare, behavior, and production, has been carried out in experimental settings with flock sizes that are varied considerably from those used in the commercial settings. In conclusion, results from studies on optimum group size have indicated some degree of confounding and interactions between enclosure size and density. Furthermore, the social and physical environment can have a significant impact on a variety of welfare-related aspects and behavioral indicators. It is important to note that this evaluation focused on studies conducted in experimental settings, making it difficult to extrapolate the findings to commercial settings where thousands of birds are reared at once.

Keywords: Chicken, Group size, Quail, Turkey, Welfare

INTRODUCTION

Poultry has been considered the most important and most efficient alternative to red meat for sustainable food supply with regard to population growth and high demands of animal protein, notably meat and eggs (Speedy, 2003; Bonnet et al., 2020). This approach has resulted in more intense poultry farming than in any other area of animal agriculture, and consequently significant changes in poultry husbandry and some serious behavioral and welfare changes (Wolfson, 1996). The poultry industry has been adopting density and group size as a common procedure to change the welfare, behavior, and production performance of birds in high-density and commercial conditions (Estevez et al., 2003). Turkeys and quails, alongside chickens, have been progressively used as industrial poultry in recent years. The welfare of turkeys, like that of other poultry, can be influenced by various husbandry management approaches.

While implementing beak trimming or low light intensities as a frequent method to prevent cannibalism generated concerns about animal welfare, additional research on other husbandry strategies, such as the appropriate group size, is needed. There is limited research on the effects of group size and density on welfare indicators in turkeys, and also the available results are inconsistent (Martrenchar, 1999).

Small body size and simple handling are benefits of quail for use in genetic studies and embryological investigations, as well as hardiness, high laying turnover, rapid generation turnover, and being an oviparous species (Tsudzuki, 1994). However, quails are used frequently for

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industrial and scientific applications since their products are generally believed to be healthier, which heightens the need to investigate the welfare issues in Japanese quail (Minvielle, 2007). Although the breeding programs of this commercial poultry are similar in several aspects, physiological variations, such as moving ability, thermal comfort zones, and body size as well as different breeding objectives (egg or meat) and local priorities in the prevalence of poultry derived products consumption have resulted in various husbandry strategies.

Several studies have shown that group size influences blood parameters, mating system, social dynamics, feather pecking, laying rate, and other factors in chickens (Campo and Davila, 2002; Estevez et al., 2007; Bovera et al., 2014). As a result, changing group size can have a considerable impact on the major welfare indicators in poultry, such as hip joint lesions, metabolic and skeletal disorders, and painful leg disorders, including tibial dyschondroplasia, angular bone deformity, and contact dermatitis, such as hock burns, breast burns, and foot pad dermatitis (Vits et al., 2005).

In the wild, poultry creates social groups of various sizes; for example, multiple females are linked to one male in chickens, turkeys form either mixed-sex groups or same-sex, and ostriches form mixed-sex groups. To commercialize poultry production, selective breeding programs have been used to increase the physiological efficiency of organisms in commercial strains, such as the digestive system, respiratory system, skeletal system, and nutritional needs (Rauw et al., 1998). Several husbandry and farming strategies, including density, feeding systems, and ventilation, were altered as a result of these changes. Therefore, it appears that other parameters in commercial rearings, such as group size, must be reconsidered and justified in the same way.

Furthermore, as there are no possibilities for hens to engage in natural behavior, conventional cages have been banned in Sweden since 1999 (SFS, Swedish Ministry of Agriculture, 1988), and furnished cages (including, cages furnished with litter, perches, and nests) have been substituted for conventional cages (Wall and Tauson, 2007).

In addition, in recent years, poultry husbandry strategies for laying hens have experienced considerable adjustments in Germany, resulting in major overall improvements. This is mainly due to the fact that in Germany, poultry housing in traditional battery cages has been prohibited since January 1, 2010, and only organic production systems, small-group housing systems, or barn and free-range systems, have been authorized since then (federal ministry of food and agriculture, Germany). Furthermore, the German animal welfare law states that no more than 6,000 laying hens may be housed together without being separated spatially (Council Regulation 834/2007 for animal production; KAT, 2013).

In recent years, the number of animal product labeling programs based on welfare assessment standards has expanded, in addition to increasing regulations. For example, the European Commission's Directorate-General for Health and Consumers (2010) determined that a reconsideration of overall risk assessment techniques is required to guarantee continuing consumer, animal welfare, and environmental protection (Egeberg, 2010).

Even though group size has been recognized as one of the key determinants affecting poultry welfare (Wechsler and Schmid, 1998; Estevez et al., 2003; Buchwalder and Huber-Eicher, 2005), particular group size recommendations for commercial poultry production vary greatly among certifying programs and industrial guidelines. Furthermore, since group size is frequently linked to behavioral parameters and welfare (Estevez et al., 2007), a better understanding of the elements that influence or are influenced by group size can improve individuals' understanding of behavioral parameters and welfare issues in poultry. This research aimed to examine the scientific literature on the impact of group size on poultry welfare, behavior, and production, with a focus on chicken, turkey, and quail. Understanding the importance and effects of group size can assist the optimization of guidelines for commercially housed poultry flock size.

Chickens

Domesticated poultry species show different forms of social structures (Mench and Keeling, 2001). While jungle fowl live in small and stable groups, the typical pairings are several females with one male, with other males alone or in small groups (Collias and Collias, 1996). In domesticated poultry species, each group has a designated foraging and roosting space and establishes different social groups with their own home ranges (Wood-Gush et al., 1978). Small farmyard flocks face similar conditions, and their social behavior is likely to be similar to that of wild birds, however, commercial poultry has undergone significant modifications as a result of domestication and subsequent breeding efforts. Domesticated animals converted to less frightened and fearful animals, and their food-searching techniques changed. Hierarchy decreased aggression when multiple birds were reared in the same house, and birds with higher egg production rates were selected for breeding purposes.

As a result, there is a stronger demand for food and energy, as well as more time to look for new food sources in domesticated poultry (Eklund and Jensen, 2011). Schütz et al. (2001) found that there was a decreasing tendency in the incidence of energy-demanding behaviors, such as exploratory behaviors and foraging, as well as social contact in selected leghorn hens for high production. These researchers indicated that breeding programs based on genetic selection for production traits could lead to a decrease in social behaviors. In addition, Pagel and Dawkins (1997) found that hens in small groups can pay high costs of establishing dominance relationships, while cost of establishing dominance increases as group size decreases.

Furthermore, it has been demonstrated that the formation of a hierarchy breaks down at greater group sizes mainly because group members do not benefit from using recognition by all group mates (Pagel and Dawkins, 1997; Pizzari and McDonald, 2019). Commercial chickens can largely be split into two main categories of broilers and laying hens.

Table 1. Summary of published literature examining group size effects on laying hen's welfare and productivity

Reference	Age (week)	Experimental design	Evaluated parameters	Group size	Density	Results
Lindberg and Nicol (1996) Experiment 1	-	T-maze preference tests	Preference for being in a larger or a smaller group of familiar flockmates	5, 120	Constant for both groups	When space was constant and large, a strong preference for the smaller group in a large space emerged.
Experiment 2	-	5 different group size/space options were tested using a T-maze	Pecking behaviors in different group sizes	4, 70		There were preferences for a larger group (70 over 4 or 0 hens), a larger space (9 m^2 over 1 m^2), and 4 hens rather than an empty space.
Hughes (1977) Experiment 1	1-18	Battery brooder subdivided into groups of 50 at 2 weeks, 25 at 6 weeks, and 12 at 10 weeks of age	Selection of cages containing different numbers of birds	1, 2, 3, 4, 5	-	Cages became progressively less attractive as the number of birds in them increased.
Experiment 2	-	Large battery was divided into 8 cages with a central runway	Selection of empty cage versus occupied cage	1, 2, 3, 4, 5	-	Hens reared singly chose empty cages rather than cages occupied by one other unfamiliar bird, whereas group reared hens selected the occupied cages.
Hughes and Wood-Gush (1977)	1-72	Factorial design with two housing methods (battery cage and deep-litter pen)	Aggressive head pecking, threats, pecks, and pulls	3, 6	0.76, 0.81 m^2/bird	Aggressive head pecking occurred more often in groups of six than in groups of three
Abrahamsson and Tauson (1997)	1-79	Two housing systems were used, a modified furnished cage in two blocks and a conventional battery cage in one block	performance, health, and space usage	5, 6, 7, 8	600 cm^2/bird	The rolling out efficiency from nests was best in the larger group sizes but hens in the larger group sizes had the dirtiest feet
Bilčík et al. (1998)	1-40	Randomized block design	Tonic immobility	15, 30, 60, 120	5 m^2/bird	Duration of tonic immobility increased with group size
Nicol et al. (1999)	14 -30	Four identical percheries, each perchery was treated as one independent unit	Production performance, feather pecking, and aggression	72, 168, 264, 368	6, 14, 22, 30 m^2/bird	Aggressive pecking was most common in the smaller flocks at the lowest stocking densities.
Bilčík and Keeling (2000)	1-37	Randomized block design	Feather pecking and ground pecking	15, 30, 60, 120	5 m^2/bird	Higher rate of feather pecking in the largest group size
Campo and Davila (2002)		Different mating ratios with two group sizes	Blood indicators of fearfulness and stress	12, 60, 120, 240		The heterophil to lymphocyte ratio was significantly higher when the group size was 60 birds than when it was 12 birds
Estevez et al. (2003)	3-18	4 groups (12 focal birds per pen were used for tests)	Aggressive behaviors	5, 30, 60, 120	5 m^2/bird	Linear reduction in the frequency of pecks and threats given per focal bird with increasing group size but the frequency of pecks and threats received per focal bird was higher in larger than smaller groups
D'Eath and Keeling (2003)		Two large pens and four small pens	Social discrimination and aggression	10, 120	6.67 m^2/bird	Hens in small groups discriminated between familiar and unfamiliar subjects by more aggression towards

						unfamiliar hens. In large groups, the overall level of aggression towards subjects was reduced in that attempted fights were rare
Vits et al. (2005)		Three different furnished cage systems with different group sizes	Production, performance, Bone and egg parameters	10, 20, 40, 60	Constant for all groups	The highest egg production was found in the groups of 20 hens in the Aviplus system and the highest proportion of dirty eggs was found in the groups of 10 hens in the Eurovent 625A system.
Fahey and Cheng (2008)	17-60	2 genetic strains of White Leghorn hens were used in response to group size and density	Blood samples, body weight, adrenal weight, and hematological parameters	4, 6	542, 434 cm^2/bird	The genetic basis of variations in immunity may correlate with the line-unique ability of birds to cope in social environments and their survivability
Guo et al. (2012)	1-36	Three housing systems: a standard battery cage system two furnished systems	Performance, Nesting, perching, and walking behavior and blood parameters	4, 21, 48	398, 543, and 586 cm^2/bird	The furnished cage systems with small group sizes were favorable for hen welfare without markedly affecting performance
Bovera et al. (2014)	20 -36	2 groups	Performance and egg quality	25, 40	749 cm^2/bird	Hens raised from a group of 40 hens had a lower percentage of egg production and higher feed conversion ratio than a group of 25 hens
Marin et al. (2014)	1-44	Randomly assigned to 45 pens provided with nests and perching	Production performance, first egg laid, and morphometric measures of the eggs	10, 20, 40	8 m^2/bird	Groups of 40 individuals showed a reduction in BW gain and weekly hen-day-egg production after 30% phenotypic appearance changes
Mohammed and Rehan (2018)	50	360 birds (180 Lohmann brown and 180 Lohmann selected leghorn) in 6 cages (60 layers/cage “5 m^2”), 198 birds (99 Lohmann brown and 99 Lohmann selected leghorn) (33 layers/cage “2.8 m^2”)	Immunological indicators and welfare status in two strains of Lohmann layers	33, 60	same floor space relatively	In large group sizes, the scores of plumage condition were referred to the best, especially in Lohmann brown. In large group feet condition in Lohmann brown was better than Lohmann selected leghorn

Broiler chickens

Since reducing group size has a large economic and husbandry impact on broiler farms, it is critical to figure out the association between group size and welfare as precisely as possible. When a more precise assessment of the interplay between group size and welfare characteristics is available, decisions on what group size is appropriate from the standpoint of animal welfare can be made. However, unlike the association between group size and profitability, identifying the relationship between group size and welfare can be a complex issue. Studies on commercial and rural breeds, on the other hand, have led to distinct findings addressing the effect of group sizing behavior on welfare and productivity in various environments (Parveen et al., 2017; Sohsuebngarm et al., 2019). However, the assessment of rural poultry populations and the optimization of breeding goals have received insufficient attention (FAO, 2011).

Some researchers have investigated the effects of stocking density and group size on behavior and welfare indicators in broilers (Leone et al., 2007; Leone et al., 2010; Kiani and von Borstel, 2019), and found that detrimental behaviors, such as cannibalism, feather pecking, fear, aggression, stress, and behavioral disturbances are all affected. On the other hand, studies that evaluated the effects of group size, density, and enclosure size show some discrepancies (Christman and Leone, 2007). Reiter and Bessei (2000) used a two-factorial design to separate the effects of group size and density, as well as interactions between the two. They used four different group sizes (10, 20, 40, and 60 birds) and three different stocking densities (5, 10, and 20 birds/m or 9, 18, and 36 kg/m^2 floor area) to measure performance and behavioral parameters for a 5-week rearing period. This study showed that increasing group size caused a significant increase in feeding activity in the second week of the rearing period, and scratching activity increased significantly in the fifth week. Reiter and Bessei (2000) indicated that feeding activity at the fifth week was highest when broiler chickens were kept in a group size of 20 birds. Also, there was a short-time periodicity of activity and resting with a cycle length of 20 minutes, however, this rhythm was not observed in large group sizes with high stocking density. Reiter and Bessei (2000) concluded that in the tested area of their experiment, both group size and stocking density had only a minor impact on the birds' performance and behavior. They found that litter conditions, ambient temperature, and social stimulation, rather than physical space restriction, explained the effects of both parameters on scratching and wandering behaviors. Reiter and Bessei (2000) also concluded that a lack of behavioral synchronization among group members could lead to the elimination of short-term activity and resting rhythms. Preliminary research showed that there are different types of hysterical or nervous behavior experienced by chickens of different ages, caused by different factors involved, for example, by disturbance during operations, such as feeding, or spontaneously with no observable stimulus (Hansen, 1976). Moreover, several studies investigated associations among age, husbandry management practices (such as light period and litter quality), animal welfare indicators (such as foot pad dermatitis and lameness), and behaviors (such as fear, scratching, and wandering) in broiler chickens (Bassler et al., 2013; Riber et al., 2018, Phibbs et al., 2021). However, to the best of the researcher's knowledge, systematic research into different nutritional or environmental treatments in relation to group size in broiler production is very limited and would be valuable for making clear recommendations to the industry.

While several researchers have revealed the impact of group size on broiler production, contradictory outcomes have been reported. Some of these outcomes may have been influenced by differences in experimental study design (controlled versus on-farm, modifying group size by changing pen size or density), while others may have been influenced by using different welfare metrics which makes it difficult to compare the results of various investigations. As a result, no precise range of group size that influences welfare has yet been found. Some researchers have demonstrated that describing a relevant factor for broiler welfare as a whole is easier to assess when key components of the multidimensional concept of welfare respond simultaneously to the same factor, such as response to variable group size or density (Buijs et al., 2009; Kiani and von Borstel, 2019). For example, Buijs et al. (2009), used physiological (leg health and postmortem measurements) and behavioral indicators (corticosteroid metabolites and tonic immobility) to assess the welfare of four replicates of broiler chickens kept at 8, 19, 29, 40, 45, 51, 61, and 72 broilers per pen (or 6, 15, 23, 33, 35, 41, 47, and 56 kg achieved BW/m^2). The 72 broiler chicken group exhibited a longer tonic immobility duration than the 8, 19, 29, 45, and 51 broiler chickens and they tended to deviate from the 61 broiler chicken group. There was also a substantial difference in latency to lie between the 8 broiler chicken group and all groups ≥ 40 broiler chickens per pen. A shortcoming of the strategy by Buijs et al. (2009) was that a high score on one indicator could cover a low score on another indication. The effects of different group sizes include small (100 broiler chickens, 10 m^2), medium (300 broiler chickens, 30 m^2), large (1000 broiler chickens, 100 m^2), and very large (5000 broiler chickens, 500 m^2) with a constant density (10 broiler chickens/m^2) on leg disorders and plumage cleanliness in broiler chickens were explored in another study by Kiani and von Borstel (2019). Gait scores, plumage cleanliness, and hock burn were found to predict improved welfare in small groups in this study. According to Kiani and von Borstel (2019), the general assumption that large group sizes have negative impacts should be reconsidered, especially for new commercial broilers with commercially relevant group sizes.

Perching is considered a highly natural and driven habit for chickens and undisturbed napping is critical to the chickens' welfare. In laying hens, a link between group size and welfare indicators, such as perching behaviors has been established (Abrahamsson and Tauson, 1997; Wall and Tauson, 2007), however, few researchers have investigated this possibility in broilers. Martrenchar et al. (2000) evaluated broiler perching behavior between two groups of broiler chickens (1020 versus 4590 broiler chickens, 17 broiler chickens/m^2 with no replicates). These researchers demonstrated that the perching behavior of broilers in the large group size during weeks 5 and 6 was slightly lower, compared to the small group size, (6.8% versus 7.9% respectively in week 6). Since the difference in the absolute value of incidence of perching birds between the 1020 and 4590 group sizes was 1.1% at week 6, these researchers concluded that group size has no significant effect.

Several studies have been reported on the effects of group size, density, as well as the dimensions and shape of the pens (Christman and Leone, 2007; Leone et al., 2010; Kiani and von Borstel, 2019). In these investigations, some researchers combined the effects of group sizes with other parameters to study interaction effects, in addition to diverse experimental settings, such as age, breed, and husbandry conditions (Christman and Leone, 2007; Leone et al., 2010). As a result, it may be difficult to separate and divide the outcomes of each effective component, particularly group size. Some researchers have attempted to adopt a different experimental design that allows them to manipulate one component at a time and control important effects by several contrasts to separate and compare the main effects of experimental treatments (Newberry and Hall, 1990; Leone et al., 2010). For example, Leone et al. (2010), included several factors, such as group size, density, and enclosure size in their study and hypothesized that these factors could have a distinct effect on movement and space usage in broiler chickens. They built square enclosures with three group sizes of 10, 20, and 30 broiler chickens as small (S., 1.5m^2), medium (M., 3.0m^2), and large (L., 4.5m^2). When the group size was kept constant (10S, 10M, 10L), they found no variations in movement activity among enclosures of different sizes, however when the density was kept constant (10S, 20M, 30L) and comparisons were made across consistent enclosure sizes, differences between enclosure sizes were significant (10M, 20M and 10L, 30L). It could beconcluded from studies that group size, density, and enclosure size have different effects on space usage and movement of broilers. Furthermore, it has been demonstrated that broiler chickens in small pens use less space than broiler chickens in large pens. This limitation is likely due to the fact that broiler chickens could move a shorter distance before hitting an end wall and moving back to areas where they had already spent time (Newberry and Hall, 1990). As a result, changing group size, which is linked to modifying pen size, can vary the space use and movement of chickens.

Sohsuebngarm et al. (2019) evaluated the fluctuations of microclimate variables (relative humidity, ambient temperature, heat index, air velocity, effective temperature, and ammonia) over the length of commercial broiler houses and found that the microclimate variables had different trends. Specifically, regardless of the social hierarchy structure of the group, it is impossible to determine the size of the group. Several elements, including sex, breeds, husbandry practices, and environmental conditions, have been confirmed to influence hierarchy formation (Siegel and Hurst, 1962; Hocking, 1993). In addition, several studies have shown that age has an impact on hierarchy formation in poultry flocks (Newberry and Hall, 1990; Hocking, 1993; Anderson et al., 2004). In another study, Newberry and Hall (1990) have studied the impact of pen size and age on space used by male broiler chickens. The broilers were divided into two groups of large pens (407 m^2) with 3040 broiler chickens and small pens (203.5 m^2) with 1520 broiler chickens. At hourly intervals, the positions of 18 marked chickens in a large group and 10 marked chickens in each of two small groups were recorded. The results of their investigation revealed that broilers in small groups consumed less space, compared to broilers in large groups over 6 weeks. They hypothesized that broiler chickens in small groups move within a shorter distance before colliding with an end wall and being reflected back to regions where they had previously spent time. Newberry and Hall (1990) also mentioned that chicken's tendency for staying close to the walls is the reason for a larger proportion of the available pen area, which is not used by broilers. According to these researchers, the distance moved by male broilers at a commercial stocking density can be altered by group size and age. Newberry and Hall (1990) showed that chickens in the large pens spent more time near their home brooder, compared to chickens in the smaller pens.

Broiler slaughter age has been reduced as a result of selection for production qualities, which has also influenced broiler behavior (Schutz and Jensen, 2001). Several studies have found that with increasing age in broiler chickens, they restrict their mobility due to social pressure (McBride and Foenander, 1962; Craig et al., 1969; Craig and Bhagwat, 1974). It has been shown that pecking and threatening behavior in broilers fed *ad libitum* remained extremely low between 4 and 9 weeks of age (Mench, 1988). The availability of food, the movements of the chickens, and strategies to escape predators during the night have all been found to influence the movements of young domestic chickens living in the wild (McBride et al., 1969; Wood-Gush et al., 1978). Similarly, it has been shown that with increasing age, walking time and distance moved per hour decrease, which is usually linked with increased difficulty in walking leading to a decrease in home range (Newberry et al., 1986). Yang et al. (2020) concluded that broiler activity index at different ages, at the feeder and open area generally decreased from week one to week seven. In domestic fowl, developing and maintaining social bonds in groups with more than 100 groupmates is not possible (Guhl, 1953). As a result, for broiler chickens reared in large flocks with several thousand birds, confronting strangers during normal activities within the pen during the mating time is unavoidable. Adrenal hypertrophy occurs when broilers are exposed to stranger flock mates which increases the chance of aggressive behavior and has a negative impact on broiler welfare (Siegel and Siegel, 1961). On the other hand, some studies indicated that in commercial poultry farming, large group chickens would be restricted to narrow regions, allowing chickens to become acquainted with other birds in the area and prevent confrontations with outsiders (McBride and Foenander, 1962).

Laying hens

Currently, there are three main types of housing systems for laying hen, namely standard cages, furnished cages, and barn systems with and without outdoor access (Philippe et al., 2020). Corresponding to the growth of laying hen husbandry and egg production in the 1960s and the use of cage batteries, animal welfare organizations, scientists, and political activists began criticizing this method of animal farming in Europe, which eventually expanded to Northern America. The ability for hens to engage in species-specific behaviors, such as foraging, dustbathing, perching, and building or selecting a suitable nest varies depending on the housing system. If hens cannot accomplish such high-priority behaviors, they may experience substantial frustration, deprivation, or damage, which consequently deteriorate their welfare condition (Molnár and Szőllősi, 2020). On the other hand, there is relatively limited information about how hens react to varied numbers of cage-mates, and these responses are not evaluated in alternative housing systems with different group sizes.

Many behavioral interactions within a group are linked to reproduction traits, which has an impact on group size. In reproduction behaviors that are based on increased available energy profits at reproduction season, two main parameters are involved: first, increased available energy for aggressive behaviors in the population during the reproductive season, and second, a range of behavior including production and care of young appears in the breeding season. In poultry, social interaction among group members during reproduction activities has not been extensively explored (Brown and Brown, 1981; Brown, 1982). Those wild birds that defend territories, but do not breed in them during the non-breeding season, do not defend their territories and mate in groups of more than two birds (Davies and Houston, 1981; Faaborg and Arendt, 1984). Vocalization behavior, as a behavioral interaction within a group in chickens, is also considered a welfare indicator (Manteuffel et al., 2004). Distress vocalization can be found in chickens when they are exposed to a conflict or lose group interaction to call for help (Andrew, 1964). It also raises the question of whether the birds are aware when their groupmates are removed from the herd in a commercial environment (Jones and Harvey, 1987).

A preliminary study on the effects of group size on laying hen's welfare suggested that hens should not be housed either separately or in groups of four or more, but that their welfare would be best served in groups of two or three (Brambell, 1965). However, these recommendations were modified based on additional studies and sufficient data to support the association between welfare and group size, which was primarily based on two indicators of egg production and mortality. Guo et al. (2012) investigated the way group size and stocking density affected the welfare and production performance of chickens housed in furnished cage systems during the summer. Three different housing systems were used, namely a standard battery cage system (control, 4 hens/cage, 398 cm^2 /hen) and two furnished systems (including nest and perches), one with small group size (21 hens/cage; 586 cm^2/hen) and one with large group size (48 hens/cage; 543 cm^2/hen). The furnished cage with small group size hens showed a higher rate of egg breakage in comparison to the control group. In addition, hens reared in the furnished cage with a small group size cage had a lower rectal temperature, compared to the control group. Guo et al. (2012) concluded that using furnished cage systems with small group sizes (about 20 hens) was more effective in maintaining thermal balance during the summer. The findings imply that furnished cage systems with small group sizes are more desirable for hen welfare while having no negative impact on performance. In another study, Vits et al. (2005) assessed the classification of furnished cages under practical situations. There were three different furnished cage systems in their experiment (Aviplus, Eurovent 625a, and Eurovent 625A), each with four tiers of double-decker cages. In the Aviplus and Eurovent 625A systems, hens were kept in groups of 10 and 20 per cage, respectively, and in groups of 40 and 60 per cage in the Eurovent 625a system. These researchers have found that the size of a group inside a housing system had a significant impact on all production traits and Haugh units (the measure of albumen quality used by the poultry industry). The Aviplus system had the highest egg production per average hen housed (89.4%), however, the proportion of cracked eggs was greater (0.7%) in groups of 60 hens, compared to other group sizes. The Aviplus system groups of 10 hens had the strongest humerus bones (198.2 N), whereas the Eurovent 625A system's groups of 20 hens had the strongest tibias (146.7 N). More cracked eggs in bigger groups (60 hens) in their research may be due to more eggs in the nest box and/or on the conveyor belt at the same time.

Injurious pecking is a major issue in the production of laying hens, and it is particularly difficult to control in large group furnished cages and non-cage systems (Singh and Groves, 2020). Appropriate housing and management, as well as genetic selection, can help the alleviation of this problem. With increasing group size, it is more likely for laying hens to be disturbed by other group mates and increase aggressive behavior in cage mates. Although feather pecking is more common in caged layers than in pens with deep litter (Hughes and Duncan, 1972), it has been demonstrated that feather pecking and aggressive pecking are two distinct behavior patterns (Hughes, 1973; Blokhuis and Arkes, 1984).

Considering recent regulations on poultry welfare, minimizing feather pecking and cannibalistic pecking by beak trimming is a questionable issue because some pieces of evidence indicated that painful trimmingscan increase sensitivity that persists for at least a few weeks or a month (Kaukonen and Valros, 2019). Selection for behavioral traits in poultry breeding programs is considered as an alternative for modifying aggressive behaviors in poultry. It was indicated that when cannibalism among intact-beak hens is a significant problem for a genetic stock, selection of hens based on family averages improves both survival and hen-housed egg production when sisters are housed together but separately from hens of other families (Craig and Muir, 1996).

Furthermore, reports on the effective determinants of group sizing behavior, welfare, and production differ across commercial and rural broiler breeds. For example, Parveen et al. (2017) compared the growth performance of Desi and Fayoumi (Pakistani rural poultry breeds) and Rhode Island Red breeds (commercial poultry breeds) under local environmental conditions and found that Rhode Island Red breeds outperformed rural chicken breeds.

Savory et al. (1999) have studied the influence of certain environmental and dietary parameters on the development of feather pecking damage in groups of 10 to 20 growing bantams in multi-unit brooders up to 6 weeks of age. They used two group sizes (10 and 20 hens) and three stocking densities (744, 372, and 186 cm^2/hen) in their study. Results of their study showed that the mean pecking damage score was considerably higher in the larger group (20 hens) and maximum density (186 cm^2 floor space per hen), compared to the smaller group/density. According to Savory et al. (1999), the number of birds in large groups, as in alternative layer housing systems, may be less essential than stocking density. Bilčík and Keeling (2000) conducted another experiment with four different group sizes of 15, 30, 60, and 120 hens at four different ages to determine the rate of feather pecks and aggressive pecks, both given and received. The findings of this investigation revealed that groups with 120 hens differed from groups of 15 hens and 60 hens in terms of severe pecks. The group of 120 hens differed significantly from groups 15, 30, and 60 hens in terms of soft feather pecks received. Groups of 120 hens were significantly different from the other groups in terms of the number of severe feather pecks they received. They concluded that increasing group size provides grounds for increasing the frequency of aggressive pecks.

Large group size can impair laying hen performance, including feed intake, feed efficiency, and laying rate, in addition to behavior. In current poultry production systems, more freedom of movement and behavioral options may increase the occurrence of undesired behaviors, negatively impacting animal health, welfare, and production performance of laying hens (Sossidou and Elson, 2009). Marin et al. (2014) investigated whether variations or changes in the phenotype of Hy-line Brown laying hens can change egg production body and weight; The hens were divided into groups of 10, 20, or 40 (8 hens/m^2). They altered the phenotypic appearance of hens to maintain constant proportions of hens throughout the various group size treatments in their study; therefore, in a small group, 30% consisted of 3 whereas the 30% in groups of 20 and 40 consisted of 6 and 12 hens, respectively. At the end of the first phase of the study, there were no impacts of initial phenotype or group size on first egg laid, cumulative 25% egg production, or cumulative 50% egg production, and no effects on cumulative hen-day egg production (34 weeks of age). These findings imply that early life factors influenced the adaptation capacity of layers. When certain social conditions (group sizes and phenotypic appearance combinations) were imposed from a very early breeding period and age, egg production was not affected.

By definition, tonic immobility is a state of motor inhibition and reduced response to external stimuli caused by a brief duration of physical restriction (Gallup, 1977; Jones, 1990). Some studies have considered tonic immobility as a criterion for assessing fearfulness. For example, Bilčík and Keeling (2000) used tonic immobility to assess the influence of group size on fearfulness in laying hens kept in floor pens in groups of 15, 30, 60, and 120. When the hens were evaluated in their home pens, they discovered that group size had a significant impact on tonic immobility duration. The findings of this study disprove the theory that smaller groups of hens are more scared than larger ones due to a theoretically higher chance of predation.

Because of scaling effects, the results of trials conducted on small flocks cannot always be applied to commercial flocks where birds are kept in flocks of thousands. For instance, aggressive behaviors, such as feather pecking are more common in small groups, compared to large flocks because birds can adapt to avoid harmful social interactions (Hughes et al., 1997; Nicol et al., 1999). Zimmerman et al. (2006) investigated the behavior of laying hens under commercial stocking densities (low: 7 hens/m^2, medium: 9 hens/m^2, high: 12 hens/m^2), flock sizes (small: 2450/3150 birds, large: 4200 birds), and management settings (standard and modified). They discovered that the connection between flock size and age affects feather pecking and aggression levels. Nicol et al. (2006) also assessed the physiological and physical responses of chickens in non-cage commercial setups and showed that welfare indicators were not affected by flock size. A summary of published studies on laying hens is provided in Table1.

The general assumption is that a larger group size is associated with a higher prevalence of disease (Nunn et al., 2015). Otte et al (2021) carried out a partial budget analysis of the breakeven cost of biosecurity investments for free-range poultry flocks of 1-20 and 21-50 birds. In their study, average parameter values (initial and final inventory, number of birds lost to disease, and number of eggs produced) and prices of the flock size groups of 1-20 and 21-50 birds were used for the analysis. These researchers indicated breakeven costs of biosecurity measures above which their cost would be higher than the returns. However, Otte et al (2021) reported an average loss (deaths/initial flock plus entries) of 22% for small group size (1-20 birds), compared to 13% of birds in large group size (21-50 birds).

On the other hand, social network analysis (SNA), also known as network analysis or contact analysis, has recently gained popularity in the field of animal behavior concerning group size and infectious disease to evaluate animal social networks and to compare social networks within and between groups. It has been indicated that poultry, the contact structure is heterogeneous, however instead of being tied to social systems, contacts are typically dependent on group size, spatial structure, and animal movements, which are commonly controlled by husbandry management systems (Craft, 2015).

All management practices, including group size and density, can contribute to the health of the flocks and the transmission of infectious disease, and the efficiency of reproduction organs in layers (Edwards and Hemsworth, 2021). Since complex environmental factors are usually associated with difficulties in cleaning and persistency of parasites and infectious diseases, the disease agents can spread in a larger group size easily (Lay et al., 2011). Therefore, there is a need for more studies on the association of different infectious and respiratory diseases, such as infectious bronchitis (IB) or egg drop syndrome, caused by a viral infection in laying hens, and group size in layers.

Turkey

Turkeys, like chickens, can form different group sizes in the wild and live in small mixed-sex groups during the non-breeding season. Separating males from females and all-female or all-male flocks are more common in commercial conditions (Schorger, 1966; Brant, 2007). Male and female flocks are divided due to varying growth rates and dietary requirements. Commercial turkeys are sometimes found in groups similar to wild turkeys, particularly during the breeding season, with several females and one male, but male sibling groups are more typically kept together in mixed-sex production (Appleby et al., 2004).

Fast-growing turkey broiler strains are typically housed in vast buildings that can hold 1000-25000 birds at stocking rates of up to 60 kg/m^2 (FAWC, 2009), or around 3 adult males/m^2. Turkeys raised for commercial purposes have a high level of aggression. Some researchers believe that this intensive activity is caused by exogenous variables such as genetic disposition or endogenous factors such as housing, management, and food (Sherwin and Kelland, 1998; Hafez, 1999). Increased aggressive behavior in turkeys could be due to domestication-related causes because wild and commercial fattening breeds have different fighting behavior patterns (Healy, 1992).

A limited number of studies have been conducted on the effect of flock size on welfare or behavioral indicators in commercial turkeys, and available studies do not reflect the flock sizes in a commercial situation. There are no simple methods to separate the influence of group size and density for turkey flocks or laying hens. Different housing systems, climates, and husbandry practices make it difficult to draw conclusions from the few published studies on the effect of group size, however, some studies address the main subject more directly than others, which are intermixed with density effect. For example, Buchwalder and Huber-Eicher (2005) conducted a study to evaluate how adding individual birds into small or large test groups of turkey toms affected the incidence of hostile encounters. These researchers expected that in small groups, the reaction to an introduced turkey tom would be more hostile than in large groups. These researchers used six groups of six animals (small groups) and six groups of 30 animals (large groups) to count and time hostile behavior such as pecks, fights, and leaps between locals and introduced or reintroduced turkey toms. Their findings revealed that turkeys in small groups were more hostile with the imported species than turkeys in large groups. In comparison to the large group (6×13 m), the small group (2×3 m) received more pecks toward newly introduced unknown toms. Some other researchers have reported similar behaviors when unfamiliar conspecifics are introduced to wild turkey flocks in order to drive them out (Watts and Stokes, 1971; Williams, 1981). According to Buchwalder and Huber-Eicher (2005), turkeys in large groups are barely able to distinguish between resident group members and introduced birds, but domesticated and wild turkeys can distinguish between group members and non-group members, and non-group members would exhibit aggressive behaviors significantly more than group members, at least in groups of four.

Several studies have assessed the welfare of turkey broilers housed at high stocking densities, particularly during the final fattening period when the body weight of turkey broilers per space is high (Coleman and Leighton, 1969; Zuidhof et al., 1993; Martrenchar et al., 1999). There was a discrepancy between group size and density in some studies because experimental pen size was not changed across treatments. For example, Martrenchar et al. (1999) provided floor space of 24 dm^2, 18.5 dm^2, and 15 dm^2 until week 12 and 40 dm^2, 31 dm^2, and 25 dm^2 from week 12 for the males and 16 dm^2, 12.3 dm^2, and 10 dm^2 for the females, but because the size of the pens was the same in all experimental treatments, treatments differed in both stocking density and group size. As a result, it is impossible to determine the relative effect of each variable. These researchers stated that this experimental design was chosen intentionally in their experiment because, despite new regulations regarding stocking density, farmers are unlikely to change the size of their houses and pens; instead, they prefer to house fewer birds while simultaneously changing stocking density and group size.

Sherwin and Kelland (1998) examined the frequency of comfort behaviors and the incidence of injurious pecking for varied group sizes and stocking densities when male turkeys were housed as pairs in pens. These researchers, in contrast to Buchwalder and Huber-Eicher (2005), found that the degree of injuries and the frequency of fighting were reduced in small groups, implying that small group size and/or low stocking density may mitigate or lessen the effects of harmful pecking in turkeys.

Although observations of relatively lower aggression in large groups of domestic fowl, some researchers support the hypotheses that aggressive behaviors decrease with increasing group size (Carmichael et al., 1999; Nicol et al., 1999; Estevez et al., 2002). Estevez et al. (2003) hypothesized that domestic fowl in small groups create a dominance hierarchy through violent interactions, whereas domestic fowl in large groups adopt a low-aggression (tolerant) social strategy. These researchers tested aggressive interactions among group members as group size increased using groups of 15, 30, 60, and 120 female White Leghorn hens housed in a constant density. Estevez et al. (2003) indicated that while the majority of birds in larger groups can adopt a tolerant strategy, a minority may exhibit more aggressive behaviors and be despotic, directing aggression indiscriminately toward other members of the group. A dominating member of a group's optimal group size may differ from that of new or junior members. Many facets of conduct in social interactions can be influenced by dominance. When food resources are scarce or improperly distributed within a group, a dominant has easier access to food and will often take food discovered by subordinates (Baker et al., 1981; Rohwer and Ewald, 1981, Lindenwald et al., 2021). As a result, the effects of resource depletion may be less for a dominant than for a subordinate (Rohwer and Ewald, 1981; Brown, 1982; Lacher et al., 1982). Different social interactions among group members, such as competing for resources and space, might have an impact on new member acceptance (Brown, 1982).

It is not straightforward to classify acceptable group sizes for commercial conditions. Most behavioral tests and observations are conducted on much smaller groups than possible group sizes under commercial situations. Large pens are divided into smaller ones in behavioral experiments, and each little pen is treated as an independent replicate. Because of technical constraints, most studies only have a few replications (typically less than six), making it challenging to extrapolate the outcomes of these tests to commercial flocks (Denbow et al., 1984; Cunningham, 1992; Classen et al., 1994).

Quails

In comparison to chicken and turkey farming, quail farming is a relatively new addition to industrialized poultry production. During the nonbreeding season, the Northern Bobwhite, *Colinus virginianus*, forms social groups (coveys) of around a dozen birds of various ages and sexes (Johnsgard and Jones, 1988). Northern bobwhites congregate in small groups of no more than 30 quails, with an average group size of 12 individuals (Wing, 1941). These coveys change in the spring as males and females team up for breeding, and new coveys arise.

The rate of migration affects social interaction in Japanese quail, and the composition of groups varies as a result of migration. Overall, group size and social organization in the wild are influenced by a variety of factors, including the current availability of resources in the habitat and the risk of predation, and can fluctuate as these conditions change (Wilson and Bermant, 1972).

In a breeding cage of quails, stocking density and group size are effective environmental characteristics that can alter performance parameters and welfare indicators (Seker et al., 2009; El Sabry et al., 2022). Seker et al. (2009) have studied the effects of group sizes of 3 and 10 quails with a constant density of 125 cm^2/quails on the performance of Japanese quails. The results of this study revealed that with a constant density (125 cm^2/quails), a group size of 10 may yield better results in terms of live weight, feed intake, and feed conversion ratio than a group size of 3 quails/cage. Waheda et al. (1999) reared 90 Japanese quails from 50 to 125 days of age in two group sizes (6 and 9 birds/cage) and three stocking densities (150, 175, and 200 cm^2/bird) and reported a higher egg production in the smaller group size with intermediate stocking density, compared to the larger group sizes and higher stocking density. The size of the group can have a significant impact on the association between group mates in domesticated fowl, social interactions, and modifying their adaptation to new situations (Jones, 1996; Bilčík et al., 1998; Estevez et al., 2003), consequently, the quality of group-mated interactions can have an impact on performance, health, and welfare metrics.

Despite the fact that Japanese quail have been widely utilized as a model animal to study social behavior in large groups of domestic birds (Schweitzer et al., 2009), there are few studies on social connections in Japanese quail.

Several characteristics of social interactions, such as cohesiveness, affiliation, and aggression, are likely to be influenced by social motivation (Launay et al., 1991; François et al., 2000; Williams et al., 2003). Breeding groups of 15-20 birds are kept in battery cages with a floor space of 1 m × 0.5 m and a height of 16-20 cm in industrial cage production (Gerken and Mills, 1993). Quail are typically distressed in industrial settings, with issues like head-banging as a result of escape responses, aggressive pecking, leg weakness, feather damage, and foot disorders. Aggressive pecking is one of the most common causes of skin or eyelid lesions, quail head injuries, and eye loss, all of which can negatively impact quail welfare in commercial quail farming. Wechsler and Schmid (1998) investigated the effect of breeding groups on the aggressive behavior of Japanese quail. They used a 2×2 factorial design with four groups of 5 males and 15 hens and 4 groups of 5 males and 35 hens, introducing 2 groups of each composition into the pens at the ages of 4 and 6 weeks, respectively. These researchers showed that the effect of group size or age of introduction into the experimental pen on pecking rate was not significant, and there was no significant interaction between the two factors.

Environmental enrichment or alterations can be utilized to promote animal welfare, reduce aggression and fear, and change social behavior in poultry husbandry because environmental enrichment can boost behavioral possibilities and lead to improvements in biological functioning (Gvaryahu et al., 1994; Newberry, 1995). Environmental enrichment has been observed to promote aggressive interactions among caged laying hens (Reed et al., 1993), hence it is hypothesized that environmental enrichment will alter social behaviors in poultry, particularly grouping behaviors. Japanese quail has been the subject of numerous environmental enrichment and social behavior studies as a common laboratory and production species. Miller and Mench (2005) found that social housing versus singleton dwelling had an effect on social proximity choice in Japanese quail.

Since strong social motivation is the primary criterion for quail selection, they prefer to spend more time with conspecifics (Launay et al., 1991; Carmichael et al., 1998; Formanek et al., 2008) and show more social isolation in comparison to quails selected for low social motivation (Launay et al., 1993; Mills et al., 1993). Low social motivation encourages social bonding between cage mates in quail chicks housed in pairs, but high social motivation chicks display a social attraction for any conspecific, whether they are familiar or not (Schweitzer et al., 2010). Schweitzer et al. (2011) conducted an experiment in Japanese quail with varying levels of social incentive to see how group size impacts the strength of social connections between familiar conspecifics. Quails with high or low social reinstatement behavior were selected and housed in various group sizes. Quails that demonstrated high or poor social reinstatement behavior were chosen and housed in groups of 6, 15, or 30; Increasing group size improved the calming index only in high social reinstatement quail chicks which point to a lower calming effect of the return of a conspecific with increasing group size. In all lines, the number of nonaggressive pecks and the time spent in contact decreased as group size increased. The findings of this study show that social bonds exist in both high and low social reinstatement quail chicks, contrary to the findings of Schweitzer et al. (2010), who found that social bonds between familiar conspecifics exist in low social reinstatement but not in high social reinstatement quail chicks housed in pairs. In addition, Craig et al. (1969) discovered that strangeness and crowding in female chickens are connected with higher rates of social interaction compared to socially undisturbed and uncrowned flocks.

Precocial bird mothers can modify their chicks' emotional and social behavior through non-genetic postnatal mechanisms, causing both long-term and transgenerational effects (Houdelier et al., 2013). The few studies that investigated the impact of brood size on precocial birds were more concerned with offspring survival than with mother care (Pittet et al., 2014; Aigueperse et al., 2017). Aigueperse et al. (2017) evaluated the impact of brood size on Japanese quail maternal behavior and its interactions with chicks. In their study, two types of broods were compared: small broods of three chicks (N = 9) and large broods of six chicks (N = 9), and also assessed mother behavior by using two methods. Aigueperse et al. (2017) showed that mothers in the large group produced more maternal vocalization (cooing and food calls) one day after maternal induction than mothers in the small group. These researchers also observed that brood size had no effect on the time spent warming chicks and that mothers in the large group had fewer covering postures, compared to mothers in the small group. The authors find that brood size influences mother behaviors such as warmth, vocalization, and huddling.

Parasites are one of the most common worries in the poultry industry (chicken, turkey, and quail), and they can be found practically anywhere poultry is produced and cause serious economic and production consequences. It has been established that a mix of interconnected elements such as stress, management, and diet resulted in parasite exposure (Lynch Ianniello et al., 2014). Moore et al. (1988) hypothesized that parasite transmission is easier and larger in stable social groupings and conducted an experiment with varying covey sizes in bobwhite quail over different seasons to test the theory. Their findings revealed that the number of monoxenous parasites is related to the size of the group. Moore et al. (1988) also discovered that *T. tenuis* and *R. cesticillus* intensities were higher in large coveys than in small coveys. These researchers concluded that for parasitism evaluation, the immune system of the host animal, variation caused by the biology of intermediate hosts, or a longer generation time must all be taken into account.

CONCLUSION

Many recent studies reveal that optimum group size on an industrial scale needs to be thoroughly studied, preferably in commercial trials, with consideration to recent specific legalization in the poultry industry in various regions. However, it is clear that studies focusing on the optimum group size have some confounding and interactions between density and enclosure size. It is important to note that this evaluation focused on studies conducted in experimental settings, making it difficult to extrapolate the findings to commercial settings where thousands of chickens are bred at once. On the other hand, many of the scientific findings can be implemented in the industry. According to the findings of the current review, future research in poultry welfare and behavior should concentrate on the effect of group size on more specific responses and the separation of the effect of group size from other correlated factors. In addition, in comparison to small group sizes, more specialized factors, including parameters with more economical use, such as leg diseases, growth performance, and laying rate, should be evaluated in different types and breeds of poultry in commercial-scale group sizes.

DECLARATION

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Ethical consideration

Ethical issues (including plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy) have been checked by the author.

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