Aggressive behavior in the genus *Gallus* sp[1]

■ **Author(s)**

Queiroz SA[2]
Cromberg VU[3]

[1]   Funded by Associação de Criadores e de Preservação das Raças de Galos Combatentes.
[2]   Departamento de Zootecnia, Faculdade de Ciências Agrárias e Veterinárias de Jaboticabal, Universidade Estadual Paulista (UNESP)
[3]   ETCO – Grupo de Estudos e Pesquisa em Etologia e Ecologia - UNESP/FCAV

■ **Mail Address**

Sandra Aidar de Queiroz
Departamento de Zootecnia
Faculdade de Ciências Agrárias e Veterinárias de Jaboticabal - UNESP
Via de acesso Prof. Paulo D. Castelane, s/n
14.884-900. Jaboticabal, SP, Brazil
Phone: 55 16 3209 2678

E-mail: saquei@fcav.unesp.br

■ **Keywords**

Aggressiveness; behavior; fighting birds; *Gallus* sp.

ABSTRACT

The intensification of the production system in the poultry industry and the vertical integration of the poultry agribusiness have brought profound changes in the physical and social environment of domestic fowls in comparison to their ancestors and have modified the expression of aggression and submission. The present review has covered the studies focusing on the different aspects linked to aggressiveness in the genus *Gallus*. The evaluated studies have shown that aggressiveness and subordination are complex behavioral expressions that involve genetic differences between breeds, strains and individuals, and differences in the cerebral development during growth, in the hormonal metabolism, in the rearing conditions of individuals, including feed restriction, density, housing type (litter or cage), influence of the opposite sex during the growth period, existence of hostile stimuli (pain and frustration), ability to recognize individuals and social learning. The utilization of fighting birds as experimental material in the study of mechanisms that have influence on the manifestation of aggressiveness in the genus *Gallus* might comparatively help to elucidate important biological aspects of such behavior.

INTRODUCTION

Domestic fowls are social birds that live naturally in groups constituted by a rooster with many hens in a determined territory. Group structure is hierachical with male dominance over all hens and, among these, social hierarchy is determined by pecking order and perch location. Such hierarchical system is rigorously maintained by aggressive behaviors, but once the hierarchy has been established, the aggressiveness decreases and is substituted for demonstrations of dominance (threatening) and submission (subordination). Roosters and hens form separate social hierarchies. The dominance of males over females is seldom contested, so that aggressive male behavior towards hens is hardly seen under natural conditions (Milman and Duncan, 2000). On the other hand, aggression between males during the reproductive season is fairly common due to the increase in testosterone levels (Ros *et al.*, 2002) and competition for mating opportunities.

The physical aspects of rearing environment and social experience might have important roles in the development and expression of agonistic behaviors by captive animals. There is an increase in the threshold of defensive behavior responses with domestication, resulting in captive animals that show lower submission response or social inhibition in comparison to wild animals (Lorenz, 1950). Selection against defensive behavior might represent an adaptation in order to minimize stress of inhabiting an environment where it is not possible to escape from aggression.

1

Evidences indicate that one of the most important effects of domestication on animal behavior is the reduction of emotional reactivity. Such effect is noticed in all populations of domestic animals and affects many behaviors that characterize the domestic phenotype and improve economically important indices such as growth rates, social interaction, response to humans, response to unfamiliar objects and places (Price, 2002).

The intensification of production systems in the poultry industry and the vertical integration of the poultry agribusiness over the 20th century, which separated the activities of selection, reproduction and production, might have occurred and might still be occurring more rapidly than the genetic adaptation mechanisms of populations to these changes (Newman, 1994). This might result in situations in which the individuals do not have adequate biological resources and behavioral mechanisms to respond to the challenges. Therefore, this review aimed to cover scientific studies that have focused on the different aspects linked to the aggressiveness in the genus _Gallus_ and to identify the strategies of social adaptation in such conditions.

Aggression

The aggressive behavior generally involves some aspect of threaten or attack, normally directed to another individual of the same species. The aggression is a ritualized form of communication with the purpose of establishing and maintaining the hierarchy within a small group (Loiselet, 2004).

In the genus _Gallus_ sp., the competition between individuals is authoritarian; the strongest birds dominate the best resources and force the others to the areas where resources are scarce or of lower quality. Such competition occurs in two different manners: fights between males in order to establish territories to constitute groups (territorial behavior) and aggressive competition for the resources within groups (hierarchic dominance). Nevertheless, since aggression is a means of communication, the attitudes shown by the individuals must be inequivocally recognized, so that the animals spend little energy in the process. Thus, the evidence of a submission posture subsequently to aggression by another individual is effective in avoiding conflicts.

Imprinting and first social interactions

The most important post-hatching learning is the so-called filial imprinting, i.e., the recognition of the hen as the mother; consequently, the chicks follow the hen immediately (Sluckin, 1966). Filial imprinting is different from the sexual imprinting. The latter occurs in older birds and leads to the choice of conspecifics as sexual partners (Vidal, 1980). On the other hand, sexual imprinting is affected by the previous experiences with the mother and siblings, and such effects are only noticed when the chicks reach sexual maturity.

Filial imprinting is not only a following response; rather, it refers to the acquisition of a social preference. There is a predisposition of the chick to come closer to a model that contains the neck and the head of a hen, and such predisposition is developed in the two first days of life (Johnson _et al._, 1992). On the other hand, learnings concerning hearing (Gottlieb, 1965) and smelling (Vallortigara and Andrew, 1994) also occur prior to hatching.

After imprinting, chicks no longer come closer to unfamiliar objects. Contrarily to the first days, they show fear to new stimuli. Such fear might occur as a consequence of imprinting (Bateson, 1964) or, independently, as a consequence of the running tendency (Hess, 1959). According to Salzen (1962), imprinting and development of fear against novel objects are inseparable aspects of the same neural mechanism. Independent of the explanation, the fear keeps chicks in contact with the hen, which assures protection to dangerous stimuli and situations (Rogers, 1995).

Fear has been shown to evolve from experiences related to the social rearing or isolation (Kruijt, 1964). Fear develops earlier in chicks reared in groups in comparison to chicks reared in isolation, probably because of the imprinting on siblings. On the other hand, fear in animals reared in isolation might be decreased if they are reared with different visual or hearing stimuli, or by regular handling (Jones and Waddington, 1992, 1993). Fear behavior changes along chick development and is different between strains (Phillips and Siegel, 1966; Jones, 1977).

Chicks also learn to recognize their siblings and to follow them, which means that the group (hen and chicks) remains united. Probably, they become individually imprinted on their siblings and use colors as indication (Kilham _et al.,_ 1968, Vallortigara and Andrew, 1991). Zajonc _et al._ (1975) has used pecking frequency in siblings and foreign birds by means of paired tests and reported that even day-old chicks were able to discriminate among family and unrelated members, and to recognize siblings even though the feathers and other characteristics changed with age (Bateson, 1979; 1990).

Chicks not only recognize their siblings, but also

seem to interpret the social interactions between them (Regolin *et al.*, 1994). In the natural habitat, the experience of social rearing with others of their own kind also directs the imprinting preference to females of the same species.

The social tolerance among the members of a group generally decreases during growth and maturing of domestic fowls. Thus, agonistic activities begin and social hierarchy is formed. Birds reared in groups since hatching start to show aggressiveness and become socially organized in older ages in comparison to birds reared in isolation and gathered only afterwards. Guhl (1958) observed that cockerels reared alone and gathered at 31 days of age established the majority of dominance relationship within six days, which was much earlier than cockerels reared in groups. Such studies have shown that living continuously as a group after hatching was associated to greater social tolerance and to the delayed beginning of combats and aggressive behaviors, and favoured the more gradual formation of social hierarchies.

ONTOGENESIS OF AGGRESSIVENESS AND HORMONAL INFLUENCE
Formation of social hierarchies and lateralization

It is generally accepted that social hierarchy begins to develop at approximately five or six weeks of age in the domestic fowl (Guhl, 1958; McBride *et al.*, 1969). Nevertheless, this perspective is correct only when the perception of social hierarchy is based in results of agonistic interactions, because very young chicks show few or none aggressive pecking. Rushen (1984) has reported that males from a domestic strain have shown aggressive pecking on the second week post-hatching and reached behavior levels similar to adult performance between the eighth and ninth week of life. Kruijt (1964) has observed the first aggressive peckings at 10 days of age in the Burmese Red Jungle Fowl (*Gallus gallus spadiceus*), and juvenile fights started at three weeks of age. Thus, if position in the ranking of chicks is measured by outbreaks of aggressive peckings among individuals of a group, it is impossible to determine a social hierarchy in the first weeks post-hatching. Nevertheless, such position might be shown through the competition for limited resources. The assessment of internal competition for a restricted food source has shown that social hierarchies existed even in the first week of life (Roger and Astiningsih, 1991). Adult hens learned and remembered the social patterns developed in agonistic interactions (Zayan, 1987).

Rogers and Workman (1989) evaluated the effect of embryo exposition to light on the formation of social hierarchy. It is known that a brief exposition of embryonated eggs to light at 19 days of incubation is enough to establish structural and functional asymmetries on the brain. Chicks hatched from eggs incubated in the dark have not shown consistent asymmetry within groups. Chicks hatched from eggs incubated in the dark from 17 days of incubation to hatching have formed a group with more flexible structure than those hatched from eggs exposed to light during this period, i.e., birds hatched from eggs exposed to light formed a more rigid social hierarchy of obtaining food access in the tests performed in the first two weeks, whereas the group of birds from eggs kept in the dark until hatching showed greater variability in the social stratification. Consequently, chicks in the lower ranks of the group incubated in the dark showed more effectiveness in competing for food than chicks from the group exposed to light. The birds in the group incubated in the dark had access to the food tray by climbing onto the others, whereas the birds from the group exposed to light approached the food tray from below, between the legs of the birds that were already at the tray. The authors considered that the hierarchy in the group comprised by individuals that show asymmetry in the same direction might be more stable, since the social interaction might result in more predictable responses. On the other hand, Diamond (1968) has observed that chicks hatched from eggs incubated in the dark were less frightened (showed less frequently immobilization behavior in the presence of novel moving visual stimuli) in comparison to chicks exposed to light in the last week of incubation. Fear reduction might explain the greater success in food competition of those individuals of lower hierarchical ranks in the group incubated in the dark.

There are evidences that the control of fear responses is lateralized in the right side of the brain (Phillips and Youngren, 1986), and that lateralization depends on the presence or absence of light. Rogers (1995) stated that, during the critical period before hatching, the embryos call the hen (Tuculescu and Griswold, 1983) and that the hen reacts by standing up and turning the eggs, so that these are exposed to light. Calling frequency (between 90 to 100 calls during 30 minutes to three hours before hatching) determines the amount of light to which the eggs are exposed; approximately two hours of exposure to light is enough to establish functional and structural brain lateralization.

Many trials have evidenced that chicks show asymmetry (right-left) when they choose between siblings or a intruder. When the chick is tested with only the left eye, it chooses the sibling, whereas tests with the right eye result in random choices. This finding suggests that the recognition occurs in the right hemisphere, on which the left eye projects the information and is associated to small differences that designate individuals, whereas the other hemisphere classifies the chicks as a category (Vallortigara and Andrew, 1991).

It is believed that testosterone levels in the cockerel might influence hierarchy position, since testosterone-treated chicks from a lower social position have achieved higher positions in the social ranking, based on the same tests of competition for food or the worm running test. The "worm" is a model made of paper; the test evaluates the speed and promptness with which the chick handles this model (Rogers and Astiningsih, 1991). The treatment with testosterone increased the agonistic behavior (Andrew, 1975a), but the tests to establish the social ranking did not include aggressive pecking. Alternatively, testosterone might affect competition through the ability of causing attention endurance or attention directioning to a given objective. Attention focused on food source might result in competition success and higher position in the social ranking.

A second method to measure social hierarchy in chickens is to assess the leaping order. In leaps of attack, the bird jumps from the floor and throws both feet towards its opponent. Attacking leaps occur before pecking when two birds are put into contact. Adult males from domestic strains were socially isolated for eight days or eight weeks and were then tested in pairs (Rajecki, 1988); the hierarchy obtained by counting the leaps during the contact reflected the hierarchy obtained by counting the aggressive peckings. The author classified leap categories and established hierarchies even in very young chicks; whereas the classification using the aggressive peckings in younger birds did not predict the subsequent leap order, classification using leaps did predict the later leap and pecking order. Therefore, leap order seems to be a useful measurement of the social hierarchy along the life of the birds.

Young animals adopt another social structure based on leadership. Adret-Hausberger and Cumming (1987) observed that some two- to three-week-old chicks showed stronger tendency to have more episodes of feeding activities than the others. The leader tends to be followed by all the others from the group. It was also reported that the oldest bird is promptly accepted as leader by the youngest birds that originate from artificial incubation and with no previous experience with older chicks. Younger chicks follow the older to the feeding place and mimmetize its behavior. Thus, attraction to one of the same kind might interact with social learning and leadership.

There are gender differences in the responses given by chicks in relation to their pairs and intruders. In tests of approach-response, females show shorter latency to approach when tested with the pairs in comparison to intruders, whereas males showed opposite effect (Vallortigara, 1992). Females tested for simultaneous choice between a cagemate and a intruder spent more time with the cagemate, whereas the males spent more time with the intruder. Both sexes directed aggressive peckings to intruders, but the males pecked more frequently than females. According to Vallortigara (1992), female chicks formed stronger social bonds than males. Consistently with this hypothesis, females have been shown to move to a place out of the sight of the dam less frequently than males (Workman and Andrew, 1989). Such gender differences that exist in the beginning of the chick life still exist at maturity, as observed by McBride *et al.* (1969) in feral domestic fowl.

Development and effect of hormones

In the genus *Gallus sp.*, sexual and aggressive behaviors are dependent on the circulating levels of sexual hormones. At hatching, the hypophysis is the only responsible for the control of gonadal steroidogenesis. Close to puberty, however, the luteinizing hormone estimulates a sudden increase in androgen production. Androgens stimulate the production of spermatozoa, and are also responsible for secondary sex characteristics and libido, fighting behavior, courting behavior and group formation. Testosterone is the most important hormone to prepare the individuals for intense social competition. In birds, testosterone facilitates aggressive behavior, increases muscle growth, and decreases fat deposition, but also inhibits molt and behaviors connected to parental care. In polygamous species, such as the domestic fowl, males are generally not involved in offspring care, but they compete fiercely for females during the reproductive season and present high basal testosterone levels (Ros *et al.*, 2002).

Andrew (1975a) devised methods to test attack and mating behaviors in young chicks using the hands. In

these tests, the human hand is used to simulate a hen or another chick, and juvenile copulation is evaluated by evidencing behaviors related to attack and mating, for example, stepping on the hand and squating it as the male does (grasping the neck of the hen, and pushing the pelvis). The hand is placed horizontally with the palm turned down, and is pushed carefully towards the thorax at a level that allows the animal to walk easily. The copulation assessment was done by attributing scores from zero to ten, corresponding respectively to avoidance and active behaviors (the chick walks towards the hand, steps on it and show pelvis movements). Attack behavior is assessed similarly; the human hand is used to simulate attack by another bird. The palm is placed in front of the chick with the fingers curved in the direction of its beak. The hand is rapidly moved from one side to the other, close to the head of the chick, as in a sparring. Attack behavior is also scored from zero, when the bird avoids looking at the hand, to ten, when it fights actively using attack leaps and repeated peckings.

Andrew (1975a,b) has reported high levels of mating, attack, "waltzing" and juvenile singing in 3-d-old male or female chicks treated IM with 5 or 25 mg testosterone enanthate, which is a slow-releasing presentation of testosterone. Waltzing refers to a courting behavior that is usually exihibited by adult cockerels, in which the male walks round the hen in a stereotyped manner, with the wing lowered and close to the female. Singing and waltzing were seen similarly in male and females after testosterone had been administered, and both showed high levels 7 days later. Attacks and copulation increased three days after administration in males, but these behaviors have not increased in females.

Other steroidal hormones have also increased the levels of copulating and aggressive behaviors. Young and Rogers (1978) have shown that copulation scores were higher after administration of estradiol, 5α-dihydrotestosterone and 9-dihydrotestosterone. Besides, effectivity was similar to that of testosterone administration. Capons treated with estradiol have shown copulation behavior, although only with cooperative and crouching partners (Davis and Domm, 1943, cited by Andrew, 1975a). Young and Rogers (1978) have administered estradiol in chicks and although copulating behavior was frequent, the same was not true for fighting behavior, differing from the earlier results with testosterone administration.

During normal growth and development, fighting and copulation behaviors increase in males during puberty with the increase of androgen levels. According to Tanabe *et al.* (1979), testosterone levels in the plasma of males started to increase 21 days after hatching, reached a plateau at 35 days and increased again after 42 days of age. At approximately six weeks of age, Queensland wild birds in Australia have shown agonistic approaches and attempts of copulation with their dams (McBride *et al.*, 1969). Copulation attempts happened when the hen was crouched, which permitted the cockerels to try stepping on their backs. Such behavior was observed for approximately one week. In the study, the hen has probably learned to get up and change positions when a male chick came closer, or started agonistic behaviors with the chick. Female chicks, on the other hand, were not treated similarly, and they were allowed to climb the hens as many times as they tried to.

Sensitivity to testosterone between a commercial strain and a feral strain has been described by Astiningsih and Rogers (1996) using one-day-old male and female chicks treated with testosterone enanthate. Comb size was measured, and the attack and copulation behaviors were assessed using the above-mentioned hand tests. All data were significantly different between sex and strains. Copulation and fighting scores were greater in the males from the wild strain. It is worth noting that even non-treated wild males had greater scores, which increased further after hormone treatment. Treated wild females have also shown greater scores than females from the commercial strain. Comb results have shown contrary effects; birds from the commercial strain had combs with greater volume, either expressed as the real values or as the values adjusted to live body weight. The results indicate that chicks from the wild strain might have a greater number of central receptors and less peripheral receptors for testosterone, or yet that receptor sensitivity in wild birds is greater than in the commercial strain.

Effects of rearing conditions on aggressiveness

The rearing system and management might have great influence on the expression of aggressiveness. Environmental stress is a possible triggering factor of aggressive behaviors. There are many stress-inducing factors in domestic bird rearing, such as feed restriction, high stocking densities, unability to walk and perform specific behaviors of feeding (foraging for food, ground scratching, digging, pecking) or cleaning (tiding up the feathers, sand-bathing), and absence of light and/or long periods of exposure to artificial lighting.

The effect of female presence on the development of sexual and aggressive behaviors in White Leghorn birds by the interaction between bird pairs was studied by Leonard *et al.* (1993). The birds were divided into two different groups: a flock of males and a flock comprised of a male with females. The males of each treatment were placed in an unbiased paddock with a female model, or a white jar that served as control stimulus. The tests were carried out after 20 and 47 weeks of age. The male flock had already been exposed to females on the second day of evaluation. The results indicated that males reared in groups without females might decrease sexual behavior and increase aggressiveness, but the difference is no longer seen in older birds or after exposing males to females.

Males from laying strains do not show aggressiveness towards females when fed *ad libitum* or submitted to feed restriction during rearing. Despite of genetic selection for fighting ability, males from fighting strains have also not shown aggressiveness towards females. Therefore, Milman and Duncan (2000) concluded that feed restriction during rearing had little influence on aggressive and sexual behaviors of adult laying-type males, and that selection for aggressiveness has not resulted in males that were more aggressive towards females. Aggression episodes for mating or during copulation were only seen in meat-type males and have not been related with feed restriction.

Lateralization and hemisphere domination for fighting and copulation

The treatment of the left hemisphere of two-day-old males or females with cycloheximide or glutamate increased the behaviors of fighting and copulation (Bullock and Rogers, 1985). Therefore, the administration of drugs to only one brain hemisphere resulted in lateralization of the control and Rogers *et al.* (1985) evaluated chicks monocularly using the hand tests after testosterone administration. Testosterone-treated chicks showed high copulation levels when the tests were carried out using the left eye, but birds tested using the right eye showed responses as if they had not been given testosterone. This finding suggests that the neural circuits of the right side of the brain, which receive stimuli from the left eye, activate copulation, whereas the neural circuits in the left side of the brain suppress copulation. Such circuits might be in the right hemisphere or in the right side of hypothalamus. Since copulation assessment in testosterone-treated chicks that were tested

binocularly was similar to the behavior of chicks that were tested using the left eye, it might be concluded that the right side of the brain shows dominance. In control birds, which were tested with the right eye, the neural circuits of the left side of the brain were dominant (Rogers *et al.*, 1985). Therefore, not only the right side dominated when testosterone levels were high, but cell processes in the right side were also able to maximize testosterone action in this side (Hutchison *et al.*, 1986). Although there were more difficulties in the methodology of monocular assessment of fighting behavior, the results were similar to those obtained for copulation. Therefore, any treatment of male chicks with steroid hormones that increase fighting and copulation seem to invert the hemisphere dominance in regard to these behaviors.

Genetic differences between individuals and populations

Aggressive behavior and sexual drive in roosters were studied by Siegel (1959), who reported strong evidences of additive genetic control of the aggressiveness in birds. On the other hand, there was inexpressive contribution of genes with non-additive effects, since the aggressiveness scores of the birds originated from crosses of the studied strains were intermediate to parental phenotypes. Estimated genetic correlations between aggressiveness and characteristics of sexual behavior in cockerels with previous sexual experience have shown moderate values: 0.47 for aggressiveness and courting, 0.50 between aggressiveness and complete mating, 0.36 between aggressiveness and stepping on the female, and 0.40 between aggressiveness and waltzing; the two last values were not significant ($p > 0.05$). The correlations between social aggressiveness and the characteristics of sexual behavior, sperm quality and fertility have also been evaluated (McDaniel and Craig, 1959). It was shown that social aggressiveness was moderate but significantly correlated with the characteristics of reproductive behavior and semen quality; values were 0.32, 0.22, 0.26 and 0.30 between aggressiveness and score of sexual effectivity at 6.5 months, female crouching and displaying of cooperative behavior, and finally concentration of spermatozoa and age at sexual maturity, respectively.

Komai *et al.* (1959) have also investigated the genetic basis of social aggressiveness, which was evaluated by the social position of females. Social position was based on classifying each individual according to the percentages of winning and losing

fights (victories and defeats), pecking, threatening and escapes. Heritability estimates were 0.34 in Leghorn birds and 0.39 in birds from other strains, while overall heritability was 0.30. These findings indicate that selection to change the aggressiveness is effective in birds, both between and within strains. Birds from submissive families have been reported to show higher age at sexual maturity and lower egg production in situations of competition with more aggressive strains of laying hens, although only low estimated values of correlation have been seen (Tindell and Craig, 1959).

A trial has been conducted for four generations using divergent selection for social aggressiveness, measured by the number of wins (victories) in the first contact with other bird and also by the social position achieved in the pecking order (Guhl *et al.*, 1960). Dominance was determined by passive submission (one bird avoided the other), threatening followed by submission, pecking followed by submission, or fighting followed by avoidance. The initial population of White Leghorn birds was randomly sub-divided into two groups. The first was selected for social aggressiveness and the other was conversely selected. Heritability of social aggressiveness was estimated to be 0.30 and there was moderate correlation (0.60) between the two forms of aggressiveness evaluation. Four generations (approximately four years in this trial) were enough to separate the initial population in two groups that were very different in regard to aggressiveness, so that divergence was evident as early as the second generation. After four generations of selection, the great majority of wins in the first contact were obtained by animals from the group selected for higher aggressiveness (75 to 100%). The authors reported marked differences in the aggressive behavior according to sex. Males were more frequently involved in fightings than females; nevertheless, frequency of fighting apparently has not been greater in males selected for higher aggressiveness than those selected for less aggressiveness. Furthermore, dominant males induced others more frequently to avoidance behaviors than females. Threatens and peckings were more decisive in females than in males. According to the authors, fighting roosters do not show submission, whereas the Red Jungle Fowl seem to show higher levels of aggressiveness and submission. Therefore, winning in the first contact is a carachteristic that would evaluate both aggressiveness and submission, or one of these behaviors would be detected more promptly than the other. If on the one hand strains that show low aggressiveness levels are desirable from the point

of view of flock management, on the other hand, higher aggressiveness levels have been related to reproductive behavior and gamete production. Therefore, genetic selection of birds should be more focused on social behavior.

The choice of breeders based on criteria of aggressiveness results in genetic differences concerning aggressiveness and male sexual activity. Such differences might be caused by different physiological responsiveness to androgen excitement.

Selection modifies the sensitivity to androgens. Ortman and Craig (1968) selected for high or low social dominance within groups of White Leghorn and Red Rhode Island chickens during five generations. Comparison was performed using four-month-old males from many strains that had been castrated before two weeks of age. The males were sub-divided into groups and androgens were administered at different doses. Assessments were performed by means of competition between two capons of each strain selected for high and low social dominance that were given the same androgen level. Two conclusions were taken: **(1)** androgen administration increased agonistic behavior in castrated males, thus without the testicular source of male hormone; and **(2)** males from the strains selected for greater aggressiveness showed more probability of winning competitions against the males of less aggressive strains. The changes produced by genetic selection were caused mainly through the changes in the physiological responses, and not due to changes in the amount of androgen that was produced.

The problems caused by aggressiveness in the poultry industry are more associated to laying hens, whereas problems with passive and docile behaviors have been generally reported in broiler breeders (Milman and Duncan, 2000). Nevertheless, such differences are probably more related to differences in maturity than genetics, since broiler breeders are marketed at approximately 42 days, i.e., they are still young. At this age, meat-type roosters showed lower aggressiveness than egg-type roosters (Mench, 1988), but it is possible that aggressiveness in broiler chickens does not increase before the sexual maturity.

According to Milman and Duncan (2000), broiler breeder producers have been facing problems of increasing aggressiveness in the rearing phase and, more recently, also in the reproductive phase. Males have shown extreme aggressiveness during mating, forcing copulation and causing serious injuries to females or even death. Some males chase females and trap them in the corners of the poultry houses.

Frightened females scape, hide in the nests and avoid the males. Therefore, they stay in less attractive areas in terms of food and water, which diminishes the flock fertility and consequently causes economical losses. In order to explain such observations, the differences in the sexual behavior have been evaluated in terms of rooster aggressiveness in three different strains: a broiler strain, a layer strain and a fighting rooster strain (Milman and Duncan, 2000). There were different levels of bird management during the experiment, i.e., fighting roosters were less docile and showed tendency to fight with other males. Nevertheless, the aggressive behavior of the male against females was reported only in the broiler strain. In the other two strains, the males elaborated all the expected reproductive behaviors and copulation, without threatening or harming the females. In the broiler strain, there were abnormalities on the sequence of reproductive behaviors of males, i.e., some of them have ignored the courting behavior, beginning directly with climbing and copulation. Females, in turn, were not aware of male intentions and would not be prepared for mating nor demonstrate the expected behaviors of crouching and exposure of the cloaca. The alterations of male reproductive behavior in this strain might have been an indirect response to the intense selection for higher growth rates and development of breast and thigh muscles.

Stress and aversion stimuli

Aggression is highly related to responses to pain in almost all species (Craig, 1981) and, it generally leads to aggression and fights if induced in the presence of partners (Ulrich, 1966).

Frustration, such as that caused by feed restriction in hens, may also trigger aggressiveness. Frustration was inflicted to hungry birds by covering the feed tray with clear plastic, so that the food was seen but could not be touched (Duncan and Wood-Gush, 1971). In every tested situation, the frustrated birds that were socially dominant showed increased aggression againt submissive birds, and aggression frequency increased considerably when feed restriction lasted the whole day in comparison to shorter periods of restriction.

Males generally exibit "passive dominance" over females and are rarely caught pecking or threatening females under everyday circumstances. Nevertheless, hungry and frustrated broilers were excessively aggressive when paired with females under the conditions of the above-mentioned study (Duncan and Wood-Gush, 1971). Females were pecked 806 times or threatened by the hungry and frustrated birds in 8 hours, in comparison to 18 peckings when kept with non-frustrated males.

King (1965) has shown that extremely frustrating situations might generate questionable results, particularly when social tension levels are already high, such as in the case of young broilers. The author has determined the social hierarchy by the pecking order in three groups of young broilers and compared the frequency of aggression and the estability of dominance relationships after restricting the birds for 24 hours and then showing the food for one hour in three different manners. Uniform spread of the food on litter resulted in very low aggression frequency, since all individuals were busy eating during that period. Food provided in a round feeder that permitted the access of all individuals, but forming groups, increased aggressions 36 times in comparison to the previous situation, and the incidence of attack by subordinates or threatening dominant birds was 5%. Finally, individual access to food caused an outburst of aggressions and violations of the pecking order that happened at a frequency of approximately 50%. The established dominance relationships returned to normal values in the absence of extremely frustrating situations.

Craig (1981) has suggested many possibilities for aggression when the animals are frustrated and, probably, more than one would be happening at the same time. Frustration occurs together with excitation and consequent movimentation. The consequent changes in the activity patterns of individuals generally leads to more frequent interactions than usual. In case that there is a single and scarce resource, the personal space of dominant individuals might be invaded by subordinates and generate an aggressive response, or the situation might be so hostile that would trigger the agonistic behavior, such as in the case of pain.

When aggression is rewarded, fighting might become a means of satisfying a necessity. Once aggression begins, it might continue for longer than the time needed to obtain a reward, although the extinction of fight response might probably happen (Craig, 1981).

Many aspects of rooster fight might be explained by rewards paired with different responses, since growing to training, until fighting. Reward might be positive, represented by stimuli with positive connotations, such as a resource indispensable to survival or with hedonistic values, such as water, feed and company, or yet negative, associated to the

absence of electrical shocks or other stimuli with aversive connotation.

Individual space and territorial behavior

Aggression or aggression threatening are commonly used to exclude individuals from the personal space of an animal. McBride _et al._ (1963) have shown that the personal space do not extends equally in every direction, but it was bigger in the front of the chickens and most of the movements were intended to avoid the personal spaces of dominant hens. Attacks or threatening behaviors were ended frequently by the subordinate escaping to the limit of the personal space of a dominant animal, or by submission postures or out-of-order behaviors. These are behaviors out of the context of the situation, such as asking for food or displaying sexual facilitation behavior.

Many species, among which the domestic fowl, allows the subordinates to stay in the group as long as they exibit submission behaviors, but subordinates might sometimes be hurt or expelled (Craig, 1981; Price, 2002). The inability to escape or the absence of a submission behavior might cause the death in fighting roosters. The personal space may be minimized in non-competitive situations, but increases when resources are limited.

There are two typical responses of individuals to others of the same species, which is dependent on if they belong or not to the group (Craig, 1981). Although personal space is also present in groups, the existence of social distance indicates cohesion. Adult members in the group normally react with aggressive behaviors against intruders. As a consequence of taming, natural social groupings are rarely permitted. Few males are kept intact, the young are separated from their dams very early and, periodically, the individuals are re-organized in new groups. Nevertheless, the knowledge of how the social groups behave and organize themselves in the space might provide valuable information to understand behavior problems that are seen under artificial rearing conditions.

McBride _et al._ (1969) have described the territorial behavior of the red jungle fowl in the Southern Asian forest, which may be seen before and after the reproductive season. Two other manifestations of this behavior have been observed. In one situation, hens incubating eggs and those with young chicks became solitary and occupied living areas (home range). Such areas were overlapped for the different birds, which resulted in dominance relationships between pairs of molting hens or with progeny. Thus, although the two

hens could live in the same area, they would tipically avoid each other. On the other situation, dominant males would stay in fixed areas out of the reproductive season, but did not have exclusive control on such areas. Subordinate males moved between the limits of the groups and stayed at the external areas of the groups to which they were joined.

The dominant rooster has a fundamental role on the determination of the group movements and vigilance for intruders. McBride _et al._ (1969) observed that when the group moved to another territory, the male was the one that gathered the females before moving. The females interacted with the rooster while in movement, and the male had control over the space when they crossed areas without vegetation. In the case of threats, the male alerted the females and would walk parallel to the predator or potential predator, whereas the females would hide quietly. When the group was threatened, the male frightened the females by running towards them with opened wings. The male would be most of the time on guard and show an alert position while females ate, raising the tail and lowering the wings. On the other hand, the females were closer to the male while he relaxed to eat. The male was generally much more cautious than the females. It protected the females from other males, and threatened the intruder. Molting females and hens with chicks controlled the movements of the group, called attention to the food, were vigilant for intruders and defender in the presence of a potential danger.

Effect of isolation and overcrowding on aggressiveness

Under some circumstances, the animals are attracted to each other and maintain a close social interaction as a function of the space (e.g., the dam and its progeny, males and females during the reproductive season, and search for shelter close to the body of others); however, it is also observed that there must be a minimum space between individuals.

Birds reared in isolation show precocious and more intense aggressiveness than those reared in groups (Guhl, 1953, 1958; Gulh _et al._, 1960). Increased density, for example, housing of 100 individuals in an area previously occupied by 25, multiplies the group size by four and decreases the area per animal to a fourth of the previously available area. Decreasing the area per bird in half might affect groups of 4 or 400 individuals very differently.

Many studies with hens have suggested an interesting relationship between the area per bir and

aggression frequency. The decrease in the available space increased the frequency of aggressions and there is then a marked decrease as a function of greater agglomeration (Al-Rawi and Craig, 1975).

Hughes and Wood-Gush (1977) have also found a marked decrease in aggression under conditions of high density of caged birds. The observations indicated that normal displaying of threatening require a minimal area per bird that is not possible in the majority of the cages. Studies by Bhagwat and Craig (1979) have also clearly evidenced the reduction in the incidence of cage threatening. There was a reduction in aggressive peckings directed towards the head in ambients with high density. This might be explained by the fact that, under situations of extreme agglomeration, the pecking mechanism of a dominant bird is not activated or triggered by subordinate chickens, if these are already within the influence area of the dominant bird. Only the entrance into the personal space of an individual would cause such behavior (Hughes and Wood-Gush, 1977).

Results obtained by Ylander and Craig (1980) have demonstrated that the socially dominant bird (the third part or the third member) inhibits the aggressive interactions between pairs of subordinate birds. Males were particularly effective as inhibitors of aggressive behavior between dominant members of pairs of hens during feeding behaviors. There were only five escapes from pecking in 24 tests of ten minutes with hen pairs close to a male; when the male was one meter away, there were 21 and, when the male was temporarily removed from the area, there were 74 escapes. Escaping from threatening followed the same pattern, but the effects were less evident. Therefore, female aggressiveness was reduced in the presence of males in large or small groups (McBride *et al.*, 1969; Craig and Bhagwat, 1974; Bsary and Lamprecht, 1994). It is not clear, however, whether this effect might be attributed to the dominance of males or because sub-group formation is facilitated (Odén *et al.*, 2000).

Pairs of males kept in large cages with solid back walls from 12 to 20 weeks of age were easily classified into dominant and subordinate before 20 weeks, since the subordinate showed clear signs of physical abuse and submission posture, giving indirect evidence of frequent and severe aggression by the dominant member (Grosse and Craig, 1960). In the birds placed in cages that permitted 30% of this space per bird (Craig and Polley, 1977), the subordinate males delayed sexual maturity, but pairs of males in the second trial did not show any sign of physical abuse. Probably,

aggression between individuals was not possible due to the reduced available space.

Effect of group size on aggressiveness

Guhl (1953) has provided partial evidence that a group with 96 birds showed a complete pecking order. In a later study, groups with 100 to 400 birds were observed (Craig and Guhl, 1969). In the groups with 200 individuals, the hens tended to stay longer in some areas and were dominant in these places. Probably, the fixation to particular areas limits the necessity of recognizing a larger number of hens. Thus, the social difficulties associated to the gathering of many intruders in bigger groups might be prevented by the tendency of hens to fix in their own neighborhood.

Although groups of 100 or more birds might be socially organized, Banks (1956) has observed that the violations of the pecking order were more frequent when group size increased from 6 to 24 birds. A violation of the pecking order consists in a subordinate attacking its social superior. The relative frequency of such behavior has been associated to the group size, and more violations were seen in larger groups. The violations, however, were inefficient, since insubordination was immediately retaliated, and there has not been any reversion of the dominance degree. The author suggested that the reinforcement represented by the social position occupied in particular by hens was less important in larger groups, indicating that the limits for recognition were being reached. Evidences of other studies indicated that the pecking order is relatively stable in larger groups than those mentioned herein, nevertheless temporary confusion and lack of recognition might be responsible for higher aggression levels in larger groups.

Al-Rawi and Craig (1975) evaluated agonistic behavior and reported that the frequency of aggressive acts by hens housed in cage batteries increased with the increase in the group size (4 to 28 birds). Most of the described aggressive acts were pecking instead of threatening, and these have happened during feeding or when birds approached the feeder. In groups of 4, 8 and 14 birds, Al-Rawi *et al.* (1976) observed higher levels of aggression in the larger groups in the first eight weeks, but agonistic behavior was reduced in all groups, before being observed again at 26 weeks after grouping. Possibly, the hens that must live too close to each other in cages become so familiarized that there are not temporary failures of recognition, even in groups of 8 and 14 birds.

Estevez *et al.* (2003) have studied the ontogenesis of the aggressive behavior in chickens from 3 to18

weeks of age. It was suggested that the birds establish hierarchical dominance through aggressive interactions in small groups, but larger groups adopt a more tolerant social strategy and aggressiveness is reduced. Focal observations of birds within groups showed a decrease in the frequency of peckings and threatenings with the increase in the group size, although pecking and threatening frequency has increased with group size for some birds. Therefore, it becomes evident that hens adopt different social strategies with the increase in the size of groups, and it might be speculated that most birds might adopt a strategy of tolerance in large groups, whereas a minority might be tyrannical, addressing aggression indiscriminately towards other birds.

The system of social dominance that is constructed based on fighting and memory recognition of the individual positions in large groups is not sustained (D'Eath and Keeling, 2003). Besides, hens adapt and become less aggressive or restrict the movements towards defined territories. Some evidences have also indicated that the hens in large groups have not established the territory inside a separated area. Among others, Odén *et al.* (2000) identified the existence of sub-groups associated to territories when the hens had to live in large groups and attributed the difficulty of the observer in identifying an individual bird to the failure in recognizing such sub-groups. These overall findings corroborate results reported by Pagel and Dawkins (1997), who observed that hens in large groups are less aggressive and might change the social system to a system in which hierarchy is directly determined through the access to dominance and subordination signs instead of individual recognition in the small group.

Aggression maintenance

Individuals placed together in an unfamiliar area usually inspect the new ambient and partners, and usually there is quietness. Then, one or two pairs begin to interact agonistically. Males might be involved in fightings, whereas the females interact less vigorously in the majority of the hen breeds. Breeds and strains might differ in the intensity and duration of competitions for a dominance position (Craig, 1981). Fighting roosters might fight to death, unless they are separated; nevertheless, in most groups the result is decided rapidly within pairs. If the number of grouped birds is relatively small, the dominance order of all possible pairs might be established within some hours, although agonistic interactions might continue for relatively longer periods.

It is suggested that aggression might happen between young animals because they start playing spontaneously and playing become more vigorous with aging, until pain is accidently inflicted by one of the birds. It is known that pain triggers a defensive behavior or reflexive fight. The conditioning would explain the tendency to establish immediately dominance relationships; the dominant individual is rewarded and the subordinate is rewarded by the submissive behavior, since it will no longer be attacked.

Lorenz (1950) suggested the existence of a "specific energy for aggression", which would spontaneously begin in the nervous system and would accumulate until a limit, after which it should be released, in an analogy to a water source that fills a vessel and, once a limit is reached, the water should be discharged. On the other hand, Scott (1971) has considered fear and anger as the primarily responsible emotions for social fighting, which would be triggered by external stimuli, but once they had been activated, they would be extended and would increase reactivity to external stimuli, particularly if the behavior in curse was blocked. In the absence of additional external excitement, internal stimulations associated with anger and fear would be extinguished.

Some considerations

In the different *Gallus* species, natural selection has acted in favor of birds that were more efficient in acquiring and maintaining exclusive territories that provided them with abundant feeding, shelter and protection against predators. On the other hand, natural selection has also favored an intense internal competition among individuals of a population, mainly competition for mating opportunities. In this scenery of constant competition for territorial maintenance and group exclusiveness, dominant roosters with attributes that enable them to intense vigilance, prevention against invations (threatening displays) and combat habilities had more descendants and increased the presence of its genes in the population. Similar patterns of vigilance and defense are exhibited by females imbued with care to the progeny. Therefore, it is easy to understand the importance that the aggressive behavior and the fighting abilities have on this species under natural conditions.

The same peculiarities of the hierachical social system, together with the promiscuous reproductive behavior, the extensive feeding habits and the short life cycle of these animals, made domestication easy and enabled prompt world dispersion of these species

in the genus *Gallus*. Afterwards, the birds have been submitted to different rearing systems and artificial selection of the best individuals in those specific environments, resulting in a wide range of breeds and, later, strains within breeds that have been developed mainly for human feeding. Selection of production attributes has certainly favored the permanence of animals that were more docile and with greater social tolerance.

Poultry rearing has suffered profound changes after the mid 1900s, and has become an activity in which the main decisions concerning selection and reproduction were controlled by few commercial companies. It was then called poultry industry, in which there was intensification of the production systems, smaller area per bird, higher number of birds housed in the same area, preventive administration of drugs and search for management that minimized the problems that resulted from the new rearing conditions. The majority of the reviewed literature from the second half of the 20th century deals with finding out and proposing solutions to the behavioral problems caused by the intensification of the rearing system. The virtual absence of genetic studies on behavior in the same period reflects in part the fact that some companies were not interested in revealing the advances and problems faced by them neither their search for solutions to the problems that have emerged, since there was no interest in modifying the intensive and vertical production system. However, the few genetics studies of aggressiveness behaviors in domestic fowls evidenced that neither domestication nor the intense artificial selection were able to change the social behavior of the birds, and that the intrinsic patterns of aggressiveness of this species are still seen.

It is also noticeable the lack of scientific studies with fighting breeds of birds. It is expected that the individuals from these breeds show the same biological mechanisms and aggressive behavior patterns that their conspecifics. On the other hand, these are possibly exacerbated in fighting birds, since they have not undergone the attenuating effects of artificial selection that is practiced in the commercial meat-type or egg-type strains of birds. Besides, the rearing environment of fighting birds is more close to natural habitats, i.e., both incubation and growth happen in the presence of the dam and the other birds of the group. Therefore, the study of aggressiveness expression in the birds that are closer to the original wild genotype would enable a broader comprehension of the biological mechanisms involved in such behaviors, as well as the importance and usefulness of these birds to the current animal populations.

REFERENCES

Adret-Hausberger M, Cumming RB. Social attraction to older birds by domestic chickens. Bird Behaviour 1987; 7:44-46.

Al-Rawi B, Craig JV. Agonistic behavior of caged chickens related to group size and area per bird. Applied Animal Ethology 1975; 2:69-80.

Al-Rawi B, Adams AW, Craig JV. Agonistic behavior and egg production of caged layers: genetic strain and group-size effects. Poultry Science 1976; 55:796-807.

Andrew RJ. Effects of testosterone on the behaviour of the domestic chick. I. Effects present in males and not in females. Animal Behavior 1975a; 23:139-155.

Andrew RJ. Effects of testosterone on the behaviour of the domestic chick. II. Effects present in both sexes. Animal Behavior 1975b; 23: 156-158.

Astiningsih K, Rogers LJ. Sensitivity to testosterone varies with strain, sex, and site of action in chickens. Physiology and Behavior 1996; 59:1085-1092.

Banks EM. Social organization in red jungle fowl hens (*Gallus gallus subsp*). Ecology 1956; 37(2):239-248.

Bardo P. Central nervous mechanism for expression of anger in animals. In: Reymart ML editor. Feelings and emotions. New York: McGraw-Hill; 1950.

Bateson PPG. Changes in chicks´ response to novel moving objects over the sensitive period of imprinting. Animal Behavior 1964; 12: 479-489.

Bateson PPG. How do sensitive periods arise and what are they for? Animal Behavior 1979; 27:470-486.

Bateson PPG. Is imprinting such a special case? Philosophical Transactions of the Royal Society of London 1990; 329:125-131.

Bhagwat AL, Craig JV. Effects of male presence on agonistic behavior and productivity of White Leghorn hens. Applied Animal Ethology 1979; 5:267-282.

Bshary R, Lamprecht J. Reduction of aggression among domestic hens (*G. domesticus*) in the presence of a dominant third party. Behaviour 1994; 128:311-324.

Bullock SP, Rogers LJ. Sex differences in the effects of testosterone and its metabolites on brain asymmetry for the control of copulation in young chicks. In: 16th Proceedings of the Australian Physiology and Pharmacological Society; 1985; Sydney, Australia. p.235.

Craig JV, Guhl AM. Territorial behavior and social inter-actions of pullets kept in large flocks. Poultry Science 1969; 48:1622-1628.

Craig JV, Bhagwat AL. Agonistic and mating behavior of adult

chickens modified by social and physical environments. Applied Animal Ethology 1974; 1:57-65.

Craig JV, Polley CR. Crowding cockerels in cages: effects on weight gain, mortality and subsequent fertility. Poultry Science 1977; 56:117-120.

Craig JV. Domestic animal behavior. New Jersey: Pretince-Hall; 1981.

D'Eath RBD, Keeling LJ. Social discrimination by laying hens in large groups: from peck orders to social tolerance. Applied Animal Behavior Sciences 2003; 84:197-212.

Dimond SJ. Effects of photic simulation before hatching on the development of fear in chicks. Journal of Comparative and Physiological Psychology 1968; 65:320-324.

Duncan IJH, Wood-Gush DGM. Frustration and aggression in the domestic fowl. Animal Behavior 1971; 19:500-504.

Estevez I, Keeling LJ, Newberry RC. Decreasing aggression with increasing group size in young domestic fowl. Applied Animal Behavior Sciences 2003; 84:213-218.

Gottlieb G. Imprinting in relation to parental and species identification by avian neonates. Journal of Comparative Physiology and Psychology 1965; 59: 345-356.

Grosse AE, Craig JV. Sexual maturity of males representing twelve strains of six breeds of chickens. Poultry Science 1960; 39:164-172.

Guhl AM. Social behavior of domestic fowl. Kansas: Kansas Agricultural Experimental Station; 1953. (Bulletin, 73).

Guhl AM. The development of social organization in the domestic chick. Animal Behaviour 1958; 6:92-111.

Guhl AM, Craig JV, Mueller CD. Selective breeding for aggressiveness in chickens. Poultry Science 1960; 39:970-980.

Hess EH. Imprinting. Science 1959; 130:133-141.

Hughes BO, Wood-Gush DGM. Agonistic behaviour in domestic hens: the influence of housing method and group size. Animal Behaviour 1977; 25:1056-1062.

Hutchison JB, Steimer TJ, Hutchison RE. Formation of behaviorally active oestrogen in the dove brain: induction of preoptic aromatase by intracranial testosterone. Neuroendocrinology 1986; 43:416-427.

Johnson MH, Bolhuis JJ, Horn G. Predispositions and learning: Behavioral dissociation in the chick. Animal Behaviour 1992; 44: 943-948.

Jones RB. Sex and strain differences in the open-field responses of the domestic chick. Applied Animal Ethology 1977; 3:255-261.

Jones RB, Waddington D. Modification of fear in domestic chicks, *G. gallus domesticus*, via regular handling and early environmental enrichment. Animal Behaviour 1992; 43:1021-1033.

Jones RB, Waddington D. Attenuation of the domestic chick´s fear of human beings via regular handling: in search of a sensitive period. Applied Animal Behaviour Science 1993; 36:185-195.

Kilham P, Klopfer PH, Oelke H. Species identification and color preferences in chicks. Animal Behaviour 1968; 16:238-244.

King MG. Disruptions in the pecking order of cockerels concomitant with degrees of accessibility to feed. Animal Behaviour 1965; 13:504-506.

Komai T, Craig JV, Wearden S. Heritability and repeatability of social aggressiveness in the domestic chicken. Poultry Science 1959; 38(2): 356-359.

Kruijt JP. Ontogeny of social behaviour in Burmese Red Jungle Fowl (*Gallus gallus spadiceus*). Behaviour 1964; suppl 12:1-201.

Leonard ML, Zanette L, Fairfull RW. Early exposure to females affects interactions between male White Leghorn chickens. Applied Animal Behaviour Science 1993; 36:29-38.

Loiselet J. Behaviour and feather pecking are priority areas for selection. World Poultry 2004; 7(20):22-23.

Lorenz KZ. The comparative method in studying innate behaviour patterns. Symposium of Society of Experimental Biology 1950; 4: 221-269.

McBride G, James JW, Shoffner RN. Social forces determining spacing and head orientation in a flock of domestic hens. Nature 1963; 197:1272-1273.

McBride G, Parer IP, Foenander F. The social organisation of behaviour of the feral domestic fowl. Animal Behaviour Monograph 1969; 2: 127-181.

McDaniel GR, Craig JV. Behavior traits, semen measurements and fertility of White Leghorn males. Poutry Science 1959; 38(5):1005-1014.

Mench JA. The development of aggressive behaviour in male broiler chicks: a comparison with laying-type males and the effects of feed-restriction. Applied Animal Behaviour Sciences 1988; 21:233-242.

Milman ST, Duncan IH. Strain differences in aggressiveness of male domestic fowl in response to a male model. Applied Animal Behaviour Sciences 2000; 66:217-233.

Newman S. Quantitative and molecular genetic effects on animal well-being adaptive mechanisms. Journal of Animal Science 1994; 72:1641-53.

Oden K, Vestergaard KS, Algers B. Space use and agonistic behaviour in relation to sex composition in large flocks of laying hens. Applied Animal Behaviour Sciences 2000; 67:307-320.

Ortman LL, Craig JV. Social dominance in chickens modified by genetic selection-physiological mechanisms. Animal Behaviour 1968; 16:33-37.

Pagel M, Dawkins MS. Peck orders and group size in laying hens: future contracts for non aggression. Behavioural Processes 1997; 40:13-25.

Phillips RE, Youngren OM. Unilateral kainic acid lesions reveal dominance of right archis triatum in avian fear behavior. Brain Research 1986; 377:216-220.

Phillips RE, Siegel PB. Development of fear in chicks of two closely related genetic lines. Animal Behaviour 1966; 14:84-88.

Price EO. Animal domestication and behavior. Cambridge: Cab International; 2002.

Rajecki DW. Formation of leap orders in pairs of male domestic chickens. Aggressive Behavior 1988; 14:425-436.

Regolin L, Vallortigara G, Zanforlin M. Perceptual and motivational aspects of detour behaviour in young chicks. Animal Behaviour 1994; 47:123-131.

Rogers LJ, Workman L. Light exposure during incubation affects competitive behaviour in domestic chicks. Applied Animal Behaviour Science 1989; 23:187-198.

Rogers LJ, Astiningsih K. Social hierarchies in very young chicks. British Poultry Science 1991; 32:47-56.

Rogers LJ. The development of brain and behaviour in the chicken. Cambridge: CAB International;1995.

Rogers LJ, Zappia JV, Bullock SP. Testosterone and eye-brain asymmetry for copulation in chickens. Experientia 1985; 41:1447-1449.

Ros AFH, Dieleman SJ, Groothuis TGG. Social stimuli, testosterone, and aggression in gull chicks: support for the challenge hypothesis. Hormones and Behaviour 2002; 41:334-342.

Rushen J. Frequencies of agonistic behaviours as measures of aggression in chickens: a factor analysis. Applied Animal Behaviour Science 1984; 12:167-176.

Salzen EA. Imprinting and fear. Zoological Society of London Symposium 1962; 8:199-217.

Scott JP. Theoretical issues concerning the origin and causes of fighting. In: Eleftheriou BE, Scott JP, editors. The Physiology of aggression and defeat. New York: Plenum Press; 1971.

Siegel PB. Evidence of a genetic basis for aggressiveness and sex drive in the White Plymouyh Rock Cock. Poultry Science 1959; 38(1):115-118.

Sluckin W. Imprinting and learning. London: Methuen; 1966.

Tanabe Y, Nakamura T, Fujioka K, Doi O. Production and secretion of sex steroid hormones by testes, the ovary and the adrenal glands of embryonic and young chickens (_G. domesticus_). General and Comparative Endocrinology 1979; 39:26-33.

Tindell D, Craig JV. Genetic variation in social aggressiveness and competition effects between sire families in small flocks of chicken. Poultry Science 1959; 39:1318-20.

Tuculescu RA, Griswold JG. Prehatching interactions in domestic chicks. Animal Behavior 1983; 31:1-10.

Ulrich R. Pain as a cause of aggression. American Zoologist 1966; 6: 643-662.

Vallortigara G, Andrew RJ. Lateralization of response by chicks to change in a model partner. Animal Behavior 1991; 41:187-194.

Vallortigara G, Andrew RJ. Olfactory lateralization in the chick. Neuropsychologia 1994; 32:417-423.

Vallortigara G. Affiliation and aggression as related to gender in domestic chicks (_Gallus gallus_). Journal of Comparative Psychology 1992; 106:53-57.

Vidal JM. The relations between filial and sexual imprinting in the domestic fowl: effects of age and social experience. Animal Behavior 1980; 28:880-891.

Workman L, Andrew RJ. Simultaneous changes in behaviour and lateralization during the development of male and female domestic chicks. Animal Behavior 1989; 88:596-605.

Ylander DM, Craig JV. Inhibition of agonistic acts between domestic hens by a dominant third party. Applied Animal Ethology 1980; 6: 63-69.

Young CE, Rogers LJ. Effects of steroidal hormones on sexual, attack, and search behavior in the isolated male chick. Hormones and Behavior 1978; 10:107-117.

Zajonc RB, Wilson WR, Rajecki DW. Affiliation and social discrimination produced by brief exposure in day old domestic chicks. Animal Behavior 1975; 23:131-138.

Zayan R. An analysis of dominance and subordination experiences in sequences of paired encounters between hens. In: Zayan R, Duncan IJH, editors. Cognitive aspects of social behaviour in the domestic fowl. Amsterdan: Elsevier; 1987.