



## The Effects of Housing Systems on Behaviour, Productive Performance and Immune Response to Avian Influenza Vaccine in Three Breeds of Ducks

**Mohamed A. El-Edel**

Department of Husbandry and  
Development of Animal Wealth, Faculty  
of Veterinary Medicine, Damanhur  
University, Damanhur, Egypt.  
email: eledel\_m@yahoo.com

**Sherif Z. El-kholya**

Department of Husbandry and  
Development of Animal Wealth, Faculty  
of Veterinary Medicine, Damanhur  
University, Damanhur,  
Egypt.

**Usama A. Abou-Ismael**

Department of Husbandry and  
Development of Animal Wealth, Faculty  
of Veterinary Medicine, Mansoura  
University, Gomhoria St., Mansoura,  
P.O. box 35516, Egypt.

**Abstract:** Three hundred one-day-old mixed sex ducklings (100 Cherry valley, 100 Moulard and 100 Pekin ducks) were allotted into either indoor housing system (n=2); where ducklings within each breed were brooded and reared without any access to an outdoor yard until slaughtering, or outdoor housing system (n=2); where ducklings were allowed to an outdoor access from the 3<sup>rd</sup> week of age until slaughtering. Behaviours of the birds were collected in four periods per day (observation week); two periods in the morning and two in the afternoon every week for five observation weeks. Body weights and weight gains of birds were also determined weekly for five consecutive weeks. Cellular immune responses (phagocytic activity and phagocytic index) of the birds to Avian Influenza vaccine was measured at the 3<sup>rd</sup> and 7<sup>th</sup> day of vaccination whereas, antibody responses to vaccination were measured at the 14<sup>th</sup> and the 28<sup>th</sup> days of vaccination. The obtained results showed that Cherry valley ducks exhibited higher levels of panting and total body care behaviour compared to both Moulard and Pekin. Housing ducks indoors increased standing, preening, wing stretching, wing and leg stretch, panting, total body care, floor exploration and total exploration, and aggressive behaviours. Cherry valley ducks had higher initial and final body weight than Moulard and Pekin however, Pekin ducks had heavier body weights during the 2<sup>nd</sup>, 4<sup>th</sup> and 6<sup>th</sup> week of age. Moreover, Pekin ducks gained more weight at the 2<sup>nd</sup> week of age whereas, during the 4<sup>th</sup>, 6<sup>th</sup> and 8<sup>th</sup> week of age, Cherry valley gained more weight than Moulard and Pekin. Rearing ducks in indoor housing systems resulted in a non-significant reduction in their body weights during the 8<sup>th</sup> week of age, while during the 4<sup>th</sup> week of age indoor-housed ducks had higher body weights and weight gains than rearing them under outdoor systems. On contrary, rearing ducks in outdoor systems increased their body weight gain during the 6<sup>th</sup> and the 8<sup>th</sup> week, and their total weight gain. There were no significant differences between the three duck breeds for the phagocytic activity after the 3<sup>rd</sup> and the 7<sup>th</sup> day of vaccination however, phagocytic index increased in Pekin ducks after the 7<sup>th</sup> day of vaccination compared to both Cherry valley and Moulard ducks. Moreover, keeping ducks in indoor systems increased phagocytic activity after the 3<sup>rd</sup> day of vaccination, and phagocytic index after the 7<sup>th</sup> day of vaccination. From these results it could be concluded that genotype can affect behaviour, productivity and responses of ducks to immune challenges. Taken the behavioural, productive and immunity indicators of welfare together, it appears that -under the farm conditions- Cherry valley ducks performed well under indoor housing systems, and Moulard ducks performed well under outdoor housing systems whereas, the performance of Pekin ducks was less

affected by the housing systems. Improving housing conditions of ducks intended for meat production does not only improve their welfare but may also have an economic importance through direct consequences on health, productivity and consumers demand.

**Keywords:** Duck, Housing, Behaviour, Productive Performance, Immune Response and Avian Influenza.

### I. INTRODUCTION

Among poultry, ducks can be more easily brooded, needless care and are less subjected to diseases than the chicken (Modak, 1996). As such; the people in some areas are generally more interested in raising ducks than chicken. Exotic ducks like Pekin, Moulard and Cherry valley ducks are very much popular for commercial meat production under ideal farm condition. But their production performances and behaviours are not known to us when they are kept in conventional system (farmer's condition). This popularity of rearing ducks could be due to -among other factors- their improved ability to tolerate heat. One reason of why ducks are able to tolerate high temperature is that they have a small esophagus with no crop and so they have only limited ability to store feed. This reduces heat arising from digestion and subsequent metabolic activity, preventing hyperthermia when daytime temperature increases (Cherry and Morris, 2008). Controlling the ducks' environment, particularly temperature, humidity, litter moisture and ammonia is crucial to their welfare. Effective ventilation systems, high quality straw and access to some form of open water were considered important for duck welfare (Jones and Dawkins, 2010b; Liste *et al.*, 2012). Knierim *et al.* (2004) stated that open water drinkers can affect behaviour, health, particularly eyes and nostril health of ducks and hygiene of plumage positively and can therefore improve welfare. Open water drinkers also had a positive impact on the plumage condition. The open water drinking systems were very well accepted by the birds and are, concerning behaviour, a health and welfare of birds, an improvement in housing systems of Peking ducks. Moreover, there is much potential to raise the level of duck production; however, the emphasis must shift from free-range system to semi-intensive systems with improvement in nutrition and health. It therefore appears important to improve the

housing conditions of the birds raised for human consumption. This is –in part- important because of the world-wide growing interest in higher-quality products originating from animals kept under conditions ensuring their welfare (Horne and Achterbosch, 2008).

More intensive research into nutrition, health and other management practices is required in order to maximize the potentials of the duck production (Duru *et al.*, 2006). Free-range access caused a reduction in body weight which together with increased mortality in chickens decreased welfare (Baeza *et al.*, 2001; Połtowicz and Doktor, 2011). In turn, Knust *et al.* (1995) reported that free-range Peking ducks achieved lower body weight compared to ducks reared indoors. In the case of Moulard, free-range rearing contributed to an increase in their body weight. Similar relations were reported by Muriel and Pascual, (1995) for 81-day old Red-star Shaver cockerels. Połtowicz and Doktor, (2011) reported that during the 42 days of rearing under two system of chickens rearing; indoors housing on deep litter, and outdoor housing with an access to a grassy area (0.75 m<sup>2</sup>/bird) from the morning (7 am) to the afternoon (6 pm), chickens achieved the mean body weight of 1.71 and 1.65 kg; respectively. It is therefore important to emphasize that the effects of different environmental modification regimens depend mainly on the species and strains of the animals experiencing it (Knust *et al.*, 1995; Szász *et al.*, 1997; Chapillon *et al.*, 1999). The Council of Europe (1999, T-AP: [95/20]) has therefore specifically recommended that duck genotypes should be selected to avoid health and welfare problems (article 11) and that scientific studies on welfare should be carried out before modified genotypes are used for production (article 21).

In this study a various welfare indicators regimen was used to investigate how different genotypes of ducks perform under different housing conditions. This regimen involved the use of multiple indicators of welfare including behavioural, productive performance and immunological indicators and was therefore named integrated (Smidt, 1983) or holistic (Simonsen, 1996) approach. It is generally agreed that there is no single measure of welfare and that to get a clear picture of how individuals cope with their environments and hence the biological cost to the animals responding to it, several different measurements have to be assessed (Broom, 1996; Broom and Johnson, 1993). Relative changes in production levels, particular behaviours and immune responses of individuals under controlled housing conditions can clearly indicate changes in welfare (SCAHAW, 1998). On the other hand, there are also some difficulties related to the use of this approach such as conflicting results may in some occasions be obtained (Mason and Mendl, 1993). Another problem in the evaluation of animal welfare is the lack of knowledge of how animals experience, for example, the states of disease, conflict or frustration (Fraser, 1995).

The current study was designed to quantify differences in behaviours between three genotypes of ducks; Peking, Moulard and Cherry valley White ducks. An additional objective of the study was to compare the welfare and

performances of ducks under two housing systems (indoor and outdoor) to determine the most suitable breed of ducks for meat production under farmer's condition.

## II. MATERIALS AND METHODS

This study was conducted in the period extending from December till February at the duck farm belonging to the Faculty of Veterinary Medicine, Damanhur University, Damanhur, Egypt. The experimental design and procedures were approved by the Committee for Animal Care and Faculty of Veterinary Medicine, Damanhur University. A total of 300 birds of mixed sex representing three different genotypes of ducks were used in this study; Peking (French strainstare 53), Cherry valley (the world's first hybrid egg-type duck known as CV2000, Cherry Valley Farms, England) and Moulard ducks (a cross between Peking female and Muscovy male). The birds were obtained from the French company, El Sadat city, Al Menofia province, Egypt.

### A. Flock management:

The birds were housed in a clean and well-ventilated house that was provided with a gas heater, in addition to incandescent lamps. The floor of the house was covered with a fresh and clean wheat straw as a litter. The house was equipped with suitable waterers and feeders. Feed and clean water were supplied *ad libitum*. Ducklings of all breeds were fed on a starter ration containing 21% crude protein for the first three weeks of age then on a grower feed containing 16% crude protein until marketing. The starter and grower basal diets were obtained from a commercial feed company (Fath Allah Group Company®, Etay Elbaroud, Al Behira, Egypt). Ducklings were floor brooded starting with a temperature of 33 °C at the birds' level from 1 to 3 days of age, and the temperature was then reduced gradually to room temperature (21 °C) at 14 days of age (Fan *et al.*, 2008). All birds were healthy, supplied with their requirements of feed according to NRC and were vaccinated against Avian Influenza with a 0.5 ml intramuscular (in thigh muscles) injection of Avian Influenza (AI) vaccine at the 14<sup>th</sup> day of age.

### B. Experimental design:

The birds were one-day-old at the beginning of the experiment. The birds were wing banded using metal wing bands (Fath Allah Group Company®, Alexandria, Egypt). The birds were housed and brooded in an open-sided house until three weeks of age. At the beginning of the fourth week one hundred birds of each breed (representing two replicates) was arbitrarily assigned to the following two housing systems. 1- Indoor housing system: 150 ducklings (50 birds of each breed) were brooded and reared in the same house (10 m length × 5 m width) without outdoor access until they were slaughtered (the stocking rate was 15 kg of live weight/m<sup>2</sup> of floor space). 2- Outdoor housing system: 150 ducklings (50 birds of each breed) were housed in exactly the same indoor housing system in addition to an access to an outdoor yard (a soft earth yard of 10 m length × 10 m width that was supplied with a tunnel of running water of 10 m length × 1

m width × 0.3 m depth) from the third week of age (the stocking rate in the outside yard was 5 kg of live weight/m<sup>2</sup> of the yard floor space).

**C. Behavioural observation:**

Behavioural observations were carried out once every week for five weeks experimental period starting from the 4<sup>th</sup> week and extending to the 9<sup>th</sup> week of the birds' age. Every observation day covered the time from 7:00 am till 5:00 pm. Behaviour was sampled in four periods per day (observation week). The first period was in the early morning (07:00 - 08:00 am) and the second period was in the late morning (10:00-11:00 am). Whereas, the third period was in the early afternoon (1:00-2:00 pm) and the fourth period was in the late afternoon (4:00-5:00 pm). Behaviour of the birds in each group (genotype) of the two housing systems was recorded in real time using behaviour sampling method (Martin and Frs, 1986). At each sample point, the number of birds performing a particular behavioural pattern was determined onto a check sheet. For every behaviour pattern, data was expressed as percentages (number of individual birds performing the behaviour).

**D. Productive performance:**

Average body weight of ducks was determined at 0 day (initial weight) and then biweekly until the end of the experiment. Feed was withdrawn for 12 hours with water being provided *ad libitum* before each weighing of ducks. The gain in body weight was calculated biweekly by finding the difference in weight between two successive weights.

**E. Immunological traits assessment:**

**1- Cellular immune response:** Twenty blood samples were collected by puncture from wing vein from each group. Whole blood was collected in Heparinized tubes after three and seven days after Avian Influenza vaccine was injected to investigate the cellular immune response as follows:

**Phagocytic activity:** Phagocytic activity was determined according to Kawahara *et al.* (1991).

$$\text{Phagocytic activity (PA)} = \frac{\text{Percentage of phagocytic cells containing yeast cell}}{\text{Total phagocytic cells}} \times 100$$

**Phagocytic index:** The number of phagocytized organisms was counted in the phagocytic cells and called phagocytic index (PI).

$$\text{Phagocytic index (PI)} = \frac{\text{Number of yeast cells phagocytized}}{\text{Number of phagocytic cells}}$$

**2- Antibody response:** Twenty blood samples from each group were taken randomly for humeral immune response against Avian Influenza (AI) vaccine after 14 and 28 days of injection. Serum was separated and frozen at -20 °C until assay. The antibody titer was expressed as the log<sub>2</sub> of the reciprocal of the highest dilution.

**F. Statistical analyses:**

The statistical analyses of the data were carried out by statistical analysis system (SAS, 2002) proc GLM. Two way analysis of variances was used for both behavioural and immune response data whereas, a two way analysis of co-variance was used for productive performance traits data.

### III. RESULTS

**A. Behaviour:**

The output of the two way analyses of variance showed that there was an effect to the breed of ducks on both lying and standing behaviour. Moulard ducks exhibited higher levels of lying and lower levels of standing behaviour compared to both Cherry valley and Pekin ducks (Table 1). Similarly, breeds of ducks affected their body care behaviour. Both Cherry valley and Pekin ducks performed higher levels of both preening and total body care behaviours relative to Moulard ducks (Table 2). Whereas, the level of panting behaviour was higher in Cherry valley ducks compared to both Moulard and Pekin (Table 2). The housing systems appeared to affect the behaviours of ducks with the birds in the indoor housing system stretching their wings and legs and performing more body care behaviours than those in the outdoor housing system (Table 2). Breeds of ducks also affected their exploratory behaviour with Cherry valley and Moulard ducks exhibiting higher levels of both floor exploration and total exploratory behaviours than Pekin ducks (Table 3). The housing systems of ducks affected their exploratory behaviour and aggressive pecking with the birds in the indoor housing system displaying higher levels of floor and total exploratory behaviour and aggressive pecking compared to their conspecifics in the outdoor housing system (Table 3). Average % birds displaying exploratory behaviour showed a significant breed\*housing system increasing significantly in Cherry valley ducks in indoor housing system, and in Moulard ducks in outdoor housing systems (Table 3).

Table (1): Effects of breed, housing system and their interaction on lying and movement activities of ducks (% of birds performing the behaviour ± SE).

Item	Lying	Movement activities	
		Walking	Standing
Breed			
Cherry valley	73.85±3.49 <sup>b</sup>	1.99±0.37	26.15±3.49 <sup>a</sup>
Moulard	83.65±3.09 <sup>a</sup>	1.81±0.36	16.35±3.09 <sup>b</sup>
Pekin	69.06±3.93 <sup>b</sup>	1.58±0.39	30.94±3.93 <sup>a</sup>

Housing system				
Indoor		75.81±2.53	1.71±0.26	24.62±2.53
Outdoor		75.38±3.66	1.93±0.38	24.19±3.66
Breed*Housing				
Cherry valley	Indoor	76.26±4.10	1.89±0.46	23.74±4.10
	Outdoor	69.03±4.60	1.42±0.30	30.97±4.60
Moulard	Indoor	84.34±3.37	1.89±0.46	15.66±3.37
	Outdoor	82.27±4.60	1.65±0.43	17.73±4.60
Pekin	Indoor	65.53±5.05	1.01±0.37	34.47±5.05
	Outdoor	76.12±4.21	2.72±0.62	23.88±4.21

Means within the same column under the same category carry different superscripts are significantly different ( $P < 0.05$ ).

Table (2): Effects of breed, housing system and their interaction on body care behaviour of ducks (% of birds performing the behaviour ± SE).

Item		Preening	Wing stretch	Wing & leg stretch	Panting	Total body care
Breed						
Cherry valley		18.42±2.42 <sup>a</sup>	0.12±0.09	1.25±0.30	8.00±1.27 <sup>a</sup>	27.79±2.22 <sup>a</sup>
Moulard		11.98±1.72 <sup>b</sup>	0.25±0.19	1.09±0.29	3.39±0.69 <sup>b</sup>	16.71±1.66 <sup>b</sup>
Pekin		21.51±2.58 <sup>a</sup>	0.38±0.17	0.67±0.30	3.08±0.71 <sup>b</sup>	25.63±2.64 <sup>a</sup>
Housing system						
Indoor		18.94±1.81	0.34±0.13	1.35±0.24 <sup>a</sup>	4.97±0.77	25.59±1.78 <sup>a</sup>
Outdoor		14.03±1.69	0.08±0.06	0.32±0.13 <sup>b</sup>	4.53±0.69	18.95±1.63 <sup>b</sup>
Breed*Housing						
Cherry valley	Indoor	17.05±2.72	0.13±0.19	1.64±0.36	10.23±1.09	29.04±2.67
	Outdoor	21.16±3.85	0.12±0.27	0.47±0.05	3.55±1.54	25.30±3.78
Moulard	Indoor	14.02±2.72	0.38±0.19	1.52±0.36	2.78±1.09	18.69±2.67
	Outdoor	07.92±3.85	0.01±0.01	0.24±0.05	4.61±1.54	12.77±3.78
Pekin	Indoor	25.76±2.72	0.51±0.19	0.88±0.36	1.89±1.09	29.04±2.67
	Outdoor	13.00±3.85	0.12±0.27	0.24±0.05	5.44±1.54	18.79±3.78

Means within the same column under the same category carry different superscripts are significantly different ( $P < 0.05$ ).

Table (3): Effects of breed, housing system and their interaction on exploratory behaviour and aggressive pecking of ducks (% of birds performing the behaviour ± SE).

Item		Exploratory behaviour				Aggressive pecking
		Wall	Other	Floor	Total	
Breed						
Cherry valley		0.08±0.08	0.34±0.20	1.41±0.43 <sup>a</sup>	1.83±0.51 <sup>a</sup>	0.38±0.17
Moulard		0.16±0.11	0.32±0.22	2.21±0.45 <sup>a</sup>	2.69±0.49 <sup>a</sup>	0.17±0.12
Pekin		0.00±0.00	0.00±0.00	0.54±0.23 <sup>b</sup>	0.54±0.23 <sup>b</sup>	0.17±0.12
Housing system						
Indoor		0.08±0.06	0.17±0.10	1.77±0.31 <sup>a</sup>	2.02±0.35 <sup>a</sup>	0.34±0.12 <sup>a</sup>
Outdoor		0.08±0.08	0.32±0.22	0.63±0.24 <sup>b</sup>	1.02±0.32 <sup>b</sup>	0.04±0.04 <sup>b</sup>
Breed*Housing						
Cherry valley	Indoor	0.13±0.10	0.51±0.21 <sup>b</sup>	1.64±0.46 <sup>ab</sup>	2.28±0.52 <sup>ab</sup>	0.51±0.17
	Outdoor	0.00±0.00	0.00±0.00 <sup>c</sup>	0.95±0.65 <sup>b</sup>	0.95±0.74 <sup>b</sup>	0.12±0.24
Moulard	Indoor	0.13±0.10	0.17±0.00 <sup>c</sup>	0.93±0.65 <sup>b</sup>	1.23±0.52 <sup>b</sup>	0.25±0.17
	Outdoor	0.24±0.14	0.95±0.29 <sup>a</sup>	2.60±0.46 <sup>a</sup>	3.79±0.74 <sup>a</sup>	0.00±0.00
Pekin	Indoor	0.00±0.00	0.00±0.00 <sup>c</sup>	0.76±0.46 <sup>b</sup>	0.76±0.52 <sup>c</sup>	0.25±0.17
	Outdoor	0.00±0.00	0.00±0.00 <sup>c</sup>	0.12±0.65 <sup>b</sup>	0.12±0.74 <sup>c</sup>	0.00±0.00

Means within the same column under the same category carry different superscripts are significantly different ( $P < 0.05$ ).

### B. Productive performance:

The output of the analysis of co-variance showed that there was an effect to the breed on the body weights of ducks. Cherry valley ducks had higher initial and final

body weight relative to both Moulard and Pekin ducks throughout the entire housing period (Table 4). It was also found that during the 2<sup>nd</sup>, 4<sup>th</sup> and 6<sup>th</sup> week of the housing period the Pekin ducks showed higher body weights

compared to both Cherry valley and Moulard (the 2<sup>nd</sup> week), and to Moulard ducks (the 4<sup>th</sup> and 6<sup>th</sup> week of the housing period) (Table 4). There was also an effect to the housing system on the body weights of birds with the ducks in the outdoor housing system showing higher initial body weights, weights during the 2<sup>nd</sup>, 4<sup>th</sup>, and 6<sup>th</sup> week of the housing period, and final body weights than those in the indoor housing system (Table 4). Average body weights of birds (g) showed a significant breed\*housing system effect increasing significantly in Cherry valley ducks in outdoor housing system during both the 6<sup>th</sup> and the 8<sup>th</sup> week, and in Moulard ducks in indoor housing systems during both the 4<sup>th</sup> and the 6<sup>th</sup> week of the housing period (Table 4).

With respect to the body weight gain of ducks, the output of the analysis of co-variance showed that there

was an effect to the breed on the weight gains of birds with the Moulard ducks gaining less weight compared to both Cherry valley and Pekin ducks throughout the entire housing period (Table 5). There was also an effect to the breed on the total weight gain of the three breeds of ducks with the Cherry valley achieving the highest weight gain, the Moulard showing the lowest, and the Pekin displaying an intermediate value of the weight gain (Table 5). Average body weight gain of birds (g) showed a significant breed\*housing system effect with Cherry valley ducks gaining more weights in the outdoor housing system during both the 6<sup>th</sup> week and during the entire housing period, and the Moulard ducks gaining more weights in the indoor housing systems during both the 4<sup>th</sup>, the 6<sup>th</sup> and the 8<sup>th</sup> week and during the entire housing period (Table 5).

Table (4): Effects of breed, housing system and their interaction on body weights (g) of ducks (LS means ± SE).

Item		Initial	2 <sup>nd</sup> week	4 <sup>th</sup> week	6 <sup>th</sup> week	8 <sup>th</sup> week
<b>Breed</b>						
Cherry valley		65.58±0.71 <sup>a</sup>	439.66±7.09 <sup>b</sup>	1339.93±14.83 <sup>a</sup>	2268.40±24.03 <sup>a</sup>	3049.15±40.86 <sup>a</sup>
Moulard		52.78±0.72 <sup>c</sup>	332.00±7.46 <sup>c</sup>	1047.55±14.13 <sup>b</sup>	1843.52±22.88 <sup>b</sup>	2629.18±32.20 <sup>c</sup>
Pekin		55.86±0.72 <sup>b</sup>	478.86±6.94 <sup>a</sup>	1362.32±14.42 <sup>a</sup>	2273.45±22.80 <sup>a</sup>	2898.92±37.92 <sup>b</sup>
<b>Housing system</b>						
Indoor		57.82±0.59	415.18±5.93	1275.88±11.95 <sup>a</sup>	2133.56±19.27	2831.03±31.17
Outdoor		58.33±0.57	418.5±5.77	1223.98±11.67 <sup>b</sup>	2123.35±18.68	2887.13±29.50
<b>Breed*Housing</b>						
Cherry valley	Indoor	65.23±0.97 <sup>a</sup>	430.80±10.03 <sup>b</sup>	1365.93±20.86 <sup>a</sup>	2197.68±33.77 <sup>b</sup>	2969.38±59.96 <sup>b</sup>
	Outdoor	65.94±1.02 <sup>a</sup>	448.52±10.03 <sup>b</sup>	1313.93±21.10 <sup>a</sup>	2339.13±34.19 <sup>a</sup>	3128.93±55.51 <sup>a</sup>
Moulard	Indoor	52.45±1.06 <sup>d</sup>	337.03±10.94 <sup>c</sup>	1093.64±20.62 <sup>b</sup>	1924.49±33.77 <sup>c</sup>	2632.89±47.65 <sup>c</sup>
	Outdoor	53.11±0.96 <sup>cd</sup>	326.98±10.14 <sup>c</sup>	1001.46±19.34 <sup>c</sup>	1762.55±30.89 <sup>d</sup>	2625.46±43.31 <sup>c</sup>
Pekin	Indoor	55.78±1.03 <sup>bc</sup>	477.72±9.81 <sup>a</sup>	1368.07±20.62 <sup>a</sup>	2278.52±32.60 <sup>ab</sup>	2890.83±53.63 <sup>b</sup>
	Outdoor	55.94±0.99 <sup>b</sup>	480.00±9.81 <sup>a</sup>	1356.57±20.16 <sup>a</sup>	2268.37±31.88 <sup>ab</sup>	2907.00±53.63 <sup>b</sup>

Means within the same column under the same category carry different superscripts are significantly different ( $P < 0.05$ ).

Table (5): Effects of breed, housing system and their interaction on body weight gain (g) of ducks (LS means ± SE).

Item		2 <sup>nd</sup> week	4 <sup>th</sup> week	6 <sup>th</sup> week	8 <sup>th</sup> week	Total gain
<b>Breed</b>						
Cherry valley		373.09±6.83 <sup>b</sup>	898.18±10.48 <sup>a</sup>	922.93±16.35 <sup>a</sup>	832.97±24.86 <sup>a</sup>	2978.80±41.50 <sup>a</sup>
Moulard		279.87±7.18 <sup>c</sup>	724.52±10.82 <sup>b</sup>	792.60±15.33 <sup>b</sup>	784.73±19.55 <sup>a</sup>	2577.94±32.97 <sup>c</sup>
Pekin		422.95±6.67 <sup>a</sup>	889.35±10.24 <sup>a</sup>	912.21±15.30 <sup>a</sup>	629.02±22.61 <sup>b</sup>	2848.83±38.40 <sup>b</sup>
<b>Housing system</b>						
Indoor		356.73±5.71	870.97±8.72 <sup>a</sup>	854.33±12.95 <sup>b</sup>	723.46±18.91	2774.68±31.97
Outdoor		360.53±5.55	803.72±8.44 <sup>b</sup>	897.49±12.64 <sup>a</sup>	774.35±17.73	2829.03±29.70
<b>Breed*Housing</b>						
Cherry valley	Indoor	363.47±9.71 <sup>b</sup>	931.71±14.90 <sup>a</sup>	827.69±22.98 <sup>c</sup>	844.13±35.89 <sup>a</sup>	2893.13±61.49 <sup>b</sup>
	Outdoor	382.70±9.60 <sup>b</sup>	864.64±14.73 <sup>b</sup>	1018.16±23.28 <sup>a</sup>	821.80±34.42 <sup>a</sup>	3064.46±55.73 <sup>a</sup>
Moulard	Indoor	284.73±10.47 <sup>c</sup>	778.11±15.69 <sup>c</sup>	827.17±22.41 <sup>c</sup>	713.21±29.52 <sup>b</sup>	2603.19±49.15 <sup>c</sup>
	Outdoor	275.00±9.82 <sup>c</sup>	670.93±14.90 <sup>d</sup>	758.02±20.93 <sup>d</sup>	856.24±25.66 <sup>a</sup>	2560.69±43.96 <sup>c</sup>
Pekin	Indoor	422.00±9.49 <sup>a</sup>	903.10±14.73 <sup>a</sup>	908.14±21.88 <sup>b</sup>	623.04±32.53 <sup>b</sup>	2846.72±54.76 <sup>b</sup>
	Outdoor	423.89±9.39 <sup>b</sup>	875.60±14.23 <sup>b</sup>	916.29±21.39 <sup>b</sup>	635.00±31.42 <sup>b</sup>	2850.93±53.84 <sup>b</sup>

Means within the same column under the same category carry different superscripts are significantly different ( $P < 0.05$ ).

### C. Cellular immune response:

The output of the two way analyses of variance showed

that there was no effect to the breed on the phagocytic activity of the ducks to Avian Influenza vaccine after

either the 3<sup>rd</sup> or the 7<sup>th</sup> day of vaccination (Table 6). There was however, an effect to the breed on the phagocytic index after the 7<sup>th</sup> day of vaccination with Pekin ducks showing higher phagocytic index compared to Moulard ducks (Table 6). Housing ducks in indoor versus outdoor housing systems affected their immune responses to Avian Influenza vaccines. Indoor housed ducks showed higher values of phagocytic activity than those housed in outdoor systems after the 3<sup>rd</sup> day of vaccination. Similarly, indoor housed ducks had higher phagocytic index values after the

7<sup>th</sup> day of vaccination when compared to outdoor housed ducks (Table 6). Average phagocytic activity and phagocytic index of birds showed a significant breed\*housing system effect with Cherry valley ducks having higher phagocytic index in indoor than outdoor housing system after the 7<sup>th</sup> day of vaccination, and Moulard ducks having higher phagocytic activity and phagocytic index levels in indoor than outdoor housing system after the 3<sup>rd</sup> day of vaccination (Table 6).

Table (6): Effects of breed, housing system and their interaction on cellular immune response to avian influenza vaccine in ducks (LS means  $\pm$  SE).

Item	Phagocytic activity		Phagocytic index	
	3 <sup>rd</sup> day	7 <sup>th</sup> day	3 <sup>rd</sup> day	7 <sup>th</sup> day
<b>Breed</b>				
Cherry valley	19.11 $\pm$ 0.27	20.20 $\pm$ 0.53	1.68 $\pm$ 0.06	1.57 $\pm$ 0.04 <sup>ab</sup>
Moulard	19.40 $\pm$ 0.27	19.49 $\pm$ 0.50	1.61 $\pm$ 0.06	1.49 $\pm$ 0.04 <sup>b</sup>
Pekin	19.29 $\pm$ 0.29	20.05 $\pm$ 0.52	1.68 $\pm$ 0.06	1.59 $\pm$ 0.04 <sup>a</sup>
<b>Housing system</b>				
Indoor	19.64 $\pm$ 0.26 <sup>a</sup>	19.6 $\pm$ 0.49	1.71 $\pm$ 0.05	1.62 $\pm$ 0.03 <sup>a</sup>
Outdoor	18.89 $\pm$ 0.20 <sup>b</sup>	20.22 $\pm$ 0.34	1.60 $\pm$ 0.04	1.48 $\pm$ 0.02 <sup>b</sup>
<b>Breed*Housing</b>				
Cherry valley	Indoor	19.27 $\pm$ 0.43 <sup>ab</sup>	19.94 $\pm$ 0.91	1.65 $\pm$ 0.09 <sup>ab</sup>
	Outdoor	18.94 $\pm$ 0.33 <sup>b</sup>	20.45 $\pm$ 0.55	1.71 $\pm$ 0.07 <sup>a</sup>
Moulard	Indoor	20.09 $\pm$ 0.43 <sup>a</sup>	19.68 $\pm$ 0.78	1.74 $\pm$ 0.09 <sup>a</sup>
	Outdoor	18.71 $\pm$ 0.34 <sup>b</sup>	19.29 $\pm$ 0.62	1.49 $\pm$ 0.07 <sup>b</sup>
Pekin	Indoor	19.56 $\pm$ 0.47 <sup>ab</sup>	19.17 $\pm$ 0.86	1.74 $\pm$ 0.10 <sup>a</sup>
	Outdoor	19.03 $\pm$ 0.34 <sup>ab</sup>	20.93 $\pm$ 0.57	1.62 $\pm$ 0.07 <sup>ab</sup>

Means within the same column under the same category carry different superscripts are significantly different ( $P < 0.05$ ).

#### D. Humeral immune response:

The output of the two way analyses of variance showed that there was no effect to the breed of ducks on the levels of serum antibodies to Avian Influenza vaccine after either

the 15<sup>th</sup> or the 28<sup>th</sup> day of vaccination (Table 7). There was also no effect to the housing system on the level of serum antibodies to the vaccination of ducks against Avian Influenza (Table 7).

Table (7): Effects of breed, housing system and their interaction on humeral immune response to Avian Influenza vaccine in ducks (Log geometric mean  $\pm$  SE).

Item	Antibody titer	
	15 <sup>th</sup> day	28 <sup>th</sup> day
<b>Breed</b>		
Cherry valley	2.19 $\pm$ 0.07	1.33 $\pm$ 0.08
Moulard	2.11 $\pm$ 0.08	1.43 $\pm$ 0.07
Pekin	2.18 $\pm$ 0.07	1.41 $\pm$ 0.07
<b>Housing system</b>		
Indoor	2.22 $\pm$ 0.06	1.37 $\pm$ 0.06
Outdoor	2.10 $\pm$ 0.06	1.41 $\pm$ 0.06
<b>Breed*Housing</b>		
Cherry valley	Indoor	2.20 $\pm$ 0.10
	Outdoor	2.18 $\pm$ 0.11
Moulard	Indoor	2.30 $\pm$ 0.11
	Outdoor	1.93 $\pm$ 0.11
Pekin	Indoor	2.16 $\pm$ 0.11
	Outdoor	2.20 $\pm$ 0.10

#### **IV. DISCUSSION**

##### **A. Behaviour:**

Results of this experiment demonstrated that there were significant differences in behaviours between the three genotypes of ducks investigated in the current study. Compared to both Cherry valley and Pekin ducks, the Moulard displayed higher levels of lying behaviour and lower levels of standing, preening panting and body care behaviour. This could be attributed to the fact that they are more fearful than other breeds of ducks. Moulard ducks have been reported to express a high level of fear of humans and avoidance behaviour and that appears between 5 and 6 weeks of age and results in sudden, intense, and collective motor activity. They also crowd together at the end of the pen furthest from the human (Guémené *et al.*, 2006). Therefore, these genotype-dependent changes in activity, behaviours and responses to environment should be considered when selecting a particular breed of ducks. Selecting suitable breed of birds is necessary to avoid distress and potential physical consequences such as suffocation and injury which can seriously affect the welfare of birds. Rushen *et al.* (1999) has therefore pointed out that in the production sector, animal welfare is a major issue for farmers because, in addition to ethical issues, it has direct consequences on productivity. Hoffman, (1992a; 1992b) concluded that the general behaviour of the Moulard appeared to be most similar to that of Muscovy, with the exception that they move more slowly and spent more time lying and swimming in water and that they do not fly, traits that are more similar to domestic ducks. Differences between Moulard, Pekin and Muscovy ducks in behaviour (fear responses and social behaviours) and responses to stress have been previously reported (Arnaud *et al.*, 2010). Similar genotype-based differences in behaviour have been reported in chicken (Craig *et al.*, 1983), red junglefowl (Håkansson *et al.*, 2007), and mammals such as rats (Stohr *et al.*, 1999), lambs (Boissy *et al.*, 2005; Darwish *et al.*, 2010), cattle (Morris *et al.*, 1994) and rainbow trout fish (Woodward and Strange, 1987).

Results also demonstrated that housing conditions affected the behaviour of ducks. Indoor-housed ducks displayed higher levels of wing and leg stretch, body care, exploration and aggressive pecking compared to outdoor-housed ducks. These differences of behaviour of ducks between the two housing systems could be attributed to the fact that the birds in the outdoor housing system performed other activities that were not feasible for birds in the indoor housing system such as swimming, head submersion, wet preening and the associated comfort activities. These behaviours were therefore performed by the birds in the outdoor housing systems on the expense of other activities. Differences in behaviours of ducks reared under different housing conditions have been previously reported (Fraleay *et al.*, 2013; Karcher *et al.*, 2013). On the other hand, the indoor-housed ducks might have performed higher levels of wing and leg stretch and body care behaviours because rearing in confinement and the

lack of water might have increased the soiling of the plumage by the dropping and bedding material which necessitated higher levels of body care activities relative to ducks housed in outdoor systems. It has been reported that duck behaviours are more influenced by environment, age and physical condition. Activity at an older age incorporated more of the behaviours associated with thermal comfort (panting) and maintenance of plumage condition (dry and wet preening) (Jones and Dawkins, 2010a).

Results also showed that aggressive pecking was performed at higher levels by indoor-housed than outdoor-housed ducks. This might be attributed to the constraint of the space (confinement) which might have caused birds to come in direct physical contact (meet each other) more frequently intensifying the close proximity between birds than in case of plenty of space as in the outdoor housing conditions. It has been reported in animals that the haphazard collision of individuals might induce aggressive responses (e.g. Robitaille and Bovet, 1976). Aggressive pecking may have also been expressed by the indoor-housed ducks as a redirected activity. In natural settings, ducks spend considerable time every day in bill-oriented behaviors such as feeding, which involves dabbling the bill along the water and straining out planktonic organisms, as well as preening (Council of Europe, 1999) where the bill is used to distribute water over the body and remove dirt. The lack of foraging opportunities and open water for preening in intensive duck farms can cause birds to redirect their pecking at other ducks, sometimes degenerating into cannibalism (Dean, 1985; Raud and Faure, 1994). Aggressive pecking may prompt feather pecking that is a damaging behavior that reduces the welfare of poultry. Having feathers pulled out is painful (Gentle *et al.*, 1991), and injury and death due to cannibalism in flocks can be high (Appleby *et al.*, 2004). These behaviors also cause economic losses for producers, since birds with fewer feathers lose heat faster and therefore consume more feed than fully feathered birds.

Results also showed that there was a breed\*housing system effect. Cherry valley ducks were more explorative in the indoor housing relative to their conspecifics in the outdoor housing system. Whereas, Moulard ducks were more explorative in the outdoor housing relative to their indoor-housed conspecifics. This specific type of gene-environment interaction appears to reflect the adaptation ability of the birds in different housing conditions. So genetic influences should be taken into account, particularly in livestock systems in which strains result from very intensive genetic selection.

##### **B. Productive performance:**

Results demonstrated that there were significant differences in body weights of the three genotypes of ducks investigated in the current experiment. Compared to both Moulard and Pekin ducks, the Cherry valley ducks achieved higher initial and final body weights. These differences could be attributed to the high genetic potential of the Cherry valley ducks than both Moulard or Peking ducks (André *et al.*, 2007). It could also reflect higher food intake (not measured in the study) in this genotype.

Similar genotype-based differences in body weight of ducks have been previously reported (Arnaud *et al.*, 2010; Damaziak *et al.*, 2014). Following the same trend, there were significant differences between different breeds of ducks in final weight gain with both Cherry valley and Pekin ducks gaining more weights compared to Moulard ducks. These weight gain differences might be attributed to genetic potentials of the breed, but could also reflect the changes in the body weight of the birds. Differences in weight gain between different breeds of ducks have been previously reported (Pingel, 1999; Batta, 2004; Solomon *et al.*, 2006). These differences could therefore be attributed to the effect of season of rearing, temperature, age of birds, level of lighting, quality and hygiene of the water tunnel and, more importantly, to the genotype-environment interaction.

There was also an effect to the housing system on the body weights and weight gains of ducks. Indoor-housed ducks had higher body weights and weight gains in the 4<sup>th</sup> week of housing period compared to outdoor-housed ducks. However, outdoor-housed ducks had higher weight gains in the 6<sup>th</sup> week compared to indoor-housed ducks. Data on the effects of housing systems on body weight and weight gains of birds are controversial. On one side, some experiments have shown that the body weight and weight gains of indoor housed birds were higher than those in outdoor housing systems (Knust *et al.*, 1995; Wang *et al.*, 2009; Baeza *et al.*, 2001; Ward *et al.*, 2001; Połtowicz and Doktor, 2011). On the other hand, other experiments have reported that body weights and weight gains were higher in outdoor than indoor housed ducks (Muriel and Pascual, 1995; Santos *et al.*, 2005; Ponte *et al.*, 2008; and Broom, 1986). Whereas, other research did not reveal differences in either body weight or weight gain of birds under different housing systems (Butler and McGraw, 2009; Liste *et al.*, 2012; Sari *et al.*, 2013). These differences could therefore be attributed to the effect of several environmental factors such as season of rearing, temperature, humidity age of birds, level of lighting, quality and hygiene of the water tunnel (Knierim *et al.*, 2004) and, more importantly, to the genotype-environment interaction.

Results showed that there was a significant genotype\*housing system effect with the Cherry valley ducks displaying higher body weights during the 6<sup>th</sup> week of the housing period and a higher final weight in the indoor housing systems compared to outdoor housing systems. Corresponding higher weight gains were also evident in outdoor housed ducks. Whereas, Moulard ducks displayed higher body weights during the 4<sup>th</sup> and 6<sup>th</sup> week of housing period when they were housed in indoor relative to outdoor housing systems. Again, it appears that the performance and welfare of birds do not depend on the type of housing system only but rather on the interaction of a particular genotype within a particular environment. These differences could be due to different adaptation ability, different origin of the ducks and different susceptibility to environment (Gille and Salomon, 1998; Wilkiewicz-Wawro *et al.*, 1999; Faure *et al.*, 2003). The

importance of the effects of genotypes on the phenotypic expression should therefore be considered when evaluation welfare of birds in a particular housing system and this has been previously highlighted (Damaziak *et al.*, 2014). It has been therefore reported that comparisons between individuals may be difficult because production is influenced by the strain and age of the bird, and can be manipulated by management strategies, such as the lighting programme or the nutritional content of the feed. A high level of production may even predispose the bird to production diseases and so increase the risk of poor welfare. As with health, good production does not necessarily indicate good welfare (SCAHAW, 1998).

#### *C. Immune response:*

There was an effect of the genotype of birds on their cellular responses to Avian Influenza vaccine with the Pekin ducks showing higher phagocytic index than Moulard after the 7<sup>th</sup> day of vaccination (Rana *et al.*, 2010). These results agree with previous findings that demonstrated a change in immune responses between breeds. Results showed also a significant effect to the housing system on the cellular immune responses of ducks with the indoor-housed birds showing higher phagocytic activity after the 3<sup>rd</sup> day of vaccination, and phagocytic index after the 7<sup>th</sup> day of vaccination as compared to the outdoor-housed ducks. These higher levels of immune responses in the birds of the indoor housing system could be attributed to the fact that the temperature was much controlled in the indoor than outdoor system. As the experiment was conducted during winter months, the outdoor-housed ducks might have been exposed to much lower temperature (while present in the outside yard) compared to their conspecifics housed in the indoor housing system and this might have had an impact on their immune response. An extensive amount of research work has shown that the indoor-housed ducks showed a stronger immune response than those housed in the outdoor system (Baeza *et al.*, 2001; Połtowicz and Doktor, 2011; Kolluri *et al.*, 2014).

There was also a significant genotype\*housing condition effect on both phagocytic activity and phagocytic index with all breeds showing higher immune response levels in indoor housing relative to outdoor housing system. The low level of immune response of the bird reared in the outdoor systems could be attributed to the effect of the low temperature but could also be due to the increased susceptibility to diseases (Christensen *et al.*, 1998; Katharine, 2001). Further studies are needed to control for the effects of some environmental factors on the immune response of birds kept under farmer's condition such as temperature of the house, season of the year, and sex and age of the birds.

## **V. CONCLUSION**

It could be concluded that behaviour, productive performance and response to immune challenges vary between different genotypes (breeds) of ducks. Considering the various welfare indicators adopted in this study it

was not straightforward to suggest a suitable housing system over the other in favor of the bird welfare. The effect of the housing condition appeared to depend on the type of the genotype experiencing it. Under both the physical and social environmental conditions of the current study it could be concluded that the suitable breed of the three breeds investigated-of ducks for broiler production under Egyptian farmer's condition to be reared in indoor housing systems was Cherry valley as it performed well relative to the outdoor housing systems. In contrast, the performance of Moulard ducks appeared to improve when they were housed in outdoor systems relative to the indoor systems. The performance of the Pekin ducks appeared to be less affected by the system of housing.

## REFERENCES

- [1] *André, J.M.; Guy, G.; Gontier-Lattonnelle, K.; Bernadet M.D.; Davail B.; Hoo-Paris, R. and Davail, S. (2007):* Influence of lipoprotein-lipase activity on plasma triacylglycerol concentration and lipid storage in three genotypes of ducks. *Comp. Biochem. Physiol. Mol. Integr. Physiol.*, 148:899-902.
- [2] *Appleby, M.C.; Mench, J.A. and Hughes, B.O. (2004):* Poultry Behaviour and Welfare. CAB International, Wallingford, UK.
- [3] *Arnaud, I.; Gardin, E.; Sauvage, E.; Bernadet, M.D. ; Couty, M.; Guy, G. and Guémené, D. (2010):* Behavioral and adrenal responses to various stressors in mule ducks from different commercial genetic selection schemes and their respective parental genotypes. *Poult. Sci.*, 89:1097-109.
- [4] *Baeza, E.; Lessire, M.; Berri, C. and Juin, H. (2001):* Compared carcass and meat characteristics of label and standard guinea fowl. *Proceedings of XV European Symposium on the Quality of Poultry Meat, Kusadasi, Turkey, 73-78.*
- [5] *Batta, S.S. (2004):* A study of some productive traits and their relationships in three breeds of ducks. *Al-Azhar J. Agric. Res.*, 40: 92-109.
- [6] *Boissy, A.; Bouix, J.; Orgeur, P.; Poindron, P.; Bibe, B. and Le-Neindre, P. (2005):* Genetic analysis of emotional reactivity in sheep: Effects of the genotypes of the lambs and their dams. *Genet. Sel. Evol.*, 37:381-401.
- [7] *Broom, D.M. and Johnson, K.G. (1993):* Stress and Animal Welfare (Pp.211). London: Chapman and Hall.
- [8] *Broom, D. (1996):* Animal welfare defined in terms of attempts to cope with the environment. *Acta. Agric. Scand. Supl.*, 27: 22-28.
- [9] *Butler, M.W. and McGraw, K.J. (2009):* Indoor housing during development affects moult, carotenoid circulation and beak colouration of mallard ducks (*Anas platyrhynchos*). *Avian Biol. Res.*, 2: 203-211.
- [10] *Chapillon, P.; Manneche, C.; Belzung, C. and Caston, J. (1999):* Rearing environmental enrichment in two inbred strains of mice. 1. Effects on emotional reactivity. *Behav. Genet.*, 29: 41-46.
- [11] *Cherry, P. and Morris, T.R. (2008):* Domestic Duck Production. A catalogue record for this book is available from the British Library, London, UK.
- [12] *Christensen, J.P.; Dietz, H.H. and Bisgaard, M. (1998):* Phenotypic and genotypic characters of isolates of *P. multocida* obtained from backyard poultry and from two outbreaks of avian cholera in avifauna in Denmark. *Avian Pathology*, 27: 373-381.
- [13] *Council of Europe, (1999):* Recommendation concerning Muscovy ducks (*Cairinamoschata*) and hybrids of Muscovy and domestic ducks (*Anas platyrhynchos*). Standing Committee of the European Convention for the Protection of Animals Kept for Farming Purposes, Bologna, Italy.
- [14] *Craig, J.V.; Craig, T.P. and Dayton, A.D. (1983):* Fearful behaviour by caged hens of two genetic stocks. *Appl. Anim. Ethol.*, 10:263-273.
- [15] *Damaziak, K.; Michalczyk, M.; Adamek, D.; Czaplinski, M.; Niemiec, J.; Goryl, A. and Pietrzak, D. (2014):* Influence of housing system on the growth and histological structure of duck muscles. *S. Afr. J. Anim. Sci.*, 44: 97-109.
- [16] *Darwish, R.A.; Abou-Ismael, U.A. and El-Kholya, S.Z. (2010):* Differences in post-parturient behaviour, lamb performance and survival rate between purebred Egyptian Rahmani and its crossbred Finnish ewes. *Small Rumin. Res.*, 89: 57-61.
- [17] *Dean, W. (1985):* Duck production and management in the United States. In: Farrell, D. and Stapleton, P. (eds.), *Duck Production Science and World Poultry Practice*. Armidale, NSW: University of New England, Pp. 258-66.
- [18] *Duru, S.; Akpa, G.; Sai'du, N.L.; Olugbemi, T.S. and Jokthan, G.E. (2006):* A preliminary study on duck management under peri-urban system.
- [19] *Fan, H.P.; Xie, M.; Wang, W.W.; Hou, S.S. and Huang, W. (2008):* Effect of dietary energy on growth performance and carcass quality of white growing Pekin ducks from two to six weeks of age. *Poult. Sci.*, 87: 1162-1164.
- [20] *Faure, J.M.; Val-Laillet, D.; Guy, G.; Bernadet, M.D. and Guemene, D. (2003):* Fear and stress reactions in two species of duck and their hybrid. *Horm. Behav.*, 43: 568-572.
- [21] *Fraley, S.M.; Fraley, G.S.; Karcher, D.M.; Makagon, M.M. and Lilburn, M.S. (2013):* Influence of plastic slatted floors compared with pine shaving litter on Pekin Duck condition during the summer months. *Poult. Sci.*, 92: 1706-1711.
- [22] *Fraser, D. (1995):* Science, values and animal welfare: exploring the "inextricable connection". *Anim. Welfare*, 4: 103-117.
- [23] *Gentle, M.J.; Hunter, L.N. and Waddington, D. (1991):* The onset of pain related behaviours following partial beak amputation in the chicken. *Neurosci. Lett.*, 128: 113-116.
- [24] *Gille, U. and Salomon, F.V. (1998):* The increase skeletal limbs of domestics and wild ducks. *Anat. Histol. Embryol.*, 24: 13-18.
- [25] *Guémené, D.; Bernadet, M.D.; Fournel, E.; Val-Laillet, D.; Bouy, S.; Arnaud, I.; Gardin, E.; Larzul, C.; Grasteau, S.; Guy, G. and Faure, J.M. (2006):* Nervousness or fearfulness and social behaviour in male mule ducks: An update review. *Symposium COA/INRA Scientific Cooperation in Agriculture, Tainan, Taiwan. INRA, Paris, France.*
- [26] *Håkansson, J.; Bratt, C. and Jensen, P. (2007):* Behavioural differences between two captive populations of red jungle fowl (*Gallus gallus*) with different genetic background, raised under identical conditions. *Appl. Anim. Behav. Sci.*, 102: 24-38.
- [27] *Hoffmann, E. (1992a):* A natural history of *Cairinamoschata*, the wild Muscovy duck. 9<sup>th</sup> International Symposium of Waterfowl, Pisa, Italy, World Poultry Association. Pp. 217-219.
- [28] *Hoffmann, E. (1992b):* Hybrid progeny from Muscovy and domestic ducks. 9<sup>th</sup> International Symposium of Waterfowl, Pisa, Italy, World Poultry Association. Pp. 64-66.
- [29] *Horne, P.L.M. and Achterbosch, T.J. (2008):* Animal welfare in poultry production systems: impact of EU standards on world trade. *World's Poultry Sci. J.*, 64: 40-52.
- [30] *Jones, T.A. and Dawkins, M.S. (2010a):* Effect of environment on Pekin duck behaviour and its correlation with body condition on commercial farms in the UK. *Br. Poult. Sci.*, 51:319-25.
- [31] *Jones, T.A. and Dawkins, M.S. (2010b):* Environment and management factors affecting Pekin duck production and welfare on commercial farms in the UK. *Br. Poult. Sci.*, 51:12-21.
- [32] *Karcher, D.M.; Makagon, M.M.; Fraley, G.S.; Fraley, S.M. and Lilburn, M.S. (2013):* Influence of raised plastic floors compared with pine shaving litter on environment and Pekin duck condition. *Poult. Sci.*, 92: 583-590.
- [33] *Katharine, E.M. (2011):* Review: Immunoglobulin genetics and antibody responses to influenza in ducks. *Dev. Comp. Immunol.*, 35: 1008-1017.
- [34] *Kawahara, E.; Ueda, T. and Nomura, S. (1991):* In vitro Phagocytic activity of white-spotted shark cells after injection with *Aeromonas salmonicida* extracellular products. *Gyobyo Kenkyu, Japan*, 26: 213-214.
- [35] *Knierim, U.; Bulheller, M.A.; Kuhnt, K.; Briese, A. and Hartung, J. (2004):* Water provision for ducks kept indoors A review on the basis of the literature and our own experience. *Deut. Tier. Wochen.* 111:115-118.
- [36] *Knust, U.; Wicke, M.; Pingel, H.; Lengerken, G. and Salomon, V. (1995):* Muscle structure and meat quality of ducks reared on pasture and under intensive conditions respectively. *Proceedings of*

- XII European Symposium on the Quality of Poultry Meat. Zaragoza, 189-193.
- [37] Kolluri, G.; Ramamurthy, N.; Churchil, R.R.; Dhinakar, G. and Kannaki, T.R. (2014): Influence of age, sex and rearing systems on Toll-like receptor 7 (TLR7) expression pattern in gut, lung and lymphoid tissues of indigenous ducks. *Br. Poult. Sci.*, 55: 59-67.
- [38] Lien, R.J.; Hess, J.B.; McKee, S.R.; Bilgili, S.F. and Townsend, J.C. (2007): Effect of light intensity and photoperiod on live performance, heterophil-to-lymphocyte ratio, and processing yields of broilers. *Poult. Sci.*, 86: 1287-1293.
- [39] Liste, G.I.; Kirkden, R.D. and Broom, D.M. (2012): A commercial trial evaluating three open water sources for farmed ducks: effects on health and production. *Br. Poult. Sci.*, 53:576-84.
- [40] Martin, P. and Frs, P.B. (1986): *Measuring behaviour an introductory guide.* pp. 48-49 Cambridge University Press. Cambridge, London.
- [41] Mason, G. and Mendl, M. (1993): Why is there no simple way of measuring animal welfare? *Anim. Welfare*, 2: 301-319.
- [42] Modak, M.K. (1996): Meat yield performances of Pekin × Pekin, Pekin × Desi and Pekin × Khaki Campbell. MS Thesis, Department of Poultry Science, Bangladesh Agricultural University, Mymensingh.
- [43] Morris, C.A.; Cullen, N.G.; Kilgour, N. and Brenner, K.J. (1994): Some genetic factors affecting temperament in *Bostaurus* cattle. *N. Z. J. Agric. Res.*, 37: 167-175.
- [44] Muriel, A. and Pascual, M.R. (1995): Carcass and meat characteristics from free range chickens. *Proceedings of XII European Symposium on Quality of Poultry Meat, Zaragoza*, 219-222.
- [45] O'Driscoll, K.K. and Broom, D.M. (2011): Does access to open water affect the health of Pekin ducks (*Anas platyrhynchos*)? *Poult. Sci.*, 90: 299-307.
- [46] Pingel, H. (1999): Influence of breeding and management on the efficiency of duck production. *Lohmann information, Halle, Germany No. 22*: 7-13.
- [47] Potowicz, K. and Doktor, J. (2011): Effect of free-range raising on performance, carcass attributes and meat quality of broiler chickens. *Animal Science Papers and Reports*, 29: 139-149.
- [48] Ponte, P.I.P.; Rosado, C.M.C.; Crespo, J.P.; Crespo, D.G.; Mourao, J.L.; Chaveirosoares, M.A.; Bras, J.L.A.; Mendes, I.; Gama, L.T.; Prates, J.A.M.; Ferreira, L.M.A. and Fontes, C.M.G.A. (2008): Pasture intake improves the performance and meat sensory attributes of free-range broilers. *Poult. Sci.*, 87: 71-79.
- [49] Rana, M.; Hossain, M.T.; Islam, M.A.; Rahman, M.M.; Alam, M.K. and Dutta, U.K. (2010): Comparative immunogenicity study in ducks of different breeds available at coastal regions of Bangladesh against duck plague and duck cholera vaccines. *Int. J. Bio. Res.*, 2: 23-27.
- [50] Raud, H. and Faure, J.M. (1994): Welfare of ducks in intensive units. *Revue Scientifique et Technique (International Office of Epizootics)* 13: 119-29.
- [51] Robitaille, J.A. and Bovet, J. (1976): Field observations on the social behaviour of the Norway rat, *Rattus norvegicus* (Berkenhout). *Biol. Behav.*, 1: 289-308.
- [52] Rushen, J.; Taylor, A.A. and de Passille, A. (1999): Domestic animals' fear of humans and its effects on their welfare. *Appl. Anim. Behav. Sci.*, 65: 285-303.
- [53] Santos, A.L.; Sakomura, N.K.; Freitas, E.R.; Fortes, C.M.S. and Carrilho, N.V.M. (2005): Comparison of free range broiler chicken strains raised in confined and semi-confined systems. *Braz. J. Poult. Sci.*, 7: 85-92.
- [54] Sari, M.; Önk, K.; Işık, S.; Tilki, M. and Tufan, T. (2013): Effects of housing system, slaughter age, and sex on slaughter and carcass traits of native Turkish ducks. *Turk. J. Vet. Anim. Sci.*, (2013) 37: 694-700
- [55] *Scientific Committee on Animal Health and Animal Welfare, SCAHAW, (1998): A report on welfare aspects of the production of Foie Gras in Ducks and Geese.* 1-93.
- [56] Simonsen, H.B. (1996): Assessment of animal welfare by a holistic approach: behaviour health and measured opinion. *Acta. Agric. Scand.*, 27: 91-96.
- [57] Smidt, D. (1983): Advantages and problems of using integrated systems of indicators as compared to single traits. In Smidt, D. (ed.) Indicators relevant to farm animal welfare. Martinus Nijhoff, The Hage, NL. 201-207.
- [58] Solomon, J.K.Q.; Austin, R.; Cumberbatch, R.N.; Gonsalves, J. and Seaforth, E. (2006): A comparison of live weight and carcass gain of Pekin, Kunshan and Muscovy ducks on a commercial ration. *Livestock Res. Rural Develop.* 18: (11).
- [59] *Statistical Analysis System, SAS, (2002): User's Guide, Institute, Cary, North Carolina. Library of Congress Cataloging-in-Publication Data.*
- [60] Stöhr, T.; Szuran, T.; Pliska, V. and Feldon, J. (1999): Behavioural and hormonal differences between two Lewis rat lines. *Behav. Brain Res.*, 101: 163-172.
- [61] Szász, S.; Bogenfürst, F. and Kobulej, I. (1997): Study on meat production ability of Cherry Valley, Barbarie and Mule duck. *Proc. Aust. Poult. Sci. Sym.*, 9: 187-190.
- [62] Wang, K.H.; Shi, S.R.; Dou, T.C. and Sun, H.J. (2009): Effect of a free-raising system on growth performance, carcass yield, and meat quality of slow-growing chicken. *Poult. Sci.*, 88: 2219-2223.
- [63] Ward, J.M.; Houston, D.C.; Ruxton, G.D.; McCafferty, D.J. and Cook, P. (2001): Thermal resistance of chicken (*Gallus domesticus*) plumage: a comparison between broiler and free-range birds. *Br. Poult. Sci.*, 42: 558-563.
- [64] Wilkiewicz-Wawro, E.; Bochno, R. and Szeremeta, J. (1999): Effect of age and sex on carcass of ducks. *Zeszyty Naukowe PTZ*, 45: 535-536 (abst).
- [65] Woodward, C.C. and Strange, R.J. (1987): Physiological stress response in wild and hatchery-reared rainbow trout. *Trans. Am. Fish. Soc.*, 116: 574-579.