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RESEARCH ARTICLE

Effect of Magnetic Technology on Some Productive and Physiological Traits of Aged Japanese Quail Birds

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ABSTRACT

The objective of the present study was to evaluate the effects of magnetic technology including the exposure to magnetic field (MF) and/or consumption of magnetic water (MW) on the productivity of aged Japanese quail birds. The experimental laying flock consists of 160 females and 80 males of aged quails at 50 weeks of age that was used. Birds were divided into four equal treatments, each with 40 females and 20 males, and each treatment had four replicates (10 females and five males each). The first treatment served as control group consumed zero gauss water and did not receive MF exposure, the second group consumed 2000 gauss MW, the third group received 400 gauss MF exposure, and fourth group consumed 2000 MW and received 400 gauss MF exposure. The experimental period lasted for 6 weeks. The laying performance, hematological, biochemical, and hormonal variables were estimated and compared with control one. The results revealed a significant increase ($P \leq 0.05$) in egg production, egg weight, hen day percentage, fertility, hatchability of total eggs, hatchability of fertile eggs, and hatching weight as well as, there was a significant decrease in embryonic mortality in all treated groups compared to control one. The highest values were seen in T4 among the treatments, with the exception of egg weight and hatching weight. A significant decrease in the relative weight of carcass and abdominal fat as well as and a significant increase in ovary, oviduct, and tests percentages were observed in all treated groups compared to control group. The highest decrease was showed in T4 among the treatments. Hematological parameters, plasma alkaline phosphatase enzyme activity, testosterone, and estrogen hormones were significantly increased, while total lipids, triglycerides, and cholesterol were significantly decreased in both sexes of all treated groups compared to control group. In relation to the immune response, the results of antibody sheep red blood cells-titers ($\log_2$) were significantly improved in treated groups compared to control one. The superior increase was observed in T4. It can be concluded that applying MF with MW as an alternative technique to moulting program and was the most effective strategy to combat the decline in reproduction, physiological state, immune response, and mortality of aged Japanese quail. It also improved the productivity of aged laying Japanese quail birds by lengthening the production period of flock.

Key words: Aged laying quail, biochemical and hormonal parameters, magnetic field, magnetic water, productivity

INTRODUCTION

Most commercial egg industries followed traditional strategies to re-enhance the egg production, egg quality, and immunity of aged laying hens for a second laying cycle, such as force molting programs; feed restriction, photoperiod manipulations, high dietary levels of zinc, and hormonal injection.[1,2] Hence, the egg production, egg quality, and immunity of the layer flocks decline with aging.[3] These declines might have an association with an decrease in reproductive

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hormones, nutrients absorption, metabolism, and an increase in body fat percentages which may be inhibited the growth of ovarian follicles.[4] The force molting techniques have detrimental effects on laying hens, including; sharp reduction in egg production rate, egg quality, body weight as well as high increase in stress, toxicity, hen deaths, and birds need for a prolonged period of about 4 months for recovery and to promote a new laying cycle once more.[2,5] Therefore, it is necessary to look for alternatives to force molting programs that are more effective in reducing the negative impacts of force molting programs and achieve the greatest outcomes for egg production, egg quality, performance, and immunity of aged laying hens. The environmental effects, including magnetic field (MF), can affect the reproductive system and the levels of luteinizing, follicle-Stimulating, and testosteron hormones as well as the growth of sperms and ovarian follicles.[6] According to many researchers, MF is a key factor in altering neuroendocrine function and may maintain or enhance reproductive success.[6,7] All living organisms' growth and productivity are greatly influenced by the earth's geomagnetic field as an environmental element. However, the majority of MF investigations have focused on plant fields,[8] and little attention was given to animal production and reproductive applications.[9] The application of magnetic technology is an innovative method that can be used to improve the overall productivity and physiological health of aged quails. Hence, there have been numerous studies demonstrated the benefits of exposure to MF on productive performance, hematological, biochemical, and hormonal parameters of aged inactive laying quails,[10] productive,[11-13] and reproductive[14] aspects of birds, increases blood flow, improves the immune system,[11] appositive effects on the endocrine and neurological system, reproductive performance, and physiology,[14] as well as to stimulate blood and lymphatic flow, hormone secretion, and the delivery of nutrients to all body cells.[15] The other possibility that can assist in enhancing the productivity and immunity capabilities of poultry is magnetizing the drinking water and a alliterating the physics of water by exposure to MF. Exposing water to MF can increase: the fluidity, surface tension, pH level, and dissolving of oxygen and minerals[16] and subsequently resulted in, improving the quality of water, the biological activity of drinking water[17] and the delivery of oxygen and nutrients to all areas of the body through biological membranes, as well as an improvement in the movement of the small intestines and digestion and absorption processes.[11] Recently, the poultry industry has been more interested in magnetized water technologies,[11,18] they focused on the health benefits of employing magnetic water (MW) on productive and reproductive performance of birds,[18-20] showed significant increase in egg production, of aged laying hens at 54 weeks of age received MW with intensity of 3000 gauss,[11] and showed positive effects on the performance and immune response of growing Japanese quail received magnetically treated water up to 2000 gauss for 6 weeks. Information regarding the potential effects of magnetic applications on the performance, physiological, and reproductive characteristics of aged laying hens is rare**.** The authors hypothesized that exposing aged laying quails at a rate of ≈40% egg production to MF may stimulate them to improve their laying activity again. Therefore, the objective of this study was to determine the impacts of MF exposure at 400 gauss a long with or without drinking MW at 2000 gauss on aged quail laying performance and immunity.

MATERIALS AND METHODS

Birds, Husbandry, and Experimental Treatments

A total number of 160 females and 80 males of aged Japanese quail birds at 50 weeks of age reared at poultry experimental house, Nuclear Research Center, Egyptian Atomic Energy Authority were used in this study. The study was approved by Ethics Committee (2023). Birds equal in body weight were randomly divided into four equal groups of 40 females and 20 males in each. Each group is consisting of four replicates per treatment with (10 females and five males) per replicate.

The experimental treatments included:

- Treatment 1: Birds served as control group drank normal water without magnetism and did not expose to a MF
- Treatments 2: birds drank ad lib MW which passed through bi-polar magnetrons with strength of 2000 gauss
- Treatments 3: Birds exposed to static MF

generated by permanent magnet with 400 gauss strength

- Treatments 4: Birds drank ad-lib MW which passed through bi-polar magnetrons with strength of 2000 gauss and exposed to static MF generated by permanent magnet with 400 gauss strength, during the experimental period that lasted for 6 weeks.

The measurements performed in all treatments on reproductive traits including the egg production performance, fertility, hatchability, and the blood parameters were recorded. The experimental birds equal in body weight were housed in steel wire battery cages of (50 × 60 × 100 cm; height × width × length) in size, in an experimental house at the same management, hygienic and environmental conditions; a 16 h lighting schedule and ambient temperature ranged from 20–25°C during 8-week experiment period. Cages were equipped with a feeder and a stainless-steel nipple drinker. The birds were supplied with free access of feed and water until the end of the experiment.

The diet in [Table 1] was formulated according to[21] to meet the nutrient requirements of laying Japanese quail.

Table 1: Composition and calculated values of laying Japanese quail diet

Ingredients	Percentage
Yellow corn	53.88
Soybean meal (44%)	34.5
Soybean oil	4.0
Dicalcium phosphate	1.2
Limestone	5.7
DL-methionine	0.12
Sodium chloride	0.30
Vitamin and minerals premix*	0.30
Calculated values**	
Crude protein	20.04
ME Mj/Kg	12.2
Crude fiber	3.6
Lysine	1.14
Methionine	0.45
Methionine+cysteine	0.8
Calcium	2.51
Available phosphorus	0.36

*Provided per kilogram of diet: IU: vit A 12000; vit D3 5000; mg: vit. E 16.7, vit. K 0.67, vit. B1 0.67, vit. B2 2, vit. B6 vit. B12 0.004, nicotinic acid 16.7, pantothenic acid 6.67, biotin 0.07, folic acid 1.67, choline chloride 400, zinc 23.3, manganese 10, iron 25, copper 1.67, I 0.25, selenium 0.033, magnesium 133.4; 2 calculated according to National Research Council (NRC, 1994), ME: Metabolizable energy

Source of MF

The permanent magnet pieces with 400 gauss strength were used to generate the MF around the birds. They were purchased from Magnetic Technologies LLC, www.magnetic. nefertari2.com. The strength of the magnet was measured using a gauss meter before the experiment at the application laboratory, Engineering Reactors Department, Nuclear Research Center, Egypt. Some of these magnets were placed inside cages, acting as the negative pole on the upper side of the cage, and some were placed on the floor, acting as the positive pole of the magnet.

Preparation of Magnetically Treated Water

Permanent magnet with 2000 gauss strength was used to create MW. It purchased from Magnetic Technologies LLC, www.magnetic. nefertari2. com. The strength of the magnet was measured by a gauss meter before the initiation and after the termination of the experiment at application laboratory, Engineering Reactors Department, Nuclear Research Center, Egypt. The permanent magnet with both North and South poles was fixed to the exterior surface of the incoming water pipe of the group. Hence, drinking water used in the experiment was exposed to the MF as it passed once through the pipe that connects the magnets.

Eggs Collection, Incubation and Hatching Parameters

Eggs were collected daily throughout the duration of the experiment and stored in a cooler at 17°C, average egg weight, Hen day, and egg production in grams/quail/day were recorded daily for each group during the whole experimental period. Hen day egg production for a particular day is obtained by dividing the total number of eggs produced on a day by a total number of present on that day ×100.

Egg Incubation

Eggs collected during 7 days were grouped and set in the incubator. Hatched chicks, hatching weight, and embryonic mortality from each group were

recorded. Hatchability was recorded as percent of total eggs set and as percent of fertile eggs that hatched in each treatment as following equation:

$$Hatchability\% = \frac{Number\ of\ eggs\ hatch}{Number\ of\ total\ eggs\ set} \times 100$$

$$Hatchability\% = \frac{Number\ of\ eggs\ hatch}{Number\ of\ fertile\ eggs} \times 100$$

Blood Sampling Technique and Carcass Traits

At the end of experimental period 6 weeks, 12 females and eight males from each treatment were randomly selected, close to the body weights group mean, weighed, and slaughtered for carcass traits including: Carcass, liver, proventriculus, preventriculs, abdominal fat (from the parts around the viscera and gizzard), ovary, oviduct, and tests. They were calculated as a relative percentage of live body weight for each slaughtered bird. Blood samples from the same slaughtered bird were collected in two sterile heparinized tubes per bird as an anticoagulant; one tube immediately centrifuged at 4000 rpm for 5 min to obtain plasma. The obtained clear plasma was carefully harvested and transferred to dry sterile screw capped tubes (Eppindrof) and placed in a deep freezer (−20°C) to conduct further hormonal and biochemical tests. The second tube to perform the following hematological analysis; blood hemoglobin concentration (Hb %) was determined using the cyano-methemoglobin colorimetric method and packed cell volume percentage (PCV %) determined by micro hematocrit centrifuge tube with three tubes were used for each sample in accordance with the.[22] Red blood cells (RBCs) and white blood cell (WBCs) counts were determined by a haemocytometer using Natt- Herrick solution.[23]

Plasma Biochemical and Hormonal Parameters

Blood plasma was used for the estimation of; the concentrations of total proteins, albumin, total cholesterol, triglyceride, and the activity of alkaline phosphates (ALP), were measured calorimetrically with a spectrophotometer (Shimadzu UV 1601) using commercial kits produced by (Stanbio Company, USA), following the manufacturer's protocols. Plasma globulin values were calculated by subtracting albumin values from their corresponding total proteins values of the same sample. The concentrations of plasma Estradiol-17ß (E2) hormone in female and testosterone hormone in male quail birds were measured by radioimmunoassay kits made by the Hungarian company ISOTOPES Ltd., and samples were counted on a Packard Cobra Gamma Counter (Perkin Elmer Life Sciences Inc., Boston, MA).

Immunological Test

Antibody response to sheep RBCs (SRBC) antigen

At the end of experimental period, nine males and nine females from each treatment were chosen at random and housed in multidisc batteries. Each bird was injected with 0.2 mL of 7% SRBC antigen suspended in 0.9% saline to the back of the neck. Blood samples were collected through the wing vain before injection and at days 5, 10, and 15 of post-immunization. Sera were separated by centrifugation at 3000 rpm and stored at −20°C until all samples were analyzed simultaneously. The antibody production to SRBC was measured by the microtiter hemagglutination assay as described by.[11] Birds receiving the SRBC were maintained in separate cages for the duration of the experiment. Antibody titers data were transformed to reciprocal log units.

Statistical Analysis

The observed data were statistically analyzed using one-way analysis of variance as a completely randomized design using the general linear models procedure under statistical analysis system software.[24] The data are presented as means ± standard error. Significant differences between treatment means were compared by Duncan's multiple-range test[25] and were considered to be statistically significant at ($P < 0.05$).

RESULTS AND DISCUSSION

Laying Performance

The effects of exposing aged Japanese quail birds at 50 weeks of age to MF with 400 Gauss or 40 mT strength with or without MW with 2000 Gauss or

200 mT strength on egg production, egg weight and hen day percentage, fertility, hatchability, embryonic mortality, and hatching weight are shown in Table 2. The data clearly showed significant increase in egg production, egg weight, hen day percentage, fertility, hatchability of total eggs, hatchability of fertile eggs, and hatching weight as well as, there was a significant decrease in embryonic mortality in all treated groups compared to control one. With the exception of egg weight and hatching weight T4 (which exposed to MF and received MW) showed the highest values among the treatments. While T2 which received MW showed the highest values in egg weight and hatching weight among groups. In addition, T3 which received MF had higher fertility and lower percentages of embryonic mortality percentages than T2 which received MW. There were no significant differences between T2 and T3 in terms of egg production, hen day percentage and hatchability of fertile eggs.

In general, the poultry industry uses the hen day as one of the layer production indices for measuring daily or weekly egg production. It mostly uses for the scientific studies to reflect the production capacity of the laying farm. A farm recorded 85% or higher annually is preferred. Fertility rate also is a key indicator of reproductive success. The significant improvement in laying activity; egg production and fertility of aged quails treated magnetically with MF and/or MW may initially be as a result of the MF's function in regulating the pituitary gland's activity as well as ovarian and testicular functions,[19] by causing an increase in ovarian activity for the growth, formation, and release of eggs through the secretion of the hormones FSH and LH.

Second, it may be attributed to the crucial roles of both MF and MW in promoting blood vessels expansion, improving blood flow, and transferring large amounts of nutrients such as amino acids and minerals as well as, oxygen needed for enhancing the effectiveness of body cells and tissues, for building of the protein mass of the body's vital tissues, all egg components and the fertility factors, thereby increasing the productivity of laying flocks.[17,26] Furthermore, the positive work of both MF and MW expands the gut, improving digestion, absorption, the utilization of nutrients, and protein biosynthesis, as well as their functions and the circulatory system, thereby increasing the rate of egg production and fertility.[15,27]

The results are in agreement with Khudiar and Ali[28] who reported a significant increase in egg production and reduced mortality rate in commercial egg-layers flocks exposed to MF. Ibrahim *et al*.[13] also showed a significant increase in hatching percentage, embryos surviving, sexual maturity and food conversion ratio (kg feed/kg egg) of quail eggs exposed to low-intensity magnetic flux (110 Gaus). Keirs *et al*.[29] reported also an increase in hatchability of eggs subjected to MF of 0.07 T (700 Gauss) during storage for 20–40 min. On the other hand, Toman *et al*.[30] reviewed the positive impacts of magnetized water as an alternative strategy to improve the poultry production system. Ibrahim,[11] Abd El-Ghany *et al*.[31] indicated significant effects of drinking MW on productive traits of laying chickens and the percentage of hatching compared the control group. El Sabry *et al*.,[18] Abd El-Ghany[31] showed

Table 2: Effect of magnetic field and/or magnetic water on egg production, egg weight, and hen day% percentages of fertility, hatchability, embryonic mortality, and hatching weight of aged quails

Traits	Experimental groups			
	T1 0 gauss	T2 MW 2000 Gauss	T3 MF400 Gauss	T4 MW 2000 Gauss+MF 400 Gauss
Egg production (%)	42.0±2.6^{c}	65.3±1.2^{b}	66.5±1.4^{b}	77.3±1.4^{a}
Egg weight (g)	12.4±0.27^{d}	13.3±0.1^{a}	12.8±0.1^{c}	13.1±0.24^{b}
Hen day%	66.5±1.13^{d}	84.6±1.6^{b}	85.6±2.13^{b}	90.5±3.1^{a}
Fertility %	46±0.94^{d}	86.4±1.19^{c}	92.4±0.94^{b}	94.1±1.12^{a}
Hatchability % **of** total eggs	19.3±0.52^{d}	73.9±0.9^{c}	77.2±1.04^{b}	82.1±0.9^{a}
Hatchability % of fertile eggs	42±2.6^{c}	85.5±2.20^{b}	83.6±1.9^{b}	87.2±2.05a
Embryonic mortality %	58±1.53^{d}	14.5±0.75^{b}	16.4±1.91^{c}	12.8±0.24a
Hatching weight (g)	7.5±0.3^{d}	8.7±0.26^{a}	7.9±0.25^{c}	8.31±0.35^{b}

Means in the same row of each trait with different superscripts are significantly different at $P<0.05$. T1: Control group with 0 Gauss, T2: Aged quail received water treated with 2000 Gauss, T3: Aged quail received MF with 400 Gauss, T4: Aged quail received water treated with 2000 Gauss and MF with 400 Gauss, MF: Magnetic field

significant effect on egg productive traits; mortality rate, egg weight, eggshell thickness, and eggshell weight of laying chickens received magnetized water with more than 10,000 gauss compared with hens received tap water. They explained these effects to the characteristics of magnetized water which was saturated with more oxygen, more alkaline, and had higher concentrations of (i.e.: Na+, K−, Ca^{2+}, Mg^{2+}, Cl−, and HCO_3,); it helps to increase the availability and concentration of calcium and phosphorus and in higher concentration in blood of the laying chickens thereby, improving their eggshells quality by increasing eggshell thickness and eggshell weight. Although the effects of MFs are still debatable and dependent on factors including gender, body tissue density, life stage, and MF exposure levels, the favorable benefits should generally be taken into consideration. The findings significantly support the use of MF and MW as alternate strategy techniques in aged layer quail flocks to improve both the economic benefit and production measures.

Carcass and Internal Organs

The impacts of exposing aged Japanese quail hens to MF with or without magnetic MW on carcass and some organs are presented in Table 3.

The results showed significant decrease in; carcass and abdominal fat percentages as well as, there was a significant increase in; ovary, oviduct and tests percentages in all treated groups compared to control group. The superior increase was observed with T4 which exposed to MF and received MW. While there were no differences between T2 which received MW and T3 which received MF. The highest values in carcass and abdominal fat percentages with untreated control group are agree with,[2,32] who showed significant increase in the values of carcass and abdominal fat deposit with increase in age and weight of birds. The reproductive performance of quail laying hens is negatively impacted by the accumulation of abdominal fat and excessive carcass weight.[33] It is well known that abdominal fat in aged laying hen is not a desirable trait and causes a sharp reduction in laying performance. Treatment of aged laying quails with MF and/or MW reduced the excess weight in their carcass and abdominal fat, additionally the percentages of ovary, oviduct, and tests in all treated groups increased which in turn improved egg production and fertility in this study.

The reduction of carcass and abdominal fat percentages in all treated groups was directly attributed to the impacts of MF and MW in improving variety of enzymes, pancreatic b cell function, and gut microbiota which increased the metabolism of glucose and fats, increased nutrient uptake, and stimulated protein synthesis, which may explain the improvements in egg production, fertility, and immunity in aged laying quails. According to a study by[34] exposing mice to permanent magnet with a field strength of 100 mT improved; pancreatic enzymes, gut microbiota, glucose, and iron metabolism, reduced: blood sugar levels, fatty liver, and weight gain. In a study by Yu *et al*.,[35] exposing broiler breeder to 250 gauss MF for 8 weeks resulted in a significant increase in their plasma glucose levels compared to the control group. The reduction in carcass percentage in all treated birds is in agreement with[36] who reported a significant decrease in body weight gain of meat-type breeder eggs exposed to 18 Gauss MF at 50 Hz for 75 min. In contrast, Shafey *et al*.[37] showed

Table 3: Effect of MF and/or MW on carcass and some organs of aged quails

Traits	Sex	Experimental groups			
		T1 0 gauss	T2 MW 2000 Gauss	T3 MF400 Gauss	T4 MW 2000 Gauss+MF 400 Gauss
Carcass%	F	71.5±0.35^a	68±0.57^b	67.3±0.27^b	62.83±0.44^c
	M	75.1±0.22^a	73.5±0.33^b	72.8±0.18^b	71.1±0.33^c
Abdominal fat%	F	6.81±0.02^a	4.41±0.05^b	4.21±0.02^b	3.81±0.02^c
	M	4.6±0.04^a	3.0±0.07^b	2.8±0.02^b	2.1±0.02^c
Ovary %	F	2.9±0.04^c	3.45±0.04^b	3.35±0.04^b	3.7±0.08^a
Oviduct %	F	2.7±0.08^c	3.23±0.17^b	3.1±0.07^b	3.6±0.04^a
Tests %	M	2.7±0.12^c	3.1±0.16^b	2.9±0.06^b	3.55±0.04^a

Means in the same row of each trait with different superscripts are significantly different at $P<0.05$. F: Female , M: Male, T1: Control group with 0 Gauss, T2: Aged quail received water treated with 2000 Gauss, T3: Aged quail received MF with 400 Gauss, T4: Aged quail received water treated with 2000 Gauss and MF with 400 Gauss, MF: Magnetic field, MW: Magnetic water

significant increase in the weight of rats exposed to MFs of 5 and 8mT for 3 weeks. The improvement in ovary, oviduct, and testes percentage in all treated birds is in agreement with[38] who showed significant changes in the relative ovary weight and sizes of female mice exposed to 50 Hz and 15 μTesla MF. Picazo *et al*.[39] also showed significant increase in testis size in adult rat after exposure to low frequency electromagnetic fields. Asghari *et al*.[7] reviewed that MF considers one of the most environmental factors inducing biological effects such as reproductive organs, spermatogenesis, follicular genesis, and sexual hormones. Hence, the MFs is non-ionic waves, that cannot release electrons. However, they are energy penetrate the bird's body and acting on all organs, altering the cell membrane potential and the distribution of ions and dipoles. These alterations may influence biochemical processes in various metabolic ways. Unfortunately very limited studies have documented the effect of MF and/or MW on reproductive performance of birds.

Hematological Parameters

The impact of MF with or without MW on hematological parameters of aged quails birds is presented in Table 4. The findings revealed that exposing aged quails birds to MF with or without MW have significant effect ($P \leq 0.05$) on the levels of all hematological parameters; erythrocyte (RBCs), leukocyte counts (WBCs), hemoglobin concentration (Hb), and the hematocrit value (PCV) in both sexes of all treated groups compared to control one. The highest values were recorded with T4 which exposed to MF and received MW among the treatments. While there were no differences between T2 which received MW and T3 which received MF.

The improvements in PCV values and Hb concentrations in all treated groups logically reflect the status of RBCs counts due to the positive correlation between Hb concentration, PCV values, and increase RBCs numbers.[40] The increment of PCV and Hb may be attributed to increase in production of these cells from bone marrow and circulatory system under the effect of hormonal factors which induced by MW.[11] The primary physiological function of the RBCs is to carry Hb which sequentially carries oxygen to tissues. The increase in RBCs and Hb in the blood of treated groups may be initiated by the increase of erythropoietin from kidney and increased rate of erythropoiesis.[41] It has been suggested that a static MFs have a stimulatory effect on regional blood flow and significantly increased metabolic activity.[10] The improvement in blood hematology of aged laying quails that treated with MF with or without MF is suggesting an improvement in health status of laying quail flocks and showed no physiological stressful condition was introduced in aged quails due to the magnetic treatments. In addition, the beneficial of MW could be attributed to the changes occurred in the water properties such as the reduction in the surface tension, density, and viscosity of water leading to improve blood picture and increase the blood ions concentration and therefore the speed of biological reactions.[11,17] Therefore, exposing aged hen's body or water to MFs has the primary role in influencing iron involved in the formation of the hemoglobin molecule.[42] Furthermore, the MW enhancing the metabolic cycles, minerals solubility, and blood flow in vessels and increase

Table 4: Effect of MF and/or MW on blood hematology of aged quails

Traits	Sex	Experimental groups			
		T1 0 gauss	T2 MW 2000 Gauss	T3 MF 400 Gauss	T4 MW 2000 Gauss+MF 400 Gauss
RBCs count×10^6	F	4.1±0.3^c	4.5±0.7^b	4.4±0.5^b	5.01±0.5^a
	M	4.7±0.4^c	5.2±0.4^b	5.12±0.3^b	5.6±0.2^a
Hb (g/dL)	F	8.85±0.2^c	10.7±0.2^b	10.3±0.3^b	11.7±0.3^a
	M	10.33±0.2^c	11.6±0.2^b	11.5±0.5^b	12.2±0.5^a
PCV (%)	F	47.3±1.5^c	55.2±1.3^b	55.0±1.1^a	57.0±1.1^a
	M	45.3±1.5^c	53.4±1.3^b	53.2±1.3^b	54.7±1.3^a
WBCs count×10^3	F	13.5±0.3^c	16.6±0.4^b	16.3±0.3^b	17.7±0.4^a

MF: Magnetic field, MW: Magnetic water, PCV: Packed cell volume, RBC: Red blood cell, WBC: White blood cell, Means in the same row of each trait with different superscripts are significantly different at $P<0.05$. F: Female, M: Male, T1: Control group with 0 Gauss, T2: Aged quail received water treated with 2000 Gauss, T3: Aged quail received MF with 400 Gauss, T4: Aged quail received water treated with 2000 Gauss and MF with 400 Gauss.

the transport of oxygen-bearing blood and nutrients (i.e., Fe and Cu) to various body cells to perform their function.[11]

The increase in the WBC's count in blood after MW treatment may be due to MW stimulating the growth of lymphatic tissue in the bone marrow which is necessary for the proliferation of WBC's. Raafat and Nabil[43] reported that drank MW play important immune active role in defending the biological system against different diseases. The significant increase ($P \leq 0.05$) in RBCs, WBCs, Hb, and PCV values in all treated groups is in accordance with those obtained by Wakwak[10] who showed positive effects on the hematological parameters of aged inactive quail birds exposed to MFs strengths up to 400 gauss for 60 days. MTC[44] also found significant increase in the above parameters in rats exposed to MF. Amara *et al*.[45] found significant increase in the hematological parameters of broiler chicks due to offering MW compared to that drank non-MW. Similarly, Shacir *et al*.[46] observed significant increases in RBCs, Hb, and PCV values of rabbit bucks drank MW ≈4000 gauss. Attia *et al*.[47] found that magnetically supplemented water up to 3000 gauss lead to highly significant increase in RBCs, PCV, and Hb concentration of laying hens compared with control group. Yacout *et al*.[16] showed a significant increase in Hb, RBC's, and WBC's of lactating goats received MW at the levels of 1200 and 3600 gauss.

Biochemical and Hormonal Parameters

The impact of MF with or without MW on some biochemical and hormonal parameters of aged laying quail birds is shown in Table 5. The data clearly revealed no differences in plasma total protein, albumin, and globulin among groups in both sexes.

Plasma enzyme activity ALP, testosterone, and estrogen hormones were significantly increased in both sexes of all treated groups compared to control group. The highest values were observed with both T4 and T3 in both sexes. For blood lipid profiles, plasma total lipids, triglycerides, and cholesterol levels as shown in Table 5 tended to decrease in both sexes of all treated groups compared to control one. The lowest values were recorded with T4, while there were no significant differences between T3 and T2. It is possible to attribute the reduction in plasma lipid profiles levels to their vital roles as necessary agents for nervous tissues, synthesis-steroid hormones and cell membrane interference with phospholipids, which causes the plasmatic levels of total lipids, triglycerides, and cholesterol to decrease. Another explanation may be due to increased ionization of water by magnetized water, such ions after being absorbed in the body generate new electrical energy in the blood which can decrease blood lipid profiles and resulted in improving blood circulation. In addition, the antioxidant activity of MW was claimed to be responsible for the hypolipidemic effect. The reduction in plasma total lipids, triglycerides, and cholesterol levels is in accordance with results found by Wakwak[10] who showed significant decrease on plasma lipids profile levels of aged inactive quail birds exposed to MFs strengths up to 400 gauss for 60 days. Ibrahim[11] showed significant decrease on plasma lipids profile levels of growing Japanese quail received magnetically treated water up to 2000 gauss for 6 weeks. Yacout *et al*.,[16] Khudiar and Ali[28] showed a significant decrease in serum total cholesterol and triglycerides concentrations of rabbits treated with MW for 60 days. In contract,[48] cholesterol and triglycerides concentrations were not influenced by magnetized water. Picazo *et al*.[39] showed that rats exposed to MFs of 5 mT and 8 mT intensity for 3 weeks had lower plasma cholesterol and triglyceride levels. Gilani *et al*.[49] showed a reduction in plasma cholesterol levels in mice exposed to 60 Hz and 5 Mt MFs for 8 h. The improvements in laying activity and performance in this study may be responsible for the elevated plasma ALP activity in treated groups.

As a result, there was a positive link between hens' blood levels of ALP and their laying activity or metabolism.[50] Furthermore, increased plasma ALP activity in laying hens may be related to elevated calcium mobilization from the bone.[51] Hence, the higher plasma ALP activity in laying hens may be a result of enhanced calcium deposit to the eggshell during the laying period. According to this result, Liu *et al*.[52] demonstrated a correlation between high plasma ALP activity and high eggshell thickness. The results of ALP herein are similar to the findings of[10] who revealed significant increase on plasma ALP activity of aged inactive quail birds exposed to MFs strengths up to 400 gauss for 60 days.

Table 5: Effect of magnetic field and/or magnetic water on blood biochemical parameters of aged quails

Traits	Sex	Experimental groups			
		T1 0 gauss	T2 MW2000 Gauss	T3 MF400 Gauss	T4 MW 2000 Gauss+MF 400 Gauss
Total protein (g/dL)	F	6.03±0.04	6.3±0.13	6.07±0.07	6.44±0.19
	M	4.67±0.07	4.93±0.17	4.8±0.11	4.99±0.13
Albumin (g/dL)	F	3.34±0.29	3.54±0.18	3.37±0.16	3.5±0.03
	M	2.35±0.1	2.5±0.3	2.43±0.15	2.53±0.3
Globulin (g/dL)	F	2.69±0.01	2.76±0.05	2.7±0.02	2.94±0.18
	M	2.32±0.18	2.43±0.1	2.37±0.3	2.46±0.32
Alk-Phosphatase (IU/L)	F	274.8±4.7^{c}	331±3.5^{b}	354±3.1^{a}	363.3±5.8^{a}
	M	252.7±1.3^{c}	304.7±2.6^{b}	316.3±3.3^{a}	328.3±6.0^{a}
Total lipids (mg/dL)	F	887.1±28^{a}	744.7±21^{b}	752.7±52^{b}	597.8±41^{c}
	M	936.5±30^{a}	537.6±22^{b}	466.3±9^{b}	386±22^{c}
Triglycerides (mg/dL)	F	63.5±1.4^{a}	55.9±2.3^{b}	55.0±1.2^{b}	47.6±1.2^{c}
	M	61.5±2.2^{a}	53±2.2^{b}	52±2.08^{b}	46±1.1^{c}
Cholesterol (mg/dL)	F	333±4.1^{a}	306.7±3.3^{b}	296.7±2.3^{b}	272±2.3^{c}
	M	260±2.6^{a}	200±3.01^{b}	195±1.7^{c}	190±1.3^{c}
Estradiol-17ß(E2) (pg/mL)	F	42±3.2^{b}	63±3.2 a	64±3.9^{a}	64.7±4.1^{a}
Testosterone (ng/mL)	M	0.45±0.02^{b}	0.60±0.01 b	0.61±0.01^{a}	0.65±0.05^{a}

Means in the same row of each trait with different superscripts are significantly different at $P<0.05$. F: Female, M: Male, T1: Control group with 0 Gauss, T2: Aged quail received water treated with 2000 Gauss, T3: Aged quail received MF with 400 Gauss, T4: Aged quail received water treated with 2000 Gauss and MF with 400 Gauss

Eraslan *et al*.[50] showed that MFs could increase the osteoblastic activity in bone fractures.

Regarding sex hormones; the significant increase in plasma sex hormones concentrations of all treated groups may be attributed to the influence of magnetic applications (MF and MW) on; the reproduction and physiology of birds breeding, alters endocrine and immune systems,[14] and melatonin level in birds.[53] In study by Fernie and Reynolds[14] showed significant changes in the sexual behavioral, courtship, fertility, egg laying, and clutch size of captive kestrels exposed to electro MFs 1 m of a 735-kV for 95 days. The increasing of plasma sex hormones concentration may explain the positive role of MW and MF on improving the laying performance of aged laying quails found herein. The results of sex hormones concentration are in agreement with those found by Wakwak[10] who showed significant increase in plasma sex hormones concentrations of aged inactive quail birds exposed to MFs strengths up to 400 gauss for 60 days.

The Immune Response

The impact of MF with or without MW on antibody titers against SRBC antigen of aged quails birds is presented in Figure 1.

T1: Control group with 0 Gauss, T2: Aged quail received water treated with 2000 Gauss, T3: Aged quail received magnetic field with 400 Gauss, T4: Aged quail received water treated with 2000 Gauss and MF with 400 Gauss. a, b, c, d means with different superscripts are statistically different at ($P \leq 0.05$).

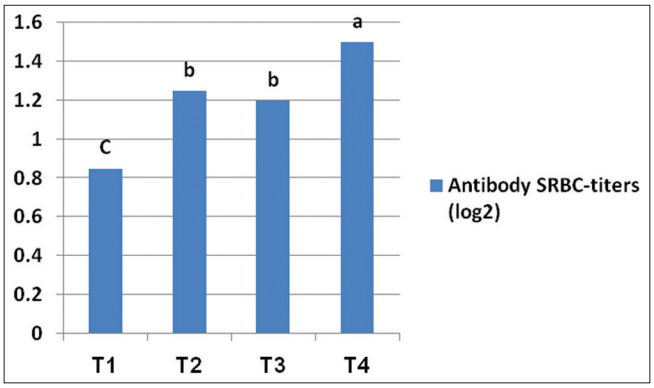

Figure 1: Antibody SRBC-titers (log_2) in aged quails birds exposed to magnetic field with or without magnetic water

In relation to the immune response, the results indicated that the antibody SRBC-titers (log_2) which act as immune response indicator was significantly improved in treated groups compared to control one. The superior increase was observed in T4. The obtained results on antibody SRBC-titers (log_2) indicated the beneficial effect of MF exposure and drinking MW by helping the body against microbial invaders and improve immune

system. In this context, several studies reported that magnetized water could influence effectively on the oxidant-antioxidant balance.[16] The obtained result illustrated the impact of magnetization on improving the health of laying quail flocks and the benefits of drinking water which is reflected in the elevation of antibody SRBC-titers (log_2). Hence, the water becomes more vital and biologically active and improves blood movement and plug in the body tissues and cells which helps in improving the immunity system abilities and antioxidant status. In this subject, Khudiar and Ali[28] revealed that MW enhanced physiological aspects and antioxidant status. In addition, the exposure to static MFs altered a number of functional parameters of immune cells, particularly macrophages, spleen lymphocytes, leukocyte, and increased apoptosis of thymus cells.[54] This finding agrees with those reported by Ibrahim[11] who showed positive effects on the immune response of growing Japanese quail received magnetically treated water up to 2000 gauss for 6 weeks. Alhammer *et al*.[55] also reported significant improvement in the immunological status of mice treated with MW. Attia *et al*.[47] showed significant increase in immunoglobulin and antioxidant enzymes of rabbit bucks drank magnetized water. Yacout *et al*.[16] showed higher antioxidant enzymes of goats that received MW. Khudiar and Ali[28] showed a significant increase in serum glutathione concentration of rabbits treated with MW daily for 60 days. The enhancing effect of MW and MF on the immune response is accordance with the improvement found herein in quail laying performance offered MW and exposed to MF.

CONCLUSION

Laying performance, carcass and internal organs, hematological parameters, biochemical and hormonal parameters, physiological functions, and immune response of aged Japanese quails lying are improved due to long-term exposure to MF with 400 gauss and consumption of magnetically treated water with 2000 gauss, suggesting an improvement in egg production, fertility, hatchability, and health status of aged quail birds. Therefore, the application of magnetic technology is utmost important for successful reproduction in poultry industry.

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