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The Effects of the Magnetic Drinking Water in Poultry: a Review

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REVIEW

Abstract

Good water quality and cleanliness increase water intake. This could lead to improved performance and reduce health problems of the flock in livestock. It does not require extra energy consumption and easy installation when a permanent magnet is used. Exposure of the water to a magnetic field changes the water's properties including raising pH, and dissolved oxygen, and the number of water molecules decreases to a smaller cluster leading to better absorption of water into the animal cell membranes. There are many results in poultry field that magnetized drinking water increases water consumption and feed intake, body weight gain, feed conversion ratio and meat quality of broilers, also it enhances egg production traits for laying hens. In addition, it improves hatchability, bioavailability, immunity and decreases mortality. This review aims to explain the existing literature on the influence the application of magnetic drinking water on the performance and health parameters of poultry.

Keywords: Magnetic water, poultry, performance.

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INTRODUCTION

Water is considered the most important nutrient for livestock, but is often overlooked. It is necessary for transportation and cell integrity (El-Hanoun et al., 2017), regulation of body temperature, growth, reproduction, lactation, digestion, lubrication of joints and eyesight as a cleansing agent (Lardy et al., 2008). Water deficiency can depress animal performance more quickly and drastically than any other nutrient deficiencies domestic animals can live about sixty days without food, but only seven days without water (Lardy et al., 2008). Animals' water requirements are affected by many factors, including body size, productivity, diet and environmental conditions. Good water quality and cleanliness can increase water intake and reduce health hazards (Scollan et al., 2010), improve livestock production (Meehan et al., 2015) and overall performance of the flock (Jacob, 2015). Jassimand and Aqeel (2017) reported that water intake on poultry farms include pH, hardness and total dissolved solids effect on animal health. Therefore, providing good quality water is necessary for life and animal production. To improve the quality of water first should be physical methods applied for organic production. Drinking water filtration, softening, acidification, neutralization, disinfecting and magnetic field applications are applied to improve the performance of high providing and utilization in poultry nutrients (Eleroglu et al., 2013). Hence magnetic or electrostatic scale control technologies can be used as a replacement for most water-softening equipment. Magnetized water (MW) has different mechanical, electromagnetic, and thermodynamic properties compared to regular tap water (Esfahani et al., 2018). MW is a more easily applicable and

cost-effective treatment compared to other chemical and physical methods. Moreover, after being connected with the magnetic apparatus, the installation system and pipeline were automatically cleared, and the solid material became loose and fell off. Thus, the life span of the installation system of poultry expectantly increased (Gholizadeh et al., 2008). Due to these specific properties, the use of MW has been increased in different applications such as in industrial, environmental, medical, agricultural fields and poultry production (Yadollahpour et al., 2014; Ghorbani et al., 2018).

Electromagnetic field exposure is considered as a possible alternative to anticoccidial drugs (Elmusharaf et al., 2010), has beneficial effects on the nervous system (Kaszuba-Zwoińskaet al., 2005) and may have an anti-inflammatory effect (Montesinos et al., 2000). In addition, some studies have concluded that magnetic treatment improved the quality of the well water and it have positive effects on the reproductive properties (Wang et al., 1998; Al-Daraji and Aziz, 2008; Hassan et al., 2018; El Sabrout and El-Hanoun, 2019). Broilers that drank MW had better hatchability, viability (El-Hanoun et al., 2017) and health (Olteanu et al., 2012). The magnetized water (500 and 1000 gauss) improved all biochemical and physiological properties of Japanese quail, which could help to improve productivity, although 1000 gauss MW showed a better effect (Al-Hilali, 2018).

Wang et al. (1998) reported that MW increased efficiency in the biological and biochemical reactions of sperm cells. Al-Daraji and Aziz (2008) revealed that the quality and quantity of the semen of roosters that received MW (500, 1000 and 2000 gauss) were significantly better than those of tap water.

Many studies focus on the properties of MW that could be useful in the poultry sector, improvement of performance, reproduction, health, immune system and viability parameters. The aim of this article is to present a general knowledge by bringing together the results of the studies on this subject.

EFFECT OF MAGNETIC FIELD ON WATER CHARACTERISTICS

Water is not homogeneous at the nanoscale and exists as clusters depending on the temperature, pressure and physical forces. Thus, the density of the water may also change depending on the forces that dominate the conditions (Reddy et al., 2014). Liquid water is affected by magnetic fields (Pang and Deng, 2008; Cai et al., 2009) and such fields can assist in its purification (Ambashta and Sillanpää, 2010). It affects both the chemical and physical processes of dissolution and crystallization of water (Ignatov and Mosin, 2015).

Magnetic fields can be measured in teslas (T) or gauss (G) (1 T=10000 G) (Grissom, 1995).

The magnetization procedure of the water is simple without extra energy consumption when a permanent magnet is used. A permanent magnet can be installed on a previously established water tube system, resulting in no further energy requirements for water magnetization. This green technology is clean and has zero energy consumption (Esmaeilnezhad et al., 2017). When water passes through a constant magnetic field at a constant speed, MW is obtained. When that happens, some definite changes occur in its molecular characteristics. The molecules of regular tap water are not separated from each other due to the existence of hydrogen bonds. They tend to attach to each other, forming clusters. As regular tap water passes through a permanent magnetic field, the size of these clusters and the number of grouped molecules decrease (Zhou et al., 2000; Esmaeilnezhad et al., 2017). Usually, a water cluster consists of many water molecules of size 11–50 depending on the dominating force in the water molecule; But when water is exposed to magnetized field, it is observed that the number of water molecules decreases to a smaller amount and is, usually of about the size 5–6 (Reddy et al., 2014). Consequently, the activity of the water molecules increases (Toledo et al., 2008). Furthermore, the smaller cluster leads to better bioavailability (Reddy et al., 2014) and better absorption of water into the plant and animal cell membranes (Verma, 2011).

Physically, exposure of water to a magnetic field changes the water's properties including raising the pH, dissolved oxygen, and vital minerals besides increasing the total hardness (Musa and Hamoshi, 2012; El-Sabroutand Hanafy, 2017), increases the fluidity, dissolving capability for various constituents like minerals and vitamins and consequently improves the biological activity of solutions, affecting positively the performance of animals (Al-Mufarrej et al., 2005; Khudiar and Ali, 2012). In addition, MW decreases the surface tension of water, increases water viscosity and improves conductivity, organic matter and total count of bacteria that its effects depend on the strength of the magnetic field and exposure time (Cai et al., 2009; Yacout et al., 2015; Ebrahim and Azab, 2017).

Some researchers (Cho and Lee, 2005; Hafizi et al., 2014) reported that surface tension in MW is reduced by 10-12% whilst its velocity is increased in comparison with regular water. Therefore, its penetration into the cell wall would be facilitated which can accelerate the ordinary diffusion of water that is vital for the growth of different organs. Moreover, MW can used as an alternative physical mechanism to remove mineral scale deposits from pipelines and equipment in poultry industry, by increasing the solubility of calcium salts (Chynoweth, 1985; Skeldon, 1990). Coey and Cass (2000) claimed there is an incubation period of several hours and memory of magnetic treatment extends beyond 200 h.

EFFECT OF MAGNETIZED WATER ON PERFORMANCE PARAMETERS

Gilani (2014) aimed to increase the water consumption of feedstuffs of broilers (Ross 308) and concluded that the consumption of MW (6500 gauss and 30 min) by broiler chickens was significantly higher than tap water throughout all periods of the experiment, while feed intake had no effect on MW. In addition, El-Hanoun et al. (2017) observed that using of MW (4000 and 6000 gauss) in geese, water consumption was increased in goose treated with MW when compared to the non-treated tap water consumed groups. Al-Mufarrej et al. (2005), Al-Fadul, (2006) and Mahmoud et al. (2017) reported that magnetization of the water reduced water consumption in broilers. The reduction of water intake for the birds consumed MW could be explained by the interpretations of McMahon (2009), since they attributed the decrease in water intake to the changes in water properties such as surface tension, fluidity, absorbency, pH level and dissolving capabilities.

Gholizadeh et al. (2008) and Soltan et al. (2018) found that MW increased feed intake in broilers compared to normal tab water. In contrast, Al-Hassani and Amin (2012) reported that feed intake in broiler chicks (Cobb-500) was not affected by the magnetizer device (500 gauss) with treatment durations of 5, 10, and 15 minutes to obtain 10 litter MW compared to untreated water. However, El-Katcha et al. (2018) found in their study that repeating every 6-hour magnetized water (MW) treatment numerically increased feed intake in Cobb 500 broiler chicks.

Mahmoud et al. (2017) reported that MW improves body weight gain in Sasso broilers. Similar to this result, Soltan et al. (2018) found that MW improves body weight and daily body weight gain (+7.3% and +7.4%) in Arbor Acres chicks. In line with findings by Nada et al. (2007) reported that magnetization of the water (400, 500 and 600 gauss) significantly increased Arbor Acres broiler's body weight, especially in the late weeks, while the effect of magnetized water of 600 gauss showed a better performance. However, Gilani (2014) observed in his study that body weight gain of broilers has been significantly increased only in the starter phase using MW (6500 gauss and 30 min). Also, MW treatment improved the growth performance of Pekin ducklings (El-Katcha et al., 2017) and final body weight (+19.6%) of geese (El-Hanoun et al., 2017). Based on the results of Gholizadeh et al. (2008), the consumption of magnetic samples (6000 gauss) has about 200 g meat more than the nonmagnetic samples (ordinary water). However, some researchers found that the use of MW did not influence the performance of chickens. Al-Hassani and Amin (2012) stated that body weight was not significantly different for birds (Cobb 500) receiving tap water or MW (500 gauss). The statistical analysis of data by El-Katcha et al. (2018) showed that repeating every 6-hour.

MW treatment non-significantly ($P \geq 0.05$) increased final body weight (2.87%) and total body weight gain (2.9%) compared with broiler chicks' group that drank tap water without treatment. Also, El-Katcha et al. (2017) reported that MW treatments non-significantly ($P \geq 0.05$) increased the final body weight of Pekin growing ducks compared with control group. The differences among results of the studies in this field may be due to broiler strain, the magnetizer device type, power of magnetization, speed of the device, experimental procedures etc. (Mahmoud et al., 2017).

In broilers that drink MW the feed conversion ratio values significantly improve (Mahmoud et al., 2017; Soltan et al., 2018). This report confirms the previous findings of Sagbaug (2003) and Nada et al. (2007), who found that the feed conversion ratio of broiler chickens was improved by the magnetization of water. Also, the consumption of MW (6000 gauss) improved the feed conversion rate (-18.2%) in geese (El-Hanoun et al. 2017). In contrast El-Katcha et al. (2018) reported that repeating every 6-hour MW treatment non-significantly ($P \geq 0.05$) improved the average feed conversion ratio, water feed ratio, protein efficiency ratio, efficiency of energy utilization, and performance index compared with broiler chicks group drank tap water without treatment. This finding is supported by those obtained by El-Katcha et al. (2017) stated that MW non-significantly ($P \geq 0.05$) increased final body weight, feed conversion ratio and protein efficiency ratio throughout the whole experimental period of Pekin growing ducks compared with control. Although numerically MW treatment improves feed efficiency of growing Pekin ducklings (El-Katcha et al., 2017).

Gholizadeh et al. (2008) found in their study that by magnetizing water (6000 gauss) the livability increased, mortality and sick cases of broilers were reduced. Furthermore, the mortality rate values showed significant ($P \leq 0.05$) better values for Sasso broiler ordinary water (2.22 %) than those for drinking MW (3.27 %) (Mahmoud et al., 2017). In agreement, Keirs et al. (2005) found that the application of a magnetic field on commercial egg-layer flocks reduced mortality rates by 47.6%. However, Mitre (2018) showed that there were no significant results in the livability of Cobb-500 chicks by using MW (1850 gauss). This finding agrees with the one found by El-Sabrout and Hanafy (2017) who stated that MW (14500 gauss) did not have a significant effect on the mortality rate of laying chickens. Also, Al-Hassani and Amin (2012) reported that mortality, viability, and production index generally were not affected by different MW (500 gauss) treatments compared to untreated water. It was speculated that liver enzymes and gut physiology in broiler chickens were influenced by magnetized drinking water, but the weights and lengths of the intestinal tract and femur and tibia bones of the MW (with 0.65 Tesla magnetic field) treated groups were similar to those of control birds (Gilani et al., 2014).

EFFECT OF MAGNETIZED WATER ON IMMUNOLOGICAL, BACTERIOGICAL, PARASITOLOGICAL AND BLOOD PARAMETERS

Several studies showed that MW could influence the oxidant-antioxidant balance. Magnetic water could decrease the malondialdehyde and nitric oxide levels; increase the superoxide dismutase activity in the heart, kidney and liver (Shah and Nagarajan, 2013; Hafizi et al., 2014; Ebrahimand Azab, 2017). Similar to the trend observed by El-Katcha et al. (2018) repeating every 6-hour MW significantly ($P<0.05$) increased blood serum total antioxidant capacity activity, improved super oxide dismutase while significantly ($P<0.05$) reduced blood serum hydrogen peroxide concentration compared with broiler chicks group drank tap water without treatment. Additionally, the magnetized drinking water could improve antibody titers of broiler chicks against Newcastle disease vaccine at 35 d of age; Moreover, it could reduce total bacterial count in jejunum and colon of broiler chicken by about 9.9% and 27.2% respectively (El-Katcha et al., 2018). In this line, Soltan et al. (2018) observed that MW treatment significantly reduced total intestinal bacterial count and coliforms bacteria by about 39.3% and 40%, respectively, while significantly increasing lactic acid bacteria count by about 44.4% and non-significantly increased Lactobacillus bacteria counts by about 14.6% when compared with control group. Furthermore, these results are supported by those obtained by Anne et al. (2016) reported that a magnetic field can be used to inhibit E*. coli*, in their experiments, they used MW of 2 mT, 6 mT, and 10 mT for 6 hours and concluded that the maximum disinfection efficiency was 82.2% for bacteria exposed to a magnetic flux of 10 mT for 6 hours. Elmusharaf et al. (2010) showed that weak electromagnetic field (5 μTesla) treatment for 30 min per day, protected against coccidiosis in broiler chickens.

Magnetized water, up to 1 Tesla, has a positive effect on hematological and histomorphometric parameters also the villus surface of Japanese quail (Abdel-Azeem et al., 2022).

Consequently, magnetic field was considered as a possible alternative to anticoccidial drugs in poultry production (Elmusharaf et al., 2010).

Electromagnetic field exposure may have an anti-inflammatory effect (Vallbona and Richard, 1999; Montesinos et al., 2000) and beneficial effects on the nervous system have been recognized (Kaszuba-Zwoińska et al., 2005). All of these effects could be due to increased mineral solubility, facilitating nutrient transfer across cell membranes and, thus, uptake and utilization (El-Kholy et al., 2008; Attia et al., 2013; 2015). Moreover, magnetic treatment may improve health status of animals by improving water quality, reducing lime deposition in pipes and bacterial load (Sargolzehi et al., 2010).

El-Hanoun et al. (2017) reported that consuming MW (6000 gauss) improved hatched from geese, it can be explained by improvements in the health and immunity of geese and, thus, passive immunity of goslings, which is similar to the results reported by Attia et al. (2013; 2015). Also, MW treatment improved immune response, intestinal health of growing Pekin ducklings (El-Katcha et al., 2017) and overcame the salmonella hazards in broiler chicks (El-Katcha et al., 2018). While immune system function was not affected by MW (500 gauss) treatment in the study of Al-Mufarrej et al. (2005).

MW treatment improved total protein and globulin blood serum concentration while increasing feed intake compared to normal tab water in Arbor Acres broiler chicks (Soltan et al., 2018). In agreement the results of Al-Hilali (2018) in Japanese quail showed that MW treatment significantly increased ($P<0.05$) serum hemoglobin levels, red blood cells, white blood cell numbers and packed cell volume compared to controls. The decrease in total cholesterol, triglycerides and very low-density lipoprotein cholesterol levels as well as the elevation in high density lipoprotein-cholesterol levels detected in the serum of MW treated birds indicates that magnetic treated water may induce hypotriglyceridemia and the beneficial elevation of "good" cholesterol (Al-Hilali, 2018).

The improvement in metabolic profiles could be attributed to enhancing metabolic cycles, minerals solubility such as iron and/or copper as evidenced by increasing red blood cells are cells and hemoglobin and nutrients transfer to various body cells, movement of blood within the arteries facilitating the transport of oxygen bearing blood and nutrients to different body cells (Al-Daraji and Aziz, 2008). Also, Jassim and Aqeel (2017) in his study indicated that to reduction in blood glucose, cholesterol, and triglycerides (115 g/l, 142.91 mg/dl and 151.88 mg/dl) as compared with control group (244 g/l, 258.24 mg/dl and 183.59 mg/dl) respectively by using MW (1000 gauss) in Ross broiler chickens. While El-Katcha et al. (2017) reported that MW significantly ($P\leq0.05$) increased blood serum HDL and reduced LDL concentrations when compared with control in growing Pekin duckling.

Animals that received MW showed a significant increase in dissolved oxygen (Hassan et al., 2018) and white blood cell count (Yacout et al., 2015). The increase in the white blood cell count may be due to an increase the severity of the water processor magnetically to increase the emergence of these cells configured sites in the bone marrow into the circulatory system by the impact of some hormonal factors, increase in body immunity through the increased proportion of lymph cells which may be due that MW increases the content of immune globulin in the blood and increase the number of defensive white blood cells (Yacout et al., 2015). However, Gilani et al. (2014) reported that magnetized drinking water (6500 gauss) had no adverse effect on blood parameters.

EFFECT OF MAGNETIZED WATER ON CARCASS PARAMETERS

Gholizadeh (2008) showed the increase in meat fat ratio by using magnetized drinking water (6000 gauss) of broiler chickens. El-Hanoun et al. (2017) found that dressing percentage was higher and abdominal fat and skin percentages were lower in goslings produced from geese that drank MW (4000 and 6000 gauss), also they concluded that magnetized tap water improved renal and hepatic functions; while Soltan et al. (2018) reported that magnetic treated water significantly improved dressing percent but had no significant effect on the other carcass traits. Also, Al-Mufarrej et al. (2005) reported that magnetization of the water (500 gauss) did not significantly influence the carcass composition at 32 days of age (carcass weight, thigh, drumstick, breast, back, neck and abdominal fat).

The magnetized drinking water (6500 gauss) profoundly improved villus height and muscle thickness in the jejunum of broiler chickens (Gilani et al., 2014). However, Al-Mufarrej et al. (2005) reported that magnetic drinking water (500 gauss) has no significant effect on the productive performance and carcass quality of broiler chickens. Also, there was no effect ($P>0.05$) of magnetic treated water on relative weights of liver, heart or gizzard of geese (El-Hanoun et al., 2017).

EFFECT OF MAGNETIZED WATER ON REPRODUCTION AND EGG QUALITY

El-Hanoun et al. (2017) found in their study that consumption of magnetic treated water (6000 gauss) improved number of eggs (+18.7%), egg weight (+4.27%) and egg mass (+24.7%) compared to the non-treated tap water on the geese; However, geese that received MW exhibited greater ($P<0.05$) eggshell percentages (+13.5%) and thickness (+10.5%) indicating better eggshell quality plus greater yolk (+8.3%) and lower albumen. El-Sabrout and El-Hanoun (2019), reported that more than 1000 gauss/month could enhance egg production traits for hens, such as eggshell thickness (approximately +9%). While in research on Lohmann Brown hens, El-Sabrout and Hanafy (2017) found that MW (14500 gauss) enhanced eggshell quality by increasing shell thickness and weight, but egg yield and egg weight generally exhibited no significant ($P<0.05$) differences. In contrast, Lin and Yotvat (1990) showed that hens have an increase in egg production when watered with MW. This could be because different devices were used with different gausses. However, El-Sabry et al. (2018) found that internal egg quality (albumen height and yolk height) was greater ($P\leq0.01$) in the eggs obtained by magnetic treated water (3000 gauss). Therefore, MW particularly with high gauss works to make calcium more available to the hen and enhance eggshell quality without negative effects on the hen (El Sabrout and Hanafy, 2017).

Magnetized water helps to precipitate calcium in the bones when the shell calcification process is occurring intensively (Roland and Harms, 1973). Magnetic field treatment of water increases the solubility of calcium salts (Verma, 2011). This would prevent the mobilization of bone calcium and phosphorus reserves, ensuring the high demands of Ca and P export during the laying cycle of hens and affecting eggshell quality (Farmer et al., 1986).
Hassan et al. (2018) concluded that productive performance, physiological response and eggshell quality of Gimmizah chickens were improved due to offering MW with 2000 gauss was adequate to provide the beneficial effects. Stronger shells in eggs from MW group may be due to thicker shells because of the strong relation between the shell thickness and breaking strength. Bennett et al. (1988) suggested that breaking strength and shell thickness information together improves the evaluations of shells. Also, Darsi et al. (2017) reported MW (0.65 Tesla) was able to numerically increase the strength of the eggs, so it is hypothesized that MW may have the potential to change the limestone availability and consequently egg strength in laying hens.

Wang et al. (1998) reported that MW increased efficiency in the biological and biochemical reactions of sperm cells. Al-Daraji and Aziz (2008) revealed that the quality and quantity of the semen of roosters (80 Hy–Line Brown cock) that received MW (500, 1000 and 2000 gauss) were significantly better than those of tap water. In agreement, El-Hanoun et al. (2017) reported that the semen quality and levels of reproductive hormones (i.e. progesterone and estrogen) of geese that drank MW (4000 and 6000 gauss) was better than those receiving tap water, although magnetic treatment improved the quality of the well water, with 6000 gauss having a stronger effect than 4000 gauss; also, they indicated that fertility rate (+9%), hatchability of fertile eggs (+11.6%) and number of hatched goslings (+45.8%) were improved by consumption of MW (6000 gauss).

CONCLUSIONS AND SUGGESTIONS

Due to the low cost and easy installation of MW compared to chemical and other physical methods, it can be used widely in the world. Exposure of the water to a magnetic field changes the water's properties including raising the pH, dissolved oxygen and the number of water molecules decreasing that it leads to better absorption of water into the animal cell membranes. Magnetized water can increase poultry performances, total antioxidant capacity, and biochemical parameters and regulate intestinal microflora; moreover, there are better hatchability, bioavailability, health (immunity) and decreased mortality. The differences among results of studies in this field may be due to animal strain, the magnetizer device type, power and time of magnetization, water quality and experimental procedures. In general, when the results in the literature are evaluated, the performance improves when the water

consumed by the poultry is exposed to stronger magnetic fields and for a longer time. It is recommended that further experiments would be carried out by different power of magnetization, duration of water exposure and by utilizing the quality and intensity of the different flows of drinking water.

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