

## Magnetized drinking water improves productivity and blood parameters in geese<sup>□</sup>

*El agua de bebida magnetizada mejora la productividad y los parámetros sanguíneos en gansos*

*A água magnetizada melhora a produtividade e os parâmetros sanguíneos em gansos*

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### Abstract

**Background:** Quality of drinking water is an issue that imposes limits on animal farming. Improving water quality can be a solution to animal farming and to the enhancement of animal production in areas with limited water supplies. **Objective:** To evaluate the effect of water quality and magnetized water on productivity and blood parameters of Egyptian geese. **Methods:** One hundred and eight (108) Egyptian geese were randomly distributed among four water treatments in a 2×2 factorial design that included two types of water (tap water and well water) and exposure or non-exposure to magnetized tap water and magnetized well water. **Results:** Well water was of poor quality. Geese consuming this water exhibited lower productive and reproductive performance, lower progesterone and estrogen levels, impaired renal and liver functions and lower total antioxidant capacity. Their eggs had lower weight, lower yolk percentage and reduced shell thicknesses. The magnetic treatment improved the quality of both types of water, with a greater effect on well water. Magnetized water increased water consumption and performance of geese, along with improved renal and liver functions, reproductive hormones, and antioxidant status. Magnetized water improved growth performance, dressing percentage of

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goslings, and the amount of meat produced. **Conclusion:** Magnetized tap water improved body weight and feed conversion rate, besides renal and hepatic functions. It also increased production, quality and hatchability of eggs, and levels of reproductive hormones (i.e. progesterone and estrogen), and the antioxidant status in blood.

**Keywords:** *antioxidant activity, magnetic field, poultry, reproductive hormones.*

### Resumen

**Antecedentes:** La calidad del agua de bebida es un problema que limita la cría de animales. Mejorar la calidad del agua puede ser una solución para la cría de animales y para aumentar su producción en áreas con limitado suministro de agua. **Objetivo:** Evaluar el efecto de la calidad del agua y del agua magnetizada sobre la productividad y los parámetros sanguíneos de gansos egipcios. **Métodos:** Ciento ocho gansos se distribuyeron al azar en cuatro tratamientos con un diseño factorial  $2 \times 2$ , que incluyó el efecto de dos tipos de agua (agua de grifo o agua de pozo) y el efecto de la magnetización de ambos tipos. **Resultados:** El agua de pozo presentó baja calidad. Los gansos que consumieron dicha agua exhibieron peor desempeño productivo y reproductivo, menor nivel de progesterona y estrógeno, deficiencia en las funciones renal y hepática y menor capacidad antioxidante total. Sus huevos mostraron menor peso, bajo porcentaje de yema y reducido espesor de cáscara. El tratamiento magnético mejoró la calidad de ambos tipos de agua, con mayor efecto sobre el agua de pozo. El agua magnetizada mejoró el consumo de agua y el desempeño de los gansos, lo cual contribuyó a una mejoría en las funciones renal y hepática, en las hormonas de la reproducción y en los índices antioxidantes. El agua magnetizada indujo una mejora en el crecimiento, rendimiento en canal y cantidad de carne producida. **Conclusión:** El agua de pozo magnetizada mejoró el peso corporal y la conversión alimenticia de las aves, además de las funciones renal y hepática; aumentó la producción, calidad y eclosión de los huevos, así como los niveles de hormonas reproductivas (i.e. progesterona y estrógeno) y el estatus antioxidante en sangre.

**Palabras clave:** *actividad antioxidante, aves de corral, campo magnético, hormonas de la reproducción.*

### Resumo

**Antecedentes:** A qualidade da água é um problema que limita a criação de animais. Melhorar a qualidade da água pode ser uma solução para a criação extensiva de animais e para ampliar a produção animal em áreas com limitado fornecimento de água. **Objetivo:** Avaliar o efeito da qualidade da água e da água magnetizada sobre a produtividade e os parâmetros sanguíneos de gansos Egípcios. **Métodos:** Cento e oito gansos Egípcios foram distribuídos ao acaso entre quatro tratamentos de água em arranjo fatorial  $2 \times 2$  incluindo dois tipos de água – água da torneira  $\times$  água de poço e a exposição ou não à água de torneira magnetizada  $\times$  água de poço magnetizada. **Resultados:** A água de poço apresentou baixa qualidade. Os gansos que receberam esta água exibiram piores desempenhos produtivo e reprodutivo, menores níveis de progesterona e estrógeno, deficiências nas funções renal e hepática, e menor capacidade antioxidante total. Seus ovos mostraram baixo peso, porcentagens menores de gema e espessura de casca reduzida. O tratamento magnético melhorou a qualidade de ambos os tipos de água, com maior efeito na água de poço. A água magnetizada melhorou o consumo de água e o desempenho dos gansos, o qual contribuiu para a melhora nas funções renal e hepática, nos hormônios da reprodução e nos índices antioxidantes. A água magnetizada induziu uma melhora no crescimento, no rendimento de carcaça e na quantidade de carne produzida. **Conclusão:** A água de poço magnetizada melhorou o peso corporal e a conversão alimentar das aves, além das funções renal e hepática, aumentou a produção, qualidade e eclodibilidade dos ovos, também os níveis de hormônios reprodutores (i.e. progesterona e estrógeno) e o status antioxidante no sangue.

**Palavras chave:** *atividade antioxidante, aves, campo magnético, hormônios da reprodução.*

## Introduction

Water is used in every action and reaction within the cell, such as transportation, cell integrity, and the regulation of body temperature. Low quality water

has been shown to reduce animal performance (Marai et al., 2005).

Underground water is used as drinking water in areas with limited water supply. In these areas, water

quality is poor, presenting a major challenge to poultry farming (Attia *et al.*, 2013; 2015). Total dissolved salts, salinity, and nitrates are among the major factors determining the suitability of a particular water source for poultry (Morsy *et al.*, 2012). In addition, the presence of excessive concentrations of inorganic ions such as  $\text{Ca}^{++}$ ,  $\text{Mg}^{++}$ ,  $\text{Na}^+$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^-$ , and  $\text{HCO}_3^-$  in water could induce poor performance, illness, or even death (Kellems and Church, 2002). The magnetic field of the earth naturally charges the water in lakes, wells, and running streams. However, water loses its magnetic charge as it passed through treatment plants and pipes. The exposure of water to magnetic fields restores and balances its natural energy (Ovchinnikova and Pollack, 2009).

The influence of magnetic treatment for improving agriculture has been studied with major emphasis on plants, while research on animal productivity has received less attention (Hozayn and Abdul Qados, 2010; Attia *et al.*, 2015). Magnetized water improves health by inhibiting bacterial growth, while reducing pain, swelling, and weakness (Verma, 2011). Bergsrud and Linn (1990) reported an increase in growth of calves and sheep and a decrease in carcass fat of sheep that received magnetized water. In addition, Lin and Yotvat (1989) showed that milk yield increased when dairy cattle drank magnetized water. El-Hanoun *et al.* (2013) observed an improvement in productive and reproductive performance of doe rabbits, and Attia *et al.* (2015) observed an improvement in buck rabbit performance after receiving magnetized drinking water. Nonetheless, Sargolzehi *et al.* (2009) found that exposing water to a magnetic field produced no significant effect in performance, carcass composition, blood constituents or milk nutrient profile of lambs and goats.

Hence, this study sought to evaluate the effects of water quality and magnetized water on productivity and blood parameters of Egyptian geese.

## Materials and methods

### *Ethical considerations*

The scientific and ethics committee of the Animal Production Research Institute approved this experiment (protocol number 1-1-3-429; 29-5-2015).

### *Animals*

A total of 108 one-year-old Egyptian female geese and 12 male geese were used in the experiment. The geese were randomly divided into four treatment groups comprised of 27 geese each, with three replicates of nine female geese plus 1 gander per replicate. Each geese group was subjected to one of the following treatments: tap water (TW), well water (WW), magnetized tap water (MTW), or magnetized well water (MWW). The WW was obtained from a 120 m depth desert well at Borg El-Arab city, and TP was obtained from the same city. The MWW consisted on exposing well water to a magnetic field of 4,000 gauss, while MTW was tap water exposed to the same magnetic field. The experiment lasted 28 weeks, from November 2012 to May 2013.

The geese were housed in twelve windowless pen houses (2 x 3 m<sup>2</sup>) furnished with wood shavings as litter. Each pen was equipped with six nests. Geese were exposed to natural light during daytime. Natural mating was allowed during the breeding season. Geese were housed in an intensive system with confinement in a house during the experiment and fed a commercial mash feed offered *ad libitum*, containing 16% CP, 2750 Kcal ME/Kg, 3% Ca, 0.35% non-phytate phosphorus, 0.60% total sulphur amino acids, and 0.70% lysine (AOAC, 2007). At the start of the experiment, all birds were vaccinated against avian influenza.

The physical characteristics of both WW and TW were determined with a Jenway 3505 pH meter (pH) and a Jenway 4150 conductivity meter (conductivity; Jenway, Stone, Staffordshire, UK). Elemental analysis were carried out using a DR3900 spectrophotometer (Hach, Loveland, CO, USA), a FIAstar 5000 analyser, model FO 55 (Foss A/S, Hillerod, DK, Denmark), and a flame photometer (Spectronic 20d, Thane, Maharashtra, India). Results are shown in Table 1.

Water was exposed to a magnetic field using a compact magnet (Aqua Correct, Blue Goose Sales, Post Falls, ID, USA; Figure 1). This is a coaxial permanent system that produces a magnetic field strength up to 4,000 gauss. The unit works as a physical magnet changing the crystal structure of

**Table 1.** Physicochemical characteristics of tap and well water with (+) and without (-) magnetization.

Parameters	Units	Tap water		Well water	
		(-)	(+)	(-)	(+)
pH	-	6.64	7.13	7.02	7.63
Conductivity	ms/cm	725	763	1068	1173
Salinity	mg/L	361	396	1011	1036
Dissolved oxygen	mg/L	847	1161	796	1147
Hardness	mg/L	9.14	13.09	26.61	37.05
Sodium (Na <sup>+</sup> )	mg/L	3.04	3.52	11.64	12.43
Potassium (K <sup>+</sup> )	mg/L	0.38	0.26	0.85	0.51
Calcium (Ca <sup>2+</sup> )	mg/L	6.8	8.2	21.3	24.5
Magnesium (Mg <sup>2+</sup> )	mg/L	2.34	2.71	6.31	7.45
Chloride (Cl <sup>-</sup> )	mg/L	4.3	3.5	58.4	42.6
Carbonate (CO <sub>3</sub> <sup>-</sup> )	mg/L	0.11	0.14	0.23	0.28
Bicarbonate (HCO <sub>3</sub> <sup>-</sup> )	mg/L	2.15	2.53	8.63	9.12

**Figure 1.** Magnetic unit mounted on the water pipe.

lime. The strength of the magnet was measured using a Teslameter (Magnetic Sciences Inc., Acton, MA, USA) at the Appligate Laboratory in the City for Scientific Research and Biotechnology of the Egypt-Japan University of Science and Technology, Egypt.

Final body weight, egg number, egg weight, egg mass, feed intake, feed conversion ratio, water consumption, and mortality rates were recorded. Eggs were collected daily and stored in a storage room for seven days at 24 °C and 60% relative humidity. The

geese were allowed to incubate and hatch their eggs naturally to determine fertility and hatchability for each treatment. A total of 12 hatches per group were used. Fertility was defined macroscopically on the 7<sup>th</sup> day of incubation. Hatchability of fertile eggs (HFE) was defined as the number of hatched goslings divided by the number of fertilized eggs per goose x 100. The number of hatched goslings per goose was calculated as = HFE x EN per bird/year, where EN is the total egg number.

During December, February, and April, 10 eggs per replicate (for a total of 30 eggs per water type) were collected to measure egg quality traits according to Attia *et al.* (1994). Eggs were weighed and broken open, and the eggshell, yolk, and albumen were weighed individually and expressed as a percentage of total egg weight. In addition, shell thickness (µm) was measured using a micrometre (B.C. Ames, Framingham, MA, USA) and egg shape index [(egg width/egg length) x 100] was estimated.

At 15 months of age, a blood sample (6 mL) was collected in the morning, before access to feed, from four hens chosen randomly per replicate for a total of 12 samples per treatment. An aliquot of blood from each bird was placed in a heparinised tube, and another in a non-heparinised tube. Plasma and serum were obtained by sample centrifugation at 1,500 x g for 20 min, and plasma and sera were stored at -20 °C until analyses. Serum urea, creatinine, alanine aminotransferase (ALT), and aspartate aminotransferase (AST) were determined using a commercial kit (Diamond Diagnostics, Egypt), as reported by Attia *et al.* (2009). Total antioxidant capacity (TAC) was determined according to Koracevic *et al.* (2001), while thiobarbituric acid-reactive substances (TBARS) were measured according to Tappel and Zalkin (1959).

Plasma 17β-estradiol (E<sub>2</sub>) and progesterone (P<sub>4</sub>) were assayed by radioimmunoassay using the commercial kits DSL-43100 and DSL-3900, respectively (Diagnostic systems Laboratories Inc., Webster, TX, USA), according to Abraham (1977). The progesterone/estrogen ratios were also calculated.

All hatched goslings from each water treatment group (with average ranging from 600 to 1,200 goslings/treatment) were raised in four floor pens furnished with



wood shavings using common management practices until 20 weeks of age. Growth performance, such as BW, body weight gain, feed intake, and feed conversion was recorded from four to 20 weeks of age. At 20 weeks of age, five goslings were randomly chosen from each treatment and slaughtered for evaluation of carcass and organ traits. Meat produced per goose per year (MPG) was calculated using the following equation: MPG (Kg) = number of goslings produced per goose per year x body weight (Kg) of the goslings at 20 weeks of age.

### Statistical analysis

Data were subjected to analysis of variance using the factorial experimental design (2 types of water × 2 magnetic treatments) of the general linear model procedure of the SAS software program, version 9.2 (SAS Institute Inc., Cary, NC, USA). Difference among means was determined using Duncan's new multiple range test (SAS, 2004) at  $p < 0.05$ .

### Results

Exposure to the magnetic field increased mineral levels, salinity and conductivity of both types of water (Table 1). The water treatment had no effect ( $p > 0.05$ ) on initial body weight nor on feed intake. However, consumption of MTW improved ( $p < 0.05$ ) final body weight (+19.6%), number of eggs (+18.7%), egg weight (+4.27%), egg mass (+24.7%), feed conversion rate (-18.2%), and water consumption (+33%) compared to the non-treated tap water and well water groups, whether treated or not (Table 2). Fertility rate (+9%), hatchability of fertile eggs (+11.6%) and number of hatched goslings (+45.8%) were improved by consumption of MTW compared to the other types of water (Table 3).

There was no effect ( $p > 0.05$ ) of water treatment on the egg shape index. However, geese that received MTW 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 (-6.6%; Table 4).

The interaction of water type × magnetic exposure affected all of blood parameters ( $p < 0.05$ ), with MTW geese presenting higher E2 and P4 and total antioxidant capacity values, and decreased blood urea,

creatinine, AST, ALT, and TBARS compared to the other treatments (Table 5).

Goslings from geese that drank MTP had the best productive performance compared to the other treatments (Table 6). There was no effect ( $p > 0.05$ ) of treatment on liver, heart, or gizzard percentage. Dressing percentage was higher and abdominal fat and skin percentages were lower in goslings produced from geese that drank MTP (Table 7).

### Discussion

As expected, well water exhibited lower quality than tap water. Well water resulted in poor performance, impaired renal and liver functions, and TBARS compared to TW. These impairments in different indices of geese performance and physiological functions can be explained by the 10% decrease in water consumption by geese receiving WW. The negative effect on MPG matched the lower number of hatched goslings due to the low fertility and hatchability of fertile eggs, and as previously mentioned, could be attributed to decreased water consumption. Poor water quality has been shown to decrease animal performance and induce health risks (Wahaab and Badawy, 2004; Attia *et al.*, 2013; 2015). Moreover, De Blas (2013) reported that compositional alterations in the gut are a possible cause of gut disorders, retarded growth, and health problems in animals.

Improved water quality occurred with exposure to a magnetic field. Exposed water showed considerable changes in its physicochemical characteristics, such as pH (8.69 vs 7.37 %), conductivity (9.83 vs 5.24 %), salinity (2.47 vs 9.69 %), Na (6.78 vs 15.78 %), Ca (15.02 vs 20.58 %), Mg (15.81 vs 20.08 %), Cl (27.05 vs 18.60 %), and dissolved oxygen (44.09 vs 37.07 %) of WW and TW, respectively, as published by Attia *et al.* (2015). According to the literature, exposing water to magnetic fields changes its properties, with a slightly alkaline pH ( $> 7$ ), higher mineral (higher salinity) and oxygen contents, and lowers germs, which fulfils animal requirements for water quality (Mg-Therapy, 2000). Magnetized water reduces the hydrogen-oxygen bond angle within the water molecule from 104 to 103 degrees, leading to better water absorption

**Table 2.** Effect of tap (TW) or well water (WW) with (+) or without (-) magnetization on initial (IBW, g) and final body weight (FBW, g), egg number (EN, egg/hen/year), egg weight (EW, g), egg mass (EM, g), feed intake (FI, g/bird/day), feed conversion ratio (FCR, g/g), and water consumption (WC, cm<sup>3</sup>/hen/day) of Egyptian geese (mean  $\pm$  SE).

Trait	Water type $\times$ magnetization interaction				Water-type effect				Magnetization effect			
	TW		WW		TW		WW		TW		WW	
	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)
IBW	3505 $\pm$ 38.1	3515 $\pm$ 42.1	3527 $\pm$ 36.5	3540 $\pm$ 47.1	3510 $\pm$ 37.1	3534 $\pm$ 33.2	3516 $\pm$ 40.8	3527 $\pm$ 39.1				
FBW	4126 <sup>b</sup> $\pm$ 46.3	4375 <sup>a</sup> $\pm$ 35.3	3658 <sup>d</sup> $\pm$ 40.1	3880 <sup>c</sup> $\pm$ 51.1	4251 <sup>A</sup> $\pm$ 33.4	3769 <sup>B</sup> $\pm$ 39.7	3892 <sup>y</sup> $\pm$ 51.6	4127 <sup>x</sup> $\pm$ 44.4				
EN	50 <sup>c</sup> $\pm$ 4.6	57 <sup>a</sup> $\pm$ 3.7	48 <sup>d</sup> $\pm$ 4.4	53 <sup>b</sup> $\pm$ 3.1	53 <sup>A</sup> $\pm$ 4.1	50 <sup>B</sup> $\pm$ 3.9	49 <sup>y</sup> $\pm$ 4.1	55 <sup>x</sup> $\pm$ 3.6				
EW	149.8 <sup>c</sup> $\pm$ 1.4	153.8 <sup>a</sup> $\pm$ 1.7	147.5 <sup>d</sup> $\pm$ 1.2	151.2 <sup>b</sup> $\pm$ 1.9	151.8 <sup>A</sup> $\pm$ 1.5	149.4 <sup>B</sup> $\pm$ 1.1	148.7 <sup>y</sup> $\pm$ 1.6	152.5 <sup>x</sup> $\pm$ 1.4				
EM	7475 <sup>c</sup> $\pm$ 14.7	8736 <sup>a</sup> $\pm$ 12.5	7006 <sup>d</sup> $\pm$ 16.1	7953 <sup>b</sup> $\pm$ 13.5	8105 <sup>A</sup> $\pm$ 15.7	7480 <sup>B</sup> $\pm$ 17.1	7241 <sup>y</sup> $\pm$ 14.4	8345 <sup>x</sup> $\pm$ 16.1				
FI	321.4 $\pm$ 12.7	326.2 $\pm$ 10.9	319.7 $\pm$ 13.1	324.1 $\pm$ 11.5	323.8 $\pm$ 14.1	321.9 $\pm$ 12.9	320.6 $\pm$ 13.7	325.2 $\pm$ 10.8				
FCR	842.7 <sup>b</sup> $\pm$ 51.3	731.9 <sup>d</sup> $\pm$ 39.5	894.4 <sup>a</sup> $\pm$ 43.8	798.7 <sup>c</sup> $\pm$ 59.7	787.3 $\pm$ 62.7	846.5 $\pm$ 55.1	868.5 <sup>x</sup> $\pm$ 43.6	765.3 <sup>y</sup> $\pm$ 35.5				
WC	313.5 <sup>c</sup> $\pm$ 16.2	376.2 <sup>a</sup> $\pm$ 15.7	282.7 <sup>d</sup> $\pm$ 14.9	344.6 <sup>b</sup> $\pm$ 17.2	344.8 <sup>A</sup> $\pm$ 16.6	313.6 <sup>B</sup> $\pm$ 14.8	298.1 <sup>y</sup> $\pm$ 13.7	360.4 <sup>x</sup> $\pm$ 15.3				

<sup>a, b, c, d</sup> Means within a row of each criteria of the interaction effect not sharing common superscripts are significantly different ( $p < 0.05$ ). <sup>A, B</sup> Means within a row of each criteria of the water type effect not sharing common superscripts are significantly different ( $p < 0.05$ ). <sup>x, y</sup> Means within a row of each criteria of the magnetic treatment effect not sharing common superscripts are significantly different ( $p < 0.05$ ).

**Table 3.** Effect of tap (TW) and well water (WW) with (+) or without (-) magnetization on fertility percentage (FP, %), fertile eggs' hatchability (FEH, %), and number of hatched goslings (NHG) per geese (mean  $\pm$  SE).

Trait	Water type $\times$ magnetization interaction				Water-type effect				Magnetization effect			
	TW		WW		TW		WW		TW		WW	
	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)
FP	81.5 <sup>c</sup> $\pm$ 2.9	85.7 <sup>a</sup> $\pm$ 3.1	78.6 <sup>d</sup> $\pm$ 2.7	83.9 <sup>b</sup> $\pm$ 3.0	83.6 <sup>A</sup> $\pm$ 2.5	81.3 <sup>B</sup> $\pm$ 2.8	80.1 <sup>x</sup> $\pm$ 3.6	84.8 <sup>y</sup> $\pm$ 2.8				
FEH	83.7 <sup>c</sup> $\pm$ 3.4	89.5 <sup>a</sup> $\pm$ 2.5	80.2 <sup>d</sup> $\pm$ 3.9	85.7 <sup>b</sup> $\pm$ 2.6	86.6 <sup>A</sup> $\pm$ 3.1	82.9 <sup>B</sup> $\pm$ 3.5	81.9 <sup>x</sup> $\pm$ 2.4	87.6 <sup>y</sup> $\pm$ 3.3				
NHG	34.0 <sup>c</sup> $\pm$ 0.5	43.6 <sup>a</sup> $\pm$ 0.3	29.9 <sup>d</sup> $\pm$ 0.4	37.8 <sup>b</sup> $\pm$ 0.3	38.8 <sup>A</sup> $\pm$ 0.6	33.9 <sup>B</sup> $\pm$ 0.4	32.0 <sup>x</sup> $\pm$ 0.3	40.7 <sup>y</sup> $\pm$ 0.5				

<sup>a, b, c, d</sup> Means within a row of each criteria of the interaction effect not sharing common superscripts are significantly different ( $p < 0.05$ ). <sup>A, B</sup> Means within a row of each criteria of the water type effect not sharing common superscripts are significantly different ( $p < 0.05$ ). <sup>x, y</sup> Means within a row of each criteria of the magnetic treatment effect not sharing common superscripts are significantly different ( $p < 0.05$ ).

**Table 4.** Effect of tap (TW) and well water (WW) with (+) or without (-) magnetization on eggshell percentage (ESP, %), shell thickness (ST, µm), egg shape index (ESI), yolk percentage (YP, %), and albumen percentage (AP, %) of Egyptian geese (mean ± SE).

Trait	Water type × magnetization interaction				Water-type effect				Magnetization effect			
	TW		WW		TW		WW		(-)		(+)	
	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)
ESP	10.2 <sup>b</sup> ± 0.15	10.9 <sup>a</sup> ± 0.11	9.6 <sup>c</sup> ± 0.13	10.3 <sup>b</sup> ± 0.14	10.6 <sup>A</sup> ± 0.13	9.9 <sup>B</sup> ± 0.15	9.9 <sup>y</sup> ± 0.11	10.6 <sup>x</sup> ± 0.14	9.9 <sup>y</sup> ± 0.11	10.6 <sup>x</sup> ± 0.14	9.9 <sup>y</sup> ± 0.11	10.6 <sup>x</sup> ± 0.14
ST	431 <sup>b</sup> ± 11	461 <sup>a</sup> ± 9	417 <sup>c</sup> ± 13	435 <sup>b</sup> ± 12	446 <sup>A</sup> ± 13	426 <sup>B</sup> ± 11	424 <sup>y</sup> ± 12	448 <sup>x</sup> ± 14	424 <sup>y</sup> ± 12	448 <sup>x</sup> ± 14	424 <sup>y</sup> ± 12	448 <sup>x</sup> ± 14
ESI	65.8 ± 0.23	66.3 ± 0.19	65.7 ± 0.27	66.1 ± 0.22	66.1 ± 0.26	65.9 ± 0.20	65.8 ± 0.24	66.2 ± 0.21	65.8 ± 0.24	66.2 ± 0.21	65.8 ± 0.24	66.2 ± 0.21
YP	32.7 <sup>b</sup> ± 0.13	33.8 <sup>a</sup> ± 0.15	31.2 <sup>c</sup> ± 0.17	32.5 <sup>b</sup> ± 0.14	33.3 <sup>A</sup> ± 0.13	31.9 <sup>B</sup> ± 0.15	32.0 <sup>y</sup> ± 0.12	33.2 <sup>x</sup> ± 0.14	32.0 <sup>y</sup> ± 0.12	33.2 <sup>x</sup> ± 0.14	32.0 <sup>y</sup> ± 0.12	33.2 <sup>x</sup> ± 0.14
AP	57.1 <sup>b</sup> ± 0.42	55.3 <sup>c</sup> ± 0.38	59.2 <sup>a</sup> ± 0.44	57.2 <sup>b</sup> ± 0.61	56.2 <sup>B</sup> ± 0.49	58.2 <sup>A</sup> ± 0.51	58.2 <sup>x</sup> ± 0.46	56.3 <sup>y</sup> ± 0.53	58.2 <sup>x</sup> ± 0.46	56.3 <sup>y</sup> ± 0.53	58.2 <sup>x</sup> ± 0.46	56.3 <sup>y</sup> ± 0.53

<sup>a, b, c, d</sup> Means within a row of each criteria of the interaction effect not sharing common superscripts are significantly different (p<0.05). <sup>A, B</sup> Means within a row of each criteria of the water type effect not sharing common superscripts are significantly different (p<0.05). <sup>x, y</sup> Means within a row of each criteria of the magnetic treatment effect not sharing common superscripts are significantly different (p<0.05).

**Table 5.** Effect of tap (TW) and well water (WW) with (+) or without (-) magnetization on plasma estrogen (E<sub>2</sub>, pg/mL), progesterone (P<sub>4</sub>, ng/mL), urea (U, mg/dL), creatinine (C, mg/dL), aspartate aminotransferase (AST, IU), alanine aminotransferase (ALT, IU), total antioxidant capacity (TAC, mmol/L), and thiobarbituric acid reactive substances (TBARS, nmol/mL) of Egyptian geese (mean ± SE).

Trait	Water type × magnetization interaction				Water-type effect				Magnetization effect			
	TW		WW		TW		WW		(-)		(+)	
	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)
E <sub>2</sub>	371 <sup>b</sup> ± 12.7	394 <sup>a</sup> ± 10.9	338 <sup>c</sup> ± 13.5	365 <sup>b</sup> ± 14.2	382 <sup>A</sup> ± 13.1	352 <sup>B</sup> ± 11.9	355 <sup>y</sup> ± 12.7	380 <sup>x</sup> ± 13.3	355 <sup>y</sup> ± 12.7	380 <sup>x</sup> ± 13.3	355 <sup>y</sup> ± 12.7	380 <sup>x</sup> ± 13.3
P <sub>4</sub>	0.428 <sup>b</sup> ± 0.10	0.457 <sup>a</sup> ± 0.13	0.413 <sup>c</sup> ± 0.11	0.434 <sup>b</sup> ± 0.12	0.442 <sup>A</sup> ± 0.14	0.424 <sup>B</sup> ± 0.12	0.420 <sup>y</sup> ± 0.13	0.445 <sup>x</sup> ± 0.15	0.420 <sup>y</sup> ± 0.13	0.445 <sup>x</sup> ± 0.15	0.420 <sup>y</sup> ± 0.13	0.445 <sup>x</sup> ± 0.15
U	20.1 <sup>b</sup> ± 2.67	18.2 <sup>c</sup> ± 2.53	24.8 <sup>a</sup> ± 3.11	19.7 <sup>b</sup> ± 2.52	19.2 <sup>B</sup> ± 2.71	22.3 <sup>A</sup> ± 2.69	22.5 <sup>x</sup> ± 2.35	18.9 <sup>y</sup> ± 2.79	22.5 <sup>x</sup> ± 2.35	18.9 <sup>y</sup> ± 2.79	22.5 <sup>x</sup> ± 2.35	18.9 <sup>y</sup> ± 2.79
C	1.34 <sup>b</sup> ± 0.11	1.18 <sup>c</sup> ± 0.08	1.64 <sup>a</sup> ± 0.12	1.33 <sup>b</sup> ± 0.10	1.26 <sup>B</sup> ± 0.13	1.49 <sup>A</sup> ± 0.09	1.49 <sup>x</sup> ± 0.10	1.26 <sup>y</sup> ± 0.8	1.49 <sup>x</sup> ± 0.10	1.26 <sup>y</sup> ± 0.8	1.49 <sup>x</sup> ± 0.10	1.26 <sup>y</sup> ± 0.8
AST	27.1 <sup>b</sup> ± 0.85	22.1 <sup>c</sup> ± 0.99	32.3 <sup>a</sup> ± 0.86	26.9 <sup>b</sup> ± 0.74	24.6 <sup>B</sup> ± 0.90	29.6 <sup>A</sup> ± 0.83	29.7 <sup>x</sup> ± 0.75	24.5 <sup>y</sup> ± 0.67	29.7 <sup>x</sup> ± 0.75	24.5 <sup>y</sup> ± 0.67	29.7 <sup>x</sup> ± 0.75	24.5 <sup>y</sup> ± 0.67
ALT	56.2 <sup>b</sup> ± 1.13	50.6 <sup>c</sup> ± 1.08	63.1 <sup>a</sup> ± 1.24	55.4 <sup>b</sup> ± 1.16	53.4 <sup>B</sup> ± 1.22	59.3 <sup>A</sup> ± 1.18	59.6 <sup>x</sup> ± 1.25	53.0 <sup>y</sup> ± 1.21	59.6 <sup>x</sup> ± 1.25	53.0 <sup>y</sup> ± 1.21	59.6 <sup>x</sup> ± 1.25	53.0 <sup>y</sup> ± 1.21
TAC	159.5 <sup>b</sup> ± 2.63	177.8 <sup>a</sup> ± 2.15	141.4 <sup>c</sup> ± 2.43	162.3 <sup>b</sup> ± 2.28	168.6 <sup>A</sup> ± 2.69	151.8 <sup>B</sup> ± 2.55	150.4 <sup>y</sup> ± 2.71	170.1 <sup>x</sup> ± 2.38	150.4 <sup>y</sup> ± 2.71	170.1 <sup>x</sup> ± 2.38	150.4 <sup>y</sup> ± 2.71	170.1 <sup>x</sup> ± 2.38
TBARS	0.985 <sup>b</sup> ± 0.006	0.856 <sup>c</sup> ± 0.005	1.188 <sup>a</sup> ± 0.007	0.933 <sup>b</sup> ± 0.005	0.920 <sup>B</sup> ± 0.003	1.061 <sup>A</sup> ± 0.008	1.086 <sup>x</sup> ± 0.006	0.894 <sup>y</sup> ± 0.005	1.086 <sup>x</sup> ± 0.006	0.894 <sup>y</sup> ± 0.005	1.086 <sup>x</sup> ± 0.006	0.894 <sup>y</sup> ± 0.005

<sup>a, b, c, d</sup> Means within a row of each criteria of the interaction effect not sharing common superscripts are significantly different (p<0.05). <sup>A, B</sup> Means within a row of each criteria of the water type effect not sharing common superscripts are significantly different (p<0.05). <sup>x, y</sup> Means within a row of each criteria of the magnetic treatment effect not sharing common superscripts are significantly different (p<0.05).

**Table 6.** Effect of tap (TW) and well water (WW) with (+) or without (-) magnetization on initial (IBW, g) and final body weight (FBW), body weight gain (BWG, g), feed intake (FI, g/bird/day), feed conversion ratio (FCR, g/g), meat produced/geese/year (MPG, Kg), water consumption (WC, cm<sup>3</sup>/geese/day), and mortality rate (MR, %) of Egyptian gosling during 4-20 weeks of age (mean  $\pm$  SE).

Trait	Water type $\times$ magnetization interaction				Water-type effect				Magnetization effect			
	TW		WW		TW		WW		(-)		(+)	
	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)
IBW	1367.5 $\pm$ 29.8	1386 $\pm$ 36.3	1349 $\pm$ 23.1	1360 $\pm$ 31.6	1377 $\pm$ 33.6	1354 $\pm$ 25.5	1358 $\pm$ 31.2	1373 $\pm$ 27.6				
FBW	3741 <sup>b</sup> $\pm$ 46.8	3861 <sup>a</sup> $\pm$ 58.1	3554 <sup>c</sup> $\pm$ 49.3	3719 <sup>b</sup> $\pm$ 61.1	3801 <sup>A</sup> $\pm$ 55.1	3637 <sup>B</sup> $\pm$ 62.4	3648 <sup>Y</sup> $\pm$ 49.7	3790 <sup>X</sup> $\pm$ 51.7				
BWG	2374 <sup>b</sup> $\pm$ 43.7	2475 <sup>a</sup> $\pm$ 41.9	2206 <sup>c</sup> $\pm$ 48.6	2359 <sup>b</sup> $\pm$ 44.2	2424 <sup>A</sup> $\pm$ 51.3	2283 <sup>B</sup> $\pm$ 46.9	2290 <sup>Y</sup> $\pm$ 43.5	2417 <sup>X</sup> $\pm$ 53.6				
FI	137.2 <sup>b</sup> $\pm$ 3.5	126.2 <sup>d</sup> $\pm$ 2.9	145.3 <sup>a</sup> $\pm$ 3.5	131.5 <sup>c</sup> $\pm$ 3.1	131.7 <sup>B</sup> $\pm$ 3.6	138.4 <sup>A</sup> $\pm$ 2.8	141.3 <sup>X</sup> $\pm$ 3.3	128.8 <sup>Y</sup> $\pm$ 2.7				
FCR	6.47 <sup>b</sup> $\pm$ 0.55	5.71 <sup>c</sup> $\pm$ 0.63	7.37 <sup>a</sup> $\pm$ 0.49	6.24 <sup>b</sup> $\pm$ 0.57	6.09 <sup>B</sup> $\pm$ 0.51	6.81 <sup>A</sup> $\pm$ 0.44	6.92 <sup>X</sup> $\pm$ 0.60	5.98 <sup>Y</sup> $\pm$ 0.54				
MPG	115.5 <sup>c</sup> $\pm$ 7.1	154.4 <sup>a</sup> $\pm$ 6.4	94.3 <sup>d</sup> $\pm$ 5.7	127.9 <sup>b</sup> $\pm$ 6.8	134.9 <sup>A</sup> $\pm$ 6.6	111.1 <sup>B</sup> $\pm$ 5.7	104.9 <sup>Y</sup> $\pm$ 7.1	141.1 <sup>X</sup> $\pm$ 6.2				
WC	172.3 <sup>b</sup> $\pm$ 9.2	196.2 <sup>a</sup> $\pm$ 8.7	151.7 <sup>c</sup> $\pm$ 10.4	177.5 <sup>b</sup> $\pm$ 9.8	184.3 <sup>A</sup> $\pm$ 10.3	164.6 <sup>B</sup> $\pm$ 9.4	162.0 <sup>Y</sup> $\pm$ 8.2	186.8 <sup>X</sup> $\pm$ 10.6				
MR	9.3 <sup>b</sup> $\pm$ 0.66	8.2 <sup>c</sup> $\pm$ 0.52	11.4 <sup>a</sup> $\pm$ 0.64	9.1 <sup>b</sup> $\pm$ 0.71	8.75 <sup>B</sup> $\pm$ 0.53	10.25 <sup>A</sup> $\pm$ 0.64	10.35 <sup>X</sup> $\pm$ 0.55	8.65 <sup>Y</sup> $\pm$ 0.49				

<sup>a, b, c, d</sup>Means within a row of each criteria of the interaction effect not sharing common superscripts are significantly different ( $p < 0.05$ ). <sup>A, B</sup>Means within a row of each criteria of the water type effect not sharing common superscripts are significantly different ( $p < 0.05$ ). <sup>X, Y</sup>Means within a row of each criteria of the magnetic treatment effect not sharing common superscripts are significantly different ( $p < 0.05$ ).

**Table 7.** Effect of water (TW) and well water (WW) with (+) or without (-) magnetization on dressing percentage (DP), and percentage of skin (PS), abdominal fat (PAF), liver (PL), heart (PH), and gizzard (PG) of 20 week-old Egyptian gosling (mean  $\pm$  SE).

Trait	Water type $\times$ magnetization interaction				Water-type effect				Magnetization effect			
	TW		WW		TW		WW		(-)		(+)	
	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)
DP	64.7 <sup>b</sup> $\pm$ 0.63	67.9 <sup>a</sup> $\pm$ 0.75	62.1 <sup>c</sup> $\pm$ 0.58	66.8 <sup>a</sup> $\pm$ 0.56	66.3 <sup>A</sup> $\pm$ 0.60	64.5 <sup>B</sup> $\pm$ 0.71	63.4 <sup>Y</sup> $\pm$ 0.57	67.4 <sup>X</sup> $\pm$ 0.63				
PS	17.6 <sup>b</sup> $\pm$ 0.55	15.6 <sup>d</sup> $\pm$ 0.41	19.2 <sup>a</sup> $\pm$ 0.61	16.4 <sup>c</sup> $\pm$ 0.52	16.6 <sup>B</sup> $\pm$ 0.48	17.8 <sup>A</sup> $\pm$ 0.56	18.4 <sup>X</sup> $\pm$ 0.44	16.0 <sup>Y</sup> $\pm$ 0.53				
PAF	3.62 <sup>b</sup> $\pm$ 0.17	3.10 <sup>c</sup> $\pm$ 0.19	3.86 <sup>a</sup> $\pm$ 0.13	3.58 <sup>b</sup> $\pm$ 0.15	3.36 <sup>B</sup> $\pm$ 0.14	3.72 <sup>A</sup> $\pm$ 0.17	3.74 <sup>X</sup> $\pm$ 0.13	3.34 <sup>Y</sup> $\pm$ 0.12				
PL	1.89 $\pm$ 0.12	1.78 $\pm$ 0.10	1.91 $\pm$ 0.13	1.85 $\pm$ 0.11	1.84 $\pm$ 0.11	1.88 $\pm$ 0.09	1.90 $\pm$ 0.12	1.81 $\pm$ 0.14				
PH	0.64 $\pm$ 0.03	0.62 $\pm$ 0.01	0.63 $\pm$ 0.04	0.61 $\pm$ 0.02	0.63 $\pm$ 0.02	0.62 $\pm$ 0.01	0.63 $\pm$ 0.03	0.62 $\pm$ 0.02				
PG	3.56 $\pm$ 0.13	3.68 $\pm$ 0.11	3.44 $\pm$ 0.16	3.59 $\pm$ 0.14	3.62 $\pm$ 0.12	3.52 $\pm$ 0.14	3.50 $\pm$ 0.11	3.63 $\pm$ 0.13				

<sup>a, b, c, d</sup>Means within a row of each criteria of the interaction effect not sharing common superscripts are significantly different ( $p < 0.05$ ). <sup>A, B</sup>Means within a row of each criteria of the water type effect not sharing common superscripts are significantly different ( $p < 0.05$ ). <sup>X, Y</sup>Means within a row of each criteria of the magnetic treatment effect not sharing common superscripts are significantly different ( $p < 0.05$ ).



across cell membranes (Verma, 2011). The increasing salinity of well water, as shown in Table 1, may be due to an increase in soluble salts associated with conductivity. Water passing through a magnetic field acquires a finer and more homogeneous structure (Tkachenko and Semyonova, 1995), which increases its fluidity and ability to dissolve various constituents such as minerals and vitamins (Kronenberg, 1985). Consequently, it improves the biological activity of solutions, positively affecting performance of animals and plants (Al-Mufarrej *et al.*, 2005). Another aspect of using magnetic fields to improve water quality is the decrease in environmental pollution (Attia *et al.*, 2013; 2015).

Magnetic treatment of both types of water improved productive performance, such as number, weight and mass of eggs, feed conversion ratio, egg fertility, and egg hatchability, as well as performance of growing goslings. The amount of meat produced by geese receiving MTW increased by 63.7% compared to the geese receiving WW (154.4 vs 94.3 Kg, respectively). The enhanced geese and gosling performance was in agreement with increases in water consumption of geese and goslings receiving MTW when compared to those receiving the other water types. Increased water consumption improved biological performance and health status of geese, as indicated by lower blood levels of urea and creatinine, associated with an improvement in renal function, and lower activities of AST and ALT enzymes, which may be a result of better liver function. Additionally, there was an increase in reproductive hormone levels and total antioxidant capacity, and decrease of TBARS levels in geese ingesting MTW. 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.*, 2009).

Improved performance of goslings hatched from geese consuming magnetized water during growth showed a long-term carryover effect of water type and magnetization on progeny performance. This could be explained by improvements in health and immunity of geese and, thus, passive immunity of goslings, which is

similar to the results reported by Attia *et al.* (2013; 2015). These improvements in progeny performance are in agreement with those reported by Lin (1995), who found that MTW improved performance of farm animals.

Interestingly, magnetized water showed a quite large long-term carryover effect in further experiments, as shown by the increased dressed carcass weights of goslings hatched from geese that drank MTW and MWW by 4.9 and 7.8%, respectively. A promising feature was a decrease in skin percentage (11.4 and 14.6%) and percentage of abdominal fat (14.4 and 7.3%) of goslings produced by geese that consumed MTW and MWW, respectively. These results indicate that magnetic exposure induced a greater effect on percentage of dressed carcass and skin of geese that drank WW, but the opposite was shown for their abdominal fat. The ability of magnetic treatment to affect lipid metabolism observed in this study is similar to that reported by Bergsrud and Linn (1990), who found an increase in growth of calves and sheep and a decrease in carcass fat of sheep receiving magnetized water.

In conclusion, the ingestion of magnetized tap water and, to a lesser extent, of magnetized well water, improved body weight and feed conversion rate of the birds, besides renal and hepatic functions; it also increased production, quality and hatchability of eggs, levels of reproductive hormones (progesterone and estrogen), and the blood antioxidant status.

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### Conflicts of interest

The authors declare they have no conflicts of interest with regard to the work presented in this report.

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