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The Effects of Different Plant Extract Supplementation into Drinking Water Egg Laying Performance and Egg Quality in Second Production Cycle

İbrahim Halil Gümüş[1,2], Güner Çil[1], Arda Sözcü [2*]

[1]Tekinler Agriculture Company, Kemalpaşa, İzmir, Turkey
[2]Department of Animal Science, Faculty of Agriculture, Bursa Uludağ University, 16059, Bursa, Turkey

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***Corresponding Author**
Tel: +90 224 294 14 61
Email:ardasozcu@uludag.edu.tr

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Abstract

This study aimed to investigate the effects of different plant extract supplementation into drinking water egg laying performance and egg quality parameters in second production cycle under commercial conditions. A total of 16657 Nick Brown laying hens in a second production cycle, kept in free-range system, used in the experiment between 75-83 weeks of age. The experimental groups were consisted of three treatment: CONT - control group (no supplementation), PEXT1 - combination of artichoke (Cynara scolymus) and turmeric (Curcuma longa) supplementation, PEXT2 – combination of cinnamon (Cinnamomum venum) + echinacea (Echinacea purpurea) + turmeric (Curcuma longa) supplementation as liquid form into drinking water. The supplementation was performed twice on weekly basis with an amount of 1 l / ton drinking water. The mean value of hen-housed and hen-day egg production, and egg weight were interestingly increased in the control group, than the PEXT1 and PEXT2 groups. However, a more efficient of FCR was found for the PEXT2 group. The breaking strength was found to be the highest in the eggs of PEXT1, whereas a higher value for shell thickness was observed in PEXT1 and PEXT2 groups. Egg yolk had a darker tone in the PEXT1 and PEXT2 groups. According to the results of the present study, it could be concluded that using a combination of cinnamon, echinacea and turmeric could improve feed efficiency. Furthermore, supplementation of plant extracts enhanced the egg quality, namely shell strength and yolk color, during the second cycle of egg production.

During last decade, the world production of egg has shown a great increment by 24.4%, reached to 1,627 trillion eggs produced globally in 2022 (FAO, 2022), and it is expected to increase further because of the rapid growth of world population and high demand for animal originated protein sources. Accordingly, the total of global demand for food shows an increment from 35% to 56% between 2010 and 2050 years (Van Dijk et al., 2021). To meet this huge demand for egg and broiler meat, some serious problems have been observed under today's commercial conditions which are performed using high yield hybrid strains which have higher performance yield, with optimum nutritional practices and management conditions. When regarding of these factors, some critical problems, for example, a higher incidence of disease, chronical stress, behavioral and welfare problems, could be largely observed, and cause reduction in performance, death and economical losses (Dilawar et al., 2021).

Due to the banning of antibiotics usage as growth promotors (O'Neill, 2016), some alternatives have been searching for possible stimulating effects for enhancing of growth and performance, modulating of immunity and health of birds. One of these alternatives of feed additives is plant extracts which have different bioactive compounds having possibility to substitute instead of antibiotics, due to their biological and aromatic properties (Gholami-Ahangaran et al., 2022). These plant extracts include the plant secondary metabolites and their derivate, and defined as phytobiotics that could be added into feed or drinking water as feed additives. It is highlighted that more than 8000 phytochemicals for example phenols, flavonoids, tannins, saponins, essential oils, have been extracted from fruits, vegetables, legumes, whole grains, nuts and herbs (Yadav et al., 2016). Besides, plant extracts have advantages in respect to reduced or zero toxicity to animals, and naturally available (Gholami-Ahangaran et al., 2022).

It is well known that the phytobiotics have much kind of desirable effects including anti-oxidative, anti-fungal, anti-carcinogenic, anti-inflammatory, and antimicrobial effects (Bahmani et al., 2014; Gholami-Ahangaran et al., 2020). According to the these properties, phytobiotics, using as individual compounds or mixed preparations, could provide improvements in the performance parameters, efficient utilization of nutrients, stimulating of immunity, antioxidant and antibacterial properties in poultry nutrition, under normal or stressful conditions (Hashemi and Davoodi, 2012; Gholami-Ahangaran et al., 2021; Kikusato, 2021).

Commercial management standards could cause stress related to high yield of modern hybrids, nutritional aspects, environmental conditions, metabolic disorders in poultry production (Farghly et al., 2019). One of the management tools that could be acted as stressor is forced molting which promote stress, inducing birds to stop eggs laying (Roland and Brake, 1982). It is an easy application and could be obtained desired results for egg production during second cycle. However, it seriously creates fasting and aggression, therefore it has to be take account of animal welfare (Landers et al., 2005, 2008).

Recently, a huge interest has been exhibited to plant extract as feed additive in poultry nutrition (Garcia et al., 2019; Gholami-Ahangaran et al., 2022; Ürüşan, 2023). In this respect, the objective of this study was to investigate the possible effects of two different plant extract supplementation (first combination: artichoke (*Cynara scolymus*) and turmeric (*Curcuma longa*), second combination: cinnamon (*Cinnamomum venum*), echinacea (*Echinacea purpurea*) and turmeric (*Curcuma longa*) into drinking water on egg laying performance and egg quality parameters in second production cycle (between 75-83 weeks of age).

MATERIALS AND METHODS

In this study, a total of 16657 Nick Brown genotype and forced-molted laying hens in a second production cycle from a commercial laying facility were used in the experiment. This study was performed after completing of molting process according to the farm procedures, and between 75 and 83 weeks of age. Three free-range houses with similar dimensions and conditions were randomly selected and used as different plant extract supplementation groups (n: 5519 hens/experimental group).

The experimental groups were consisted of two different plant extract supplementation (commercial product) as liquid form into drinking water: CONT - control group (no supplementation), PEXT1 - combination of artichoke (*Cynara scolymus*) + turmeric (*Curcuma longa*) supplementation (Natual, Techna Smart Feed and Good Health); PEXT2 – combination of cinnamon (*Cinnamomum venum*) + echinacea (*Echinacea purpurea*) + turmeric (*Curcuma longa*) supplementation (Groupe Techna). The supplementation was performed twice on weekly basis with an amount of 1 l / ton drinking water. The concentration of plant extraction in each combination (PEXT1 and PEXT2) was 0.95 kg and 1 kg per liter product, respectively. A standard commercial layer diet for post-molting period with a content of 16% CP and 2800 ME kcal/kg was formulated according to the National Research Council (NRC, 1994) to meet nutritional specifications. The content of the diet was given in Table 1. During the experimental period, feed and water were offered ad-libitum. All hens were kept under a constant lighting schedule (16 h light and 8 h dark periods daily).

Table 1. Composition and calculated analyses of the basal diet

Ingredients	%
Corn	60.2
Soybean meal, 48%	15.6
Sunflower meal, 33.5%	5.0
Soybean oil	2
DDGS (Golden)	4.9
Black cumin meal	5.0
Limestone	4.2
Di-calcium phosphate	1.6
Lysine sulphate	0.42
Sodium chloride	0.24
Sodium sulphate	0.19
Betaine	0.13
DL-methionine	0.02
Premix*	0.50
Calculated analysis	
Metabolizable energy (kcal/kg^{-1})	2810.35
Crude protein (%)	15.85
Calcium (%)	4.35
Available phosphorus (%)	0.40

* Vitamin premix provided per kg of diet: Vitamin A: 2.40 mg; Vitamin D3: 75.00 µg; Vitamin E: 5.00 mg; Vitamin K3: 2.20 mg; Vitamin B1: 1.50 mg; Vitamin B2: 4.00 mg; Vitamin B3: 8.00 mg; Vitamin B5: 35.00 mg; Vitamin B6: 2.50 mg; Vitamin B9: 0.50 mg; Vitamin B12: 10.00 µg; Vitamin H2: 0.15 mg; Choline: 468.70 mg; Mn: 80.00 mg; Fe: 75.00 mg; Zn: 64.00 mg; Cu: 6.00 mg; Se: 0.30 mg.

Performance Parameters

The eggs in each house were collected manually at 10.00 a.m. each day, and the number of eggs laid was recorded daily. The abnormal eggs (broken eggs, shell-less, or soft shells) were excluded when counting of daily egg lay. The egg production percentage was calculated as the hen-day egg production (HDEP) and egg mass were calculated by multiplying the average egg weight with HDEP. The percentage of broken eggs was calculated by dividing the number of broken and soft-shell eggs by the total number of eggs laid.

Daily feed intake and egg weight were recorded on weekly basis. Egg mass and feed conversion rate were calculated as ratio between egg production and egg weight, and ratio between feed intake and egg mass.

To determine the body weight, randomly selected hens (approximately 10% from each experimental group) were individually weighed at 75 and 83 weeks of age.

Egg Quality Parameters

Internal and external egg quality parameters were measured at 83rd weeks of age by randomly selected 12 eggs per each treatment group. The quality parameters measurements were performed 24 h after oviposition. After weighing the eggs with ±0.01 g precision, the length and width of the eggs were measured by using a digital caliper with 0.01 mm precision (Mitutoyo, 300 mm, Neuss, Germany). The measured values were used to calculate the egg shape index with a formula of (egg width/egg length) ×100 (Reddy et al., 1979). Eggshell breaking strength (kg/cm^2) was determined by using an eggshell force reader machine (Egg Force Reader, Orka Food Technology, Israel). The eggs were broken to obtain the albumen and yolk, and then the yolk weight was measured with ±0.01 g precision. These yolk samples were also used for further yolk color measurements. The egg yolk color (n = 12 eggs per experimental group) was measured visually assessing with Roche egg yolk color fan (Roche Ltd., Switzerland). Pigmentation of yolk was determined by scoring ranging from the lightest pigmentation (score 1) to the darkest pigmentation (score 15). The egg shells were carefully washed and dried 24 h in a drying oven at 105°C (Nuve FN-500, Ankara, Turkey) and then weighed with a precision of 0.01 g. Albumen weight was calculated by subtracting yolk and shell weights from the egg weight.

Eggshell thickness was measured using a special caliper with a precision of ± 0.01 mm, and it was given as the average thickness of the upper, middle, and lower end of the shell. Egg yolk diameter, albumen length, albumen width (mm) were measured with digital caliper with a precision of ± 0.01 mm (Mitutoyo, 300 mm, Neuss, Germany). The albumen and yolk height (mm) were measured using a tripod micrometer. Egg yolk index, albumen index, and Haugh unit were calculated using the formulas given by Funk (1948), Heiman and Carver (1936), and Haugh (1937), respectively:

Yolk index = (Yolk height / Yolk diameter) × 100

Albumen index = (Albumen height / (Albumen length + Albumen width)/2)) × 100

Haugh unit = 100 ×log (Albumen height + 7.57 - 1.7 × EW$^{0.37}$)

To determine the dry matter of albumen and yolk, the sampled eggs were used for the analysis. The dry matter analysis was performed according to the method (method number 934.01) given by AOAC (2006).

Statistical Analysis

Data obtained in the current study was subjected to statistical analysis using the general linear model (GLM) procedure in a randomized complete block design (Minitab 17). The following statistical model was used to determine the effects of the treatment:

$Y_{ij} = \mu + \alpha_{ij} + e_{ij}$

where μ = general mean, e_{ij} = random error, α_i = effect of dietary treatments, and Y_{ij} = response variable.

For performance parameters measured repeatedly in time (between 75 and 83 weeks of age) from the same chickens, a statistical model for repeated measurements in time was used. For egg quality measurements, an egg was the experimental unit (n: 15 eggs/experimental group). The means were presented with the standard error of the mean (SEM). The differences among treatments were analyzed by Duncan's multiple range tests. Differences were considered significant at P≤0.05.

RESULT AND DISCUSSION

The current study clearly indicated that the responses of forcing-molted laying hens to plant extracts supplementations could be challenging under commercial conditions with high capacity of laying hens in facilities. Both of egg production and egg quality parameters have been independently affected in all treatment groups.

The effects of different plant extract supplementation into drinking water on performance parameters during second production cycle of laying period was presented in Table 2. The highest level of hen-housed and hen-day egg production was obtained in the control group between 75 and 83 weeks of age (81.7 and 82.5% respectively) (P<0.05). The percentage of dirty eggs was found to be the highest in the PEXT2 (24.3%) and the lowest in the control (18.4%) group (P=0.007). Similarly, Esenbuga and Ekinci (2023) found a decline in egg production and feed intake in laying hens fed diets supplemented with anise, black cumin seed, and thyme extracts when compared to the control group. On the other hand, Awad et al. (2021) reported that egg laying performance showed an increment with dietary *Echinacea purpurea* powder supplementation (2.5–7.5 g/kg) by 35.4%–40.2% compared to the control group in ducks.

This contradiction among the results could be related to some issues, for example animal species, presence of stressful conditions, animal health status, egg production level of birds before molting process period, or the plant species used in combination (Jahanian et al., 2017). Another important issue to obtain remarkable effects is the supplementation amount of the plant extract into diet, single usage or combine usage of plant extracts, and usage types (supplementation into diet or water) of the extracts

(Bozkurt et al., 2012; Abadjieva et al., 2020). Similar to our findings, Roth-Maier et al. (2005) and Böhmer et al. (2009) found any significant differences in performance of laying hens by supplementation of *Echinacea purpurea* extract. However, Abadjieva et al. (2020) indicated any significant differences for hen-day egg production (control group 71.5%, supplementation group 73.3%) when the diet supplemented with an amount of 3g of dried and milled artichoke per kg feed. On the other hand, Suwarta and Suryani (2019) investigated the possible effects of cinnamon and turmeric powder mixture on egg production performance and egg quality in quails. According to this study, turmeric and cinnamon powder supplementation with different amounts (10 g turmeric + 10 g cinnamon, 20 g turmeric + 20 g cinnamon, 40 g turmeric + 40 g cinnamon / kg of feed) improved egg production of quails compared to the control group. This improvement was explained as stimulating effects of turmeric and cinnamon on intestinal absorption, relevant to increment in intestinal length, villus depth and width (Şimşek et al. 2015). In another study performed by Park et al. (2012), the egg production showed a significant increment when Lohmann Brown laying hens fed with supplementation of 0.10, 0.25, and 0.5% turmeric powder between 60 and 67-week-old age.

Table 2. The effects of different plant extract supplementation into drinking water on performance parameters during post-molted laying period

Performance parameters*	Experimental groups			*P values*
	Control	PEXT1	PEXT2	
Hen-housed egg production (%)	81.7 ± 7.5^{a}	73.5 ± 4.9^{b}	78.2 ± 4.5^{ab}	0.023
Hen-day egg production (%)	82.5 ± 8.0^{a}	74.0 ± 4.9^{b}	79.0 ± 4.4^{ab}	0.021
Percentage of dirty eggs (%)	18.4 ± 7.7^{ab}	13.2 ± 6.8^{b}	24.3 ± 6.1^{a}	0.007
Percentage of cracked eggs (%)	0.29 ± 0.18	0.36 ± 0.16	0.47 ± 0.67	0.634
Percentage of soft eggs (%)	0.002 ± 0.005	0.002 ± 0.004	0.01 ± 0.03	0.439
Egg weight (g)	63.9 ± 1.4^{a}	61.8 ± 1.6^{b}	61.8 ± 1.5^{b}	0.009
Egg mass (g)	52.2 ± 4.4^{a}	45.5 ± 3.6^{b}	48.3 ± 3.2^{ab}	0.004
Feed consumption (g/hen)	136.5 ± 12.4^{a}	125.3 ± 11.5^{ab}	112.3 ± 11.1^{b}	0.001
FCR	2.63 ± 0.29^{ab}	2.76 ± 0.22^{a}	2.34 ± 0.31^{b}	0.010
Body weight at 75 wks of age	1625.5 ± 128.1	1645.9 ± 120.8	1602.9 ± 143.7	0.787
Body weight at 83 wks of age	1632.3 ± 102.8^{b}	1771.7 ± 137.1^{ab}	1786.8 ± 144.4^{a}	0.034

* For performance parameters measured repeatedly between 75 and 83 weeks of age, the statistical model for repeated measurements in time was used.

As seen in Table 2, the mean value of egg weight and egg mass were found to be higher in the control group (63.9 g and 52.2 g), than the PEXT1 (61.8 g and 45.5 g) and PEXT2 (61.8 g and 48.3 g) groups (P<0.001). The laying hens in the control group consumed more feed than the other groups during the experimental period (136.5 g vs. 125.3 and 112.3 g, P=0.001), whereas a higher feed efficiency was found for the PEXT2 group (2.34, P=0.010).

Contrary to current findings Radwan et al. (2008) found a significant increment in egg weight by 0.5% level of turmeric powder supplementation. In another study, the turmeric powder supplementation with different levels (0.1, 2 and 4%) caused a reduction in feed intake in Hisex Brown laying hens between 80 and 92 weeks of age (Rahardja et al., 2016). Suwarta and Suryani (2019) indicated that both of turmeric and cinnamon supplementation and the supplementation amount into feed affected the egg weight and also feed efficiency in quails. The eggs obtained from quails fed with 10 g turmeric + 10 g cinnamon per kg of feed was found to be the heaviest among the treatment groups, also the best feed efficiency was also observed in the same group. Previous studies indicated that the supplementation of turmeric powder with different amount into feed caused a decline in feed consumption in laying hens during late period of laying (Riasi et al., 2012; Rahardja et al., 2016). On the other hand, the supplementation of *Echinacea purpurea* powder with different amount (2.5, 5. 7.5 and 10 g per kg of diet) had any significant effect on both egg weight and egg mass, but provided a significant improvement in feed efficiency in laying hens fed with 5 and 7.5 g per kg of diet between 44 and 49 weeks of age. Ürüşan (2023) investigated the possible effects of 5, 10 and 15 g/kg supplementation of artichoke leaf powder on productive performance of laying hens at 70 weeks of age. It was found that any significant effect for egg weight, but a higher egg production (89.4%) and the best value of feed efficiency (1.59) were observed in 10 g / kg artichoke leaf powder group.

The body weight of the hens was similar among the experimental groups at 75 weeks of age, whereas a higher body weight was observed in the PEXT2 group (1786.8 g) than the control and PEXT1 groups (1632.3 g and 1771.7 g, P=0.034). Observed differences among the experimental groups could be attributed to the possible positive effects of turmeric as increasing of excretion of digestive enzymes, pancreatic lipase enzyme, and stimulating villus size in intestine, subsequently enhancing nutrient absorption (Rajput et al., 2013).

The effects of different plant extract supplementation into drinking water on egg content during post-molted laying period was given on Table 3. At 83 weeks of age, the egg weight was found to be the highest with a value of 68.7 g in the PEXT1 group (P<0.001). The yolk ratio was the highest in the control group, and the lowest in the PEXT1 and PEXT2 groups (P<0.001). The highest albumen ratio was observed in the PEXT1 group, whereas the eggshell ratio was found to be the highest in the PEXT2 group (P<0.001). Ürüşan (2023) reported any significantly differences for egg weight when the diet was supplemented with 5, 10 and 15 g/kg of artichoke leaf powder, but the highest numerically value of egg weight (63.45 g) was observed in 15 g/kg of artichoke leaf powder supplementation group. Conversely to the findings, some reports indicated any differences for egg weight with artichoke supplementation (Abadjieva et al., 2020; Wen et al., 2021). Suwarta and Suyani (2019) found a higher weight of yolk, albumen and eggshell when quail feed supplemented with different amounts of cinnamon and turmeric (10 g, 20 g and 40 g) compared to the control group.

Table 3. The effects of different plant extract supplementation into drinking water on egg content during post-molted laying period

Egg content	Experimental groups			*P values*
	Control	PEXT1	PEXT2	
Egg weight (g)	63.9 ± 2.63^{b}	68.7 ± 3.06^{a}	65.6 ± 2.25^{b}	<0.001
Yolk ratio (%)	26.8 ± 0.80^{a}	23.3 ± 1.55^{b}	24.3 ± 1.47^{b}	<0.001
Albumen ratio (%)	63.4 ± 0.91^{c}	66.8 ± 1.77^{a}	65.2 ± 1.72^{b}	<0.001
Eggshell ratio (%)	9.8 ± 0.38^{b}	9.9 ± 0.84^{b}	10.5 ± 0.44^{a}	0.004

n: 12 eggs/treatment groups

The effects of different plant extract supplementation into drinking water on egg quality parameters during post-molted laying period was given on Table 4. The breaking strength was found to be the highest in the eggs of PEXT1 group, whereas a higher value for shell thickness was observed in PEXT1 and PEXT2 groups (P<0.05). Egg yolk had a darker tone in the PEXT1 and PEXT2 groups (12.6 and 12.4 vs. 10.8 in the control; P<0.001). On the other hand, yolk index was the highest in the eggs obtained from PEXT1 group (P<0.05). The dry matter content was found to be the highest in the egg yolk obtained from PEXT2 and in the albumen obtained from PEXT1 groups (P<0.05).

Table 4. The effects of different plant extract supplementation into drinking water on egg quality during post-molted laying period

Egg quality parameters	Experimental groups			*P values*
	Control	PEXT1	PEXT2	
Shape index (%)	77.7 ± 3.15	77.8 ± 1.74	78.4 ± 3.60	0.792
Breaking strength (g/cm^2)	1.810 ± 0.649^{b}	2.475 ± 0.758^{a}	2.386 ± 0.760^{ab}	0.032
Shell thickness (mm)	0.388 ± 0.04^{b}	0.430 ± 0.03^{a}	0.434 ± 0.02^{a}	<0.001
Yolk colour	10.8 ± 0.78^{b}	12.6 ± 0.51^{a}	12.4 ± 0.51^{a}	<0.001
Yolk index (%)	46.3 ± 3.48^{ab}	48.3 ± 2.70^{a}	45.5 ± 0.65^{b}	0.012
Albumen index (%)	8.4 ± 1.45	8.4 ± 1.65	7.7 ± 0.64	0.197
Haugh unit	88.2 ± 3.85	87.8 ± 4.11	85.8 ± 3.13	0.322
Yolk dry matter (%)	36.8 ± 5.97^{b}	42.8 ± 7.67^{ab}	44.3 ± 4.83^{a}	0.040
Albumen dry matter (%)	22.0 ± 7.59^{ab}	23.8 ± 7.36^{a}	17.2 ± 2.63^{b}	0.017

n: 12 eggs/treatment groups

Egg shape index and breaking strength are important egg quality criteria's and has importance for transporting and storing of eggs. The current findings clearly showed that the supplementation of various plant extracts positively affected the egg quality parameters. When the shell thickness showed an increment, eggshell breaking strength increased in the current study. Previous reports were similar the findings related eggshell breaking strength with supplementation of artichoke (Klementavičiūtė et al. 2018; Torki et al. 2018). This could be explained by rich content of inulin and oligofructose in artichoke which potentially provide a better mineral absorption, especially for calcium (Ürüşan, 2023). Many previous studies highlighted that aromatic plant additives have a positive effect on yolk color (Jahanian et al., 2017; Garcia et al., 2019; Suwarta and Suryani, 2019; Ürüşan, 2023). The darker of yolk color could be arisen due to carotenoid and phenolic components of the used plants in the experiment. Suwarta and Suryani (2019) reported a darker yolk color when quail feed supplemented with different amounts of cinnamon and turmeric (10 g, 20 g and 40 g) compared to the control group. The increment in yolk index in PEXT1 could be attributed to the anti-oxidative properties of artichoke and turmeric. These compounds such as caffeic acid, cynarin, luteolin, apigenin in artichoke (Abbasi and Samadi, 2014) and curcumin, tetrahydrocurcuminoids, demethoxycurcumin, and bisdemethoxycutcumin in turmeric (Osawa et al., 1995; Wuthi-udomler et al., 2000) have higher antioxidant capacity that provide protection against ageing and vascular diseases. Therefore, it could be hypothesized that this potential could also provide a protective effect for yolk membrane against oxidation and also damages (Jin et al., 2019; Gholami-Ahangaran et al., 2022). Similar to current results, Jahanian et al. (2017) reported any significant differences for albumen index and Haugh unit with dietary supplementation of *Echinacea purpurea* powder.

CONCLUSION

This study was performed under commercial conditions; therefore the response of birds could be differed according to the various factors. Current findings clearly showed that artichoke and turmeric supplementation (PEXT1) could have a potential effect for enhancement of feed efficiency and eggshell strength during second cycle of laying period. However, it must be highlighted that the selection of plant extracts should be decided according to the health status, laying period and egg performance capacity of flock, and also regarding to cost- benefit in egg production.

Ethical Statement: Not applicable

Your Ethical Statement: The ethical approval is not required for this study. This is a study field performed by standard free-range process. Any animal was suffered during this study. Only performance parameters, egg content and egg quality parameters were measured without giving any suffer to chickens.

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Author Contributions

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Conflict of Interest

Your Conflict of Interest: The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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