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Effects of Drinking Water Sources on Growth Performance and Carcass Traits of Ducks

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Abstract

This study was conducted to evaluate the effects of drinking water sources on the growth performance and carcass yield and quality of commercial Cherry Valley ducks raised in the coastal area of Thai Thuy (formerly Thai Binh province). A total of 225 Cherry Valley ducks (81 males and 144 females) were randomly assigned to one of three treatments corresponding to different drinking water sources (filtered water, tap water, and pond water), with three replicates of 25 ducks each. The results showed that water source significantly influenced the final body weight and average daily gain, with ducks receiving filtered or tap water performing better than those given pond water ($P < 0.05$). However, weight gain, feed intake, and the feed conversion ratio were not affected ($P > 0.05$). Carcass yield was generally unaffected by the drinking water source, except for thigh weight, while meat quality traits such as pH and color varied notably across the different water sources. Sex had a clear effect on growth and meat quality, with male ducks showing faster growth and higher thigh pH ($P < 0.05$), while females exhibited greater breast water loss ($P < 0.05$). The interaction between water source and sex also influenced the final body weight, growth rate, and several meat quality traits (L*, a*, pH15, b*) ($P < 0.05$).

Keywords

Drinking water source, growth performance, carcass traits

Introduction

Duck farming plays a significant role in Vietnam's agricultural economy and the livelihoods of farmers, especially in the Red River Delta. According to the FAO (2022), Vietnam's duck population has remained around 70 million for years, ranking second globally in both flock size and duck meat production, after China. In 2024,

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Vietnam produced approximately 182,249 tons of duck meat, placing it among the top 10 producers worldwide (FAOSTAT, 2024). Currently, urbanization and the shrinking of agricultural land have reduced the availability of pasture and floodplain areas, resulting in changes in rearing practices. Confined, semi-intensive, and intensive duck farming models have become increasingly common. These models not only help ensure food security but also expand opportunities for developing household and commercial farms.

Water plays a fundamental role as a nutrient, with its quantity and quality directly influencing animal health and growth performance. Broilers typically consume about 1.6 to 2.0 times the amount of water compared to feed, based on their weight. From a physiological standpoint, the water ingested by a bird aids in transporting nutrients, facilitating enzymatic and chemical reactions in the body, regulating body temperature, and lubricating joints and organs. Water quality for poultry farming must meet several important standards, including those for total dissolved solids (TDS), pH, nitrates, sulfates, and salinity (Reutor, 2010). An ideal pH range is between 6.0 and 6.8, and toxic compounds like lead, selenium, and arsenic should not exceed 1.0 ppm. Additionally, dissolved oxygen levels and the presence of bacteria in the water must be tightly controlled to protect the health and performance of poultry (Fairchild & Ritz, 2009).

Thai Thuy commue, Hung Yen province (20°33′54″N 106°33′14″E) is a coastal area with favorable conditions for duck farming, including a rich system of rivers, ponds, lakes, and tidal flats, which provide abundant natural feed resources. However, in recent years, this region has frequently faced saltwater intrusion (Vietnam Academy for Water Resources, 2020) and according to the local people's perspective, the current tap water used for livestock farming may be contaminated with saltwater. This may negatively affect the ducks' health, growth performance, productivity, and meat quality. Previous studies have indicated that excessively high levels of sodium and chloride in water can be toxic to poultry. According to the study by Tulu *et al.* (2024), using saline water in poultry farming may reduce production efficiency and adversely affect animal health. However, at moderate levels, it is not harmful and can even partially replace Na and Cl in the diet (Watkins *et al.*, 2005). Sulaiman *et al.* (2022) indicated that Alabio ducks consuming water with a salinity level of 3 g L^{-1} (0.3% TDS) maintained stable egg production, suggesting that this level of salinity does not have a significant negative impact.

Given the increasing challenge of saline intrusion in coastal areas, selecting safe and efficient drinking water sources for ducks has become essential. However, there is still limited research on how different water sources affect the growth, productivity, and meat quality of commercial ducks under such conditions. Therefore, this study aimed to evaluate the effects of various drinking water sources (filtered, tap, and pond water) on duck growth performance, meat yield, and quality. The results are expected to provide scientific evidence to support the selection of suitable water sources, improving production efficiency and promoting climate-resilient duck farming.

Materials and Methods

Experimental design

The experiment was conducted on 225 Cherry Valley ducks (81 males and 144 females) in Thai Thuy commune, Hung Yen Province. Ducks were assigned into one of three treatments to receive water from different drinking water sources: filtered water, tap water, or pond water. In this, filtered water was bottled water purchased in water dispensers (20 liters); tap water was the source of water used daily in the households; and pond water came from ponds in the farm area. Each treatment included three replicates with 25 ducks (namely 9 males and 16 females) per replicate.

Each duck was tagged with a numbered leg band for individual identification. The experiment lasted from day one to seven weeks of age, including a one-week adaptation period followed by six weeks of data collection. Ducks were reared on rice husk litter in closed housing. Feeding and management practices were identical across treatments and followed the recommendations of the breed supplier and the National Institute of Animal Science (NIAS), Vietnam. All ducks were fed complete compound diets (CJ Vina Agri Vietnam Co., Ltd.) based on a two-phase nutritional program: weeks 1-3 with 21% crude protein and 2,700 kcal ME kg^{-1}; and weeks 4-7 with 17% crude protein and 2,900 kcal ME kg^{-1}. Feed was provided twice daily, in the morning (8:00 AM) and in the afternoon (4:00 PM). Feed and drinking water were offered *ad libitum*. Currently, there is no specific law on animal welfare in Vietnam; however, the experimental duck rearing and management process was conducted in accordance with the Law on Livestock (2018) and the Law on Veterinary Medicine (2015).

Measurements

Water quality

Water samples were collected at the beginning, middle, and end of the experiment to assess water quality. Samples were obtained in 500mL polyethylene bottles, and the physicochemical parameters were measured immediately after sampling using an EZ-9909SP water quality analyzer. All measurements were performed in triplicate for each water source. The parameters evaluated were total dissolved solids (TDS), electrical conductivity (EC), pH, and salinity. Due to the scope and experimental conditions of the present study, microbiological parameters of water quality were not assessed, which should be considered a limitation of this research.

Survival rate

The number of animals at the beginning and the end of each experimental period were recorded to determine the survival rate.

Growth performance and FCR

The body weight of each duck was measured at the beginning and at the end of the experiment, in the morning before feeding. Average body gain (BWG) was calculated. Average daily gain (ADG, g $head^{-1}$ day^{-1}) was calculated based on changes in body weight across the rearing periods. Feed offered and feed refusals were recorded daily to determine feed intake (FI) and the feed conversion ratio (FCR).

Meat performance

To assess meat yield and quality, ducks were fasted for 24 hours and slaughtered at seven weeks of age. A total of six ducks (three males and three females) of each treatment were selected to measure the live weight, dressing percentage, carcass weight, heart and liver weights, and thigh and breast muscle weights, following the procedures described by Bui Huu Doan *et al.* (2011). Muscle pH values of the breast and thigh muscles were recorded at 15 minutes and 24 hours post-mortem, measured 2.5cm beneath the surface using a Testo 230 pH meter (Germany). Color analysis was conducted on the surface of the packaged meat using a Minolta CR-410 colorimeter (Japan), with results presented in terms of L* (lightness), a* (redness), and b* (yellowness) values. Drip loss was determined by comparing the sample weights before and after processing. After 24 hours of storage, the samples were cooked in a water bath at 75°C for 60 minutes to calculate cooking loss.

Statistical analysis

The experimental data were analyzed using the general linear model (GLM) procedure of the SAS 9.4 software (SAS Institute Inc., 2013). A two-way analysis of variance (ANOVA) was performed, with the drinking water source and sex (male and female) as fixed effects. Each treatment was conducted in triplicate to ensure statistical reliability. The interaction between water source and sex was also tested. The statistical model used was: $Y_{ijk}=\mu+A_i+B_j+(AB)_{ij}+e_{ijk}$, *where*: Y_{ijk}: observed value; μ: overall mean; A_i: effect of drinking water source (i = filtered water, tap water, pond water); B_j: effect of sex (j = male, female); $(AB)_{ij}$: interaction between drinking water source and sex; and e_{ijk}: random error. When significant effects were detected ($P < 0.05$), differences among least squares means (LSMeans) were compared using Tukey's multiple comparison test. All data are presented as least squares means (LSMeans) ± standard error (SE). Means within the same row followed by different superscript letters are significantly different ($P < 0.05$).

Results

Water analysis

The physicochemical analysis revealed significant variations among the water sources used in the experiment (**Table 1**). The filtered water demonstrated the lowest levels of total dissolved solids (TDS; 5ppm) and electrical conductivity (EC; 12 µS cm^{-1}), a neutral pH (7.24), and no detectable salinity, indicating a high filtration efficiency in removing dissolved ions and impurities. The tap water exhibited intermediate TDS (272.5ppm) and EC (547.3 µS cm^{-1}) values, low salinity (0.02%), and a slightly alkaline pH (8.54). In contrast, the pond water presented the highest TDS (464.8ppm) and EC (932.5 µS cm^{-1}) measurements, a salinity of 0.04%, and an alkaline pH of 8.72, highlighting its distinct chemical profile compared to the treated water sources.

Growth performance

The water sources significantly affected the body weight and ADG (**Table 2**). The initial body weights of the ducks given pond water were higher than those given tap water ($P<0.05$). However, by the end of the experimental period, ducks raised with filtered or tap water had higher body weights compared to those raised with pond water ($P<0.05$). Ducks given filtered or tap water also had greater ADG than those given pond water. In this study, there were no significant differences among the water sources in terms of feed intake and FCR ($P>0.05$).

Sex significantly affected almost all the studied parameters, except for initial BW (P >0.05). Males showed greater final BW, weight gain, and ADG than females ($P<0.05$).

The interaction between water source and sex did not significantly affect the initial BW or weight gain ($P>0.05$); however, significant effects were observed for the final BW and ADG ($P<0.05$). Male ducks provided different water sources had higher final BW and ADG compared to the other interaction groups ($P<0.05$).

Meat yield and quality

The effects of water source, sex, and their interaction on carcass characteristics and the internal organ weights of ducks are presented in **Table 3**. The water sources had no significant influence on almost all of the measured parameters ($P>0.05$), except for thigh weight ($P<0.05$). Sex affected the live weight and the carcass, thigh, breast, and liver weights ($P<0.05$), whereas no significant interaction effects were detected ($P>0.05$).

Table 4 presents an analysis of various meat quality parameters, namely drip loss, cooking loss, pH levels, and the color characteristics (L*, a*, b*) of both the thigh and breast meats from ducks raised with different water sources. Almost all the meat quality parameters were affected by the water sources ($P<0.05$), except for drip loss and cooking loss of both the thigh and breast meats ($P>0.05$). The pH values at both 15 minutes and 24 hours post-mortem in both the thigh and breast meats of the ducks supplied filtered water or pond water were higher compared to those supplied tap water ($P<0.05$). Regarding color, the thigh meat of ducks raised with pond water had higher L* (lightness) and b* (yellowness) values compared to those raised with filtered or tap water ($P<0.05$). Meanwhile, in the breast meat, ducks raised with tap water had lower L* values, but higher a* (redness) and b* values ($P<0.05$).

Sex affected the pH15 of the thigh meat and the drip loss of the breast meat during storage ($P<0.05$). Male ducks had a higher pH15 in their thigh meat compared to female ducks, while the drip loss of the breast meat during storage was higher in female ducks than in male ducks ($P<0.05$).

Table 1. Physicochemical analysis of the experimental water sources (Mean ± SE)

Water sources	Pond	Filtered	Tap
TDS (ppm)	$464.75^a \pm 8.13$	$5^c \pm 0.41$	$272.50^b \pm 36.30$
EC (µS cm^{-1})	$932.50^a \pm 16.96$	$12^c \pm 1.41$	$547.25^b \pm 71.27$
Salinity (%)	0.04^a	0^c	0.02^b
pH	$8.72^a \pm 0.18$	$7.24^b \pm 0.10$	$8.54^a \pm 0.01$

Note: TDS – Total dissolved solids; EC – Electrical conductivity. Within the same row, values with different superscript letters differ significantly (P <0.05).

Table 2. Survival rate, growth performance, and FCR of ducks reared with different sources of drinking water

Week of age	Water source			Sex		Water source * Sex interaction					
	Filtered	Tap	Pond	Female	Male	Filtered* Female	Filtered* Male	Tap * Female	Tap* Male	Pond* Female	Pond* Male
Initial BW (g)	212.62^{ab} ± 3.84	206.19^{b} ± 3.82	221.08^{a} ± 3.82	210.54 ± 2.66	216.05 ± 3.53	210.42 ± 4.59	214.81 ± 6.11	203.125 ± 4.58	209.26 ± 6.12	218.09 ± 4.63	224.07 ± 6.11
Final BW (g)	3904.05^{a} ± 16.02	3898.28^{a} ± 16.08	3832.11^{b} ± 15.89	3711.75^{b} ± 11.05	4044.53^{a} ± 14.81	3692.71^{b} ± 18.99	4115.38^{a} ± 25.81	3754.26^{b} ± 19.20	4242.31^{a} ± 25.82	3688.30^{b} ± 19.19	3975.93^{a} ± 25.33
Weight gain (g)	3615.22 ± 36.26	3691.87 ± 36.84	3611.03 ± 36.39	3501.19^{b} ± 25.29	3777.56^{a} ± 33.71	3482.29 ± 43.51	3748.15 ± 58.01	3551.06 ± 43.98	3832.69 ± 59.12	3470.21 ± 43.97	3751.85 ± 58.01
ADG (g head^{-1} day^{-1})	87.90^{a} ± 0.37	87.90^{a} ± 0.37	85.98^{b} ± 0.36	83.36^{b} ± 0.25	91.15^{a} ± 0.34	82.91^{b} ± 0.43	92.85^{a} ± 0.59	84.55^{b} ± 0.44	91.25^{a} ± 0.59	82.62^{b} ± 0.44	89.33^{a} ± 0.58
Feed intake (g head^{-1} day^{-1})	152.70 ± 2.15	158.53 ± 1.08	155.34 ± 3.55								
FCR	1.98 ± 0.05	2.10 ± 0.05	2.04 ± 0.04								
Survival rate (%)	98.67 ± 1.33	97.33 ± 2.67	98.67 ± 1.33								

Note: Values are presented as LSM± SE. Within each row, means with different superscript letters within the same factor (water source, sex, or their interaction) differ significantly (P < 0.05). Feed intake, FCR, and survival rate values are presented as mean and standard deviation (SD).

Table 3. Carcass yield of ducks raised with different sources of drinking water sources

	Water source			Sex		Water source * Sex interaction					
	Filtered	Tap	Pond	Female	Male	Filtered* Female	Filtered* Male	Tap* Female	Tap* Male	Pond* Female	Pond* Male
Live weight	4173.42 ± 107.45	4147.83 ± 107.45	3968.38 ± 107.45	3882.47^{b} ± 87.73	4310.60^{a} ± 87.73	3957.92 ± 126.83	4388.92 ± 126.83	3946.42 ± 126.83	4349.23 ± 126.83	3743.11 ± 126.83	4193.67 ± 126.83
Carcass	3094.28 ± 77.28	3145.88 ± 77.28	2870.11 ± 77.28	2836.63^{b} ± 63.10	3236.88^{a} ± 63.10	2916.78 ± 109.30	3271.77 ± 109.30	2992.65 ± 109.30	3299.10 ± 109.30	2600.43 ± 109.30	3139.78 ± 109.30
Thigh	186.09^{a} ± 5.22	189.03^{a} ± 5.22	160.45^{b} ± 5.22	167.14^{b} ± 4.27	189.91^{a} ± 4.27	171.45 ± 7.39	200.71 ± 7.39	184.17 ± 7.39	193.89 ± 7.39	145.79 ± 7.39	175.11 ± 7.39
Breast	301.48 ± 12.85	264.85 ± 12.85	278.79 ± 12.85	258.61^{b} ± 10.50	304.81^{a} ± 10.50	275.21 ± 18.18	327.75 ± 18.18	247.72 ± 18.18	281.97 ± 18.18	252.89 ± 18.18	304.69 ± 18.18
Liver	70.38 ± 3.70	65.91 ± 3.70	64.11 ± 3.70	60.56^{b} ± 3.02	73.04^{a} ± 3.02	62.21 ± 5.24	78.54 ± 5.24	63.86 ± 5.24	67.96 ± 5.24	55.59 ± 5.24	72.63 ± 5.24
Heart	22.06 ± 1.41	18.35 ± 1.41	19.62 ± 1.41	19.40 ± 1.15	20.62 ± 1.15	21.98 ± 2.00	22.14 ± 2.00	17.49 ± 2.00	19.21 ± 2.00	18.73 ± 2.00	20.52 ± 2.00
Spleen	2.35 ± 0.25	2.28 ± 0.25	1.99 ± 0.25	2.08 ± 0.20	2.34 ± 0.20	1.94 ± 0.35	2.75 ± 0.35	2.67 ± 0.35	1.89 ± 0.35	1.61 ± 0.35	2.37 ± 0.35
Gizzard	70.91 ± 5.70	67.02 ± 5.70	73.99 ± 5.70	64.68 ± 4.65	76.60 ± 4.65	63.67 ± 8.06	78.15 ± 8.06	68.75 ± 8.06	65.30 ± 8.06	61.63 ± 8.06	86.35 ± 8.06
Abdominal fat	26.35 ± 4.60	35.56 ± 4.60	30.23 ± 4.60	30.16 ± 3.76	31.27 ± 3.76	31.10 ± 6.50	21.59 ± 6.50	32.05 ± 6.50	39.06 ± 6.50	27.32 ± 6.50	33.15 ± 6.50

Note: Values are presented as LSMeans ± SE. Within each row, means with different superscript letters within the same factor (water source, sex, or their interaction) differ significantly ($P < 0.05$).

Table 4. Meat quality of ducks raised with different sources of drinking water

Week of age	Water source			Sex		Water source * Sex interaction					
	Filtered	Tap	Pond	Female	Male	Filtered* Female	Filtered *Male	Tap* Female	Tap* Male	Pond* Female	Pond* Male
Thigh											
Drip loss (%)	0.87 ± 0.25	0.52 ± 0.25	1.01 ± 0.25	0.78 ± 0.20	0.82 ± 0.20	0.71 ± 0.35	1.04 ± 0.35	0.56 ± 0.35	0.48 ± 0.35	1.08 ± 0.35	0.95 ± 0.35
Cooking loss (%)	27.19 ± 0.74	29.62 ± 0.74	27.79 ± 0.74	28.97 ± 0.60	27.41 ± 0.60	28.16 ± 1.04	26.22 ± 1.04	29.82 ± 1.04	29.43 ± 1.04	29.00 ± 1.04	26.59 ± 1.04
pH15	6.12^{a} ± 0.04	6.03^{b} ± 0.04	6.18^{a} ± 0.04	6.01^{b} ± 0.03	6.21^{a} ± 0.03	6.05 ± 0.06	6.18 ± 0.06	5.93 ± 0.06	6.13 ± 0.06	6.03 ± 0.06	6.32 ± 0.06
pH24	5.91^{a} ± 0.02	5.82^{b} ± 0.0206	5.89^{a} ± 0.0206	5.83 ± 0.02	5.91 ± 0.02	5.91 ± 0.03	5.92 ± 0.03	5.77 ± 0.03	5.86 ± 0.03	5.83^{b} ± 0.03	5.96 ± 0.03
L*	46.73^{b} ± 0.62	48.14^{b} ± 0.62	50.23^{a} ± 0.62	48.59 ± 0.51	48.14 ± 0.51	48.08^{ab} ± 0.88	45.3^{b} ± 0.88	47.00^{b} ± 0.88	49.28^{a} ± 0.88	50.70^{a} ± 0.88	49.76^{a} ± 0.88
a*	15.21 ± 0.46	14.09 ± 0.46	15.09 ± 0.46	15.19 ± 0.37	14.40 ± 0.37	14.16^{ab} ± 0.65	16.26^{a} ± 0.65	15.48^{a} ± 0.65	12.69^{b} ± 0.65	15.93^{a} ± 0.65	14.25^{ab} ± 0.65
b*	10.35^{b} ± 0.34	10.53^{b} ± 0.34	11.75^{a} ± 0.34	11.40 ± 0.28	10.35 ± 0.28	9.40 ± 0.48	11.30 ± 0.48	11.65 ± 0.48	9.41 ± 0.48	13.17 ± 0.48	10.33 ± 0.48
Breast											
Drip loss (%)	0.48 ± 0.25	1.17 ± 0.25	0.58 ± 0.247	0.91^{a} ± 0.20	0.58^{b} ± 0.20	0.79 ± 0.35	0.38 ± 0.35	0.63 ± 0.35	0.34 ± 0.35	0.79 ± 0.35	0.38 ± 0.35
Cooking loss (%)	20.39 ± 1.12	24.55 ± 1.12	22.61 ± 1.12	22.61 ± 0.92	22.63 ± 0.92	23.13 ± 1.58	22.09 ± 1.58	21.18 ± 1.58	19.61 ± 1.58	23.13 ± 1.58	22.09 ± 1.58
pH15	6.19^{a} ± 0.02	5.88^{c} ± 0.02	5.93^{b} ± 0.02	6.01 ± 0.01	6.00 ± 0.01	5.90^{c} ± 0.02	5.96^{c} ± 0.02	6.24^{a} ± 0.02	6.15^{b} ± 0.02	5.90^{c} ± 0.02	5.96^{c} ± 0.02
pH24	5.78^{a} ± 0.01	5.66^{c} ± 0.01	5.71^{b} ± 0.01	5.71 ± 0.01	5.73 ± 0.01	5.67 ± 0.02	5.74 ± 0.02	5.77 ± 0.02	5.79 ± 0.02	5.67 ± 0.02	5.74 ± 0.02
L*	44.11^{a} ± 0.51	40.98^{b} ± 0.51	41.73^{b} ± 0.51	41.45 ± 0.42	43.10 ± 0.42	41.12 ± 0.72	42.33 ± 0.72	42.48 ± 0.72	45.74 ± 0.72	41.12 ± 0.723	42.33 ± 0.72
a*	13.21^{c} ± 0.28	15.59^{a} ± 0.28	14.60^{b} ± 0.28	14.61 ± 0.23	14.32 ± 0.23	14.53 ± 0.40	14.68 ± 0.40	13.88 ± 0.40	12.54 ± 0.40	14.53 ± 0.40	14.68 ± 0.40
b*	6.49^{c} ± 0.23	9.13^{a} ± 0.23	7.93^{b} ± 0.23	7.73 ± 0.19	7.97 ± 0.19	6.96^{b} ± 0.33	8.90^{a} ± 0.33	7.02^{b} ± 0.33	5.96^{b} ± 0.33	6.96^{b} ± 0.33	8.90^{a} ± 0.33

Note: Values are presented as LSMeans ± SE. Within each row, means with different superscript letters within the same factor (water source, sex, or their interaction) differ significantly ($P < 0.05$); pH15 = the pH value at 15min post-mortem; pH24 = the pH value at 24h post-mortem; L = lightness, a* = redness, b* = yellownes.*

Certain meat quality traits were significantly affected by the interaction between water source and sex, namely L* and a* in thigh meat and pH15 and b* in breast meat (*P* <0.05).

Discussion

Physicochemical analysis of the water sources

Physicochemical profiling of the water sources indicated considerable variability across the treatment groups. These differences primarily reflected the origin and level of treatment of each water source. Pond water typically contains higher levels of naturally occurring minerals, decomposed organic matter, and ions from the surrounding environment, whereas tap water undergoes partial treatment. Although the TDS, EC, and salinity levels were considerably higher in the pond water compared to the filtered and tap water, these parameters remained within the acceptable limits for poultry production as outlined by the FAO (2022). It is also important to highlight that, during the experimental period, both the tap water and pond water exhibited very low salinity levels, measuring 0.02% and 0.04%, respectively. On the other hand, pond water exhibited relatively high pH and EC, with values of 8.72 and 932.50 µS cm^{-1}, respectively. These results appear to support the WHO (1996) proposition that storing water in reservoirs may promote natural self-purification processes. However, such storage can simultaneously trigger unwanted alterations in water quality. Elevated readings for certain parameters in stored water may be linked to unfavorable conditions, such as algal growth, contamination from bird and animal excreta, and water loss through evaporation. The observed rise in pH level could be associated with microbial activity within the stored water or the decomposition of these organisms, which may lead to the release of inorganic compounds like ammonia (Eniola *et al.,* 2007). In contrast, the low concentrations of TDS and EC observed in the filtered water can be attributed to the action of the RO membrane, which functions as an ultrafiltration barrier capable of removing particulate matter, including microorganisms, whose physical dimensions exceed the pore size of the membrane (ElSaidy *et al.*, 2015).

In this study, the biological parameters of water quality were not considered. Instead, we focused on assessing the influence of selected chemical parameters like pH, TDS, EC, and salinity across different water sources in relation to duck rearing.

Growth performance

There were no statistically significant differences in the survival rates of ducks among the three water source treatments. This suggests that, under controlled housing conditions with appropriate veterinary hygiene, all the tested water sources were equally adequate in supporting the general health and survival of the ducks.

Regarding BW, ducks receiving pond water exhibited higher body weights at the early stage of the experiment compared with those provided with tap water. However, by the end of the rearing period, ducks supplied with filtered or tap water showed higher final body weights than those receiving pond water. This pattern coincided with the comparatively higher electrical conductivity and pH values of the pond water. While these physicochemical characteristics remained within acceptable limits, their potential influence on growth performance over prolonged exposure cannot be excluded. According to Fairchild & Ritz (2009), a pH of 6.0 to 6.8 is preferred for broiler production; nevertheless, birds can tolerate a pH range of 4 to 8. A pH greater than 8 could result in reduced water consumption. Drinking water with an EC level under 700 µS cm^{-1} is generally regarded as suitable for livestock; if the EC value falls within the range of 700 to 3000 µS cm^{-1}, it is considered moderate and generally acceptable for livestock farming (ANZG, 2023). However, regular monitoring is recommended to prevent potential long-term adverse effects, particularly in sensitive animals or animals under intensive production systems. In addition, Ahmad *et al.* (2008) reported an increase in water in broilers with increased TDS in drinking water. In this respect, Mushtaq *et al.* (2013) suggested that higher water consumption limits gut capacity for feed intake and leads to increased nutrient excretion in feces, thus reducing weight gain. Phuong *et al*. (2025) investigated the effects of different salt concentrations (0.15%, 0.3%, 0.45%, and 0.6%) in drinking water on duck growth performance and reported that high salinity levels (0.45% and 0.6%) had a markedly negative impact on growth efficiency. Specifically, both dry matter intake and body weight gain decreased significantly as salinity increased. In addition, the feed conversion ratio of ducks consuming water with higher salinity levels was higher than that of ducks exposed to lower salinity levels. The authors also suggested that controlling the salinity of drinking water is an essential factor in maintaining farming efficiency. In our study, the pond water had the highest salt concentration of 0.04%, which was much lower than that reported in the aforementioned study. Overall, the use of pond water for duck rearing resulted in lower FBW and ADG compared to the ducks raised with tap water or filtered water. Although there were differences in the final BW, no significant differences were observed among the groups of ducks using the three different water sources in terms of weight gain, feed intake, and FCR throughout the entire experimental period. In the study by ElSaidy *et al.* (2015), broilers supplied with tap water, well water, stored tank water, or RO-filtered water showed, on a weekly basis (weeks 1-5), higher BW in the RO-water group, attributable to the lower TDS and salinity. Over the entire rearing period, no significant differences were observed among the water sources in terms of body weight gain, feed intake, or FCR, although FCR tended to be improved in ducks receiving RO-filtered water. These findings are consistent with those of Ibitoye *et al.* (2013), who reported comparable performances in broilers supplied with different drinking water sources. Overall, the ducks were able to tolerate and grow well on all the tested water sources provided that the water quality parameters remained within acceptable limits. Nevertheless, the relatively higher TDS, EC, and pH values of the pond water warrant careful monitoring during prolonged use, whereas the economic feasibility of filtered water should also be considered.

The results showed that sex had a significant effect on most of the growth performance traits of the experimental ducks (P <0.01), except for initial body weight. Male ducks exhibited higher final body weights, weight gain, and ADG compared to females. On average, the ADG of males reached approximately 91 g day^{-1}, whereas that of females was only about 83 g day^{-1}. This indicates the superior physiological growth potential of male ducks compared to females under the same rearing conditions.

The interaction between water source and sex did not significantly affect the initial body weight; however, it had a marked effect on the final body weight and ADG. Male ducks provided with filtered water achieved the highest final BW and ADG, outperforming all other groups, whereas females under the same condition showed considerably lower values. A similar trend was also observed in male ducks supplied with tap water or pond water. These findings suggest that male ducks are able to better exploit the advantages of water sources, while females are less responsive. This confirms that duck growth performance is influenced not only by water quality but also by sex characteristics.

Meat yield and quality

Among the duck groups supplied with different water sources, no significant differences were observed in the meat performance parameters, except for the thigh meat weight. The results of this study are fully consistent with previous research on the effects of different water sources on meat performance. This agrees with the findings of Folorunsho *et al.* (2011), Asaniyan *et al.* (2012), and Ibitoye *et al.* (2013) who reported similar findings. Ibitoye *et al.* (2013) found that providing broiler chickens with pipe-borne water, borehole water, or well water had no significant effect on carcass characteristics. These results may have been due to insignificant effects of different drinking water sources on feed intake and the feed conversion ratio. The carcass yields in this study ranged from 72.32% to 75.84%. This result is consistent with the range reported by Phuong *et al*. (2025), but higher than that observed by Marakan *et al*. (2017), who reported carcass yields in Muscovy ducks ranging from 68.5% to 71.6%. However, the breast and thigh yields obtained in the present study were lower than those reported by Costa *et al*. (2019) and Phuong *et al*. (2025).

Sex also exhibited a significant effect on certain carcass traits. Male ducks had markedly higher live weight and carcass weight values compared to females. In addition, liver weight was greater in males, reflecting differences in metabolic processes and physiological activity between the two sexes. Although the proportions of major meat parts, such as breast and thigh, did not differ statistically between males and females, male ducks consistently showed higher absolute weights of these parts. Regarding meat quality, most of the evaluated parameters differed when ducks were provided with the three different water sources. Our results support the findings of Kang *et al.* (2011), who suggested that the mineral profile of water may “shift” the L, a, and b* values in different directions between breast and thigh meats. The observed trend in duck meat quality across the different water sources in this study further demonstrates that the L and a values are not necessarily positively correlated. In this study, ducks reared on pond water exhibited higher thigh meat L* values but lower breast meat L* values compared to ducks reared on filtered water; moreover, the breast meat of ducks given tap water was redder (higher a* value) than those of ducks given pond or filtered water.

In poultry, meat with a pH below 5.6 is typically classified as PSE (pale, soft, and exudative) (Medic *et al.*, 2009), whereas meat with a pH above 6.4 is considered DFD (dark, firm, and dry) (Ristic, 1977). The pH level is closely linked to various meat quality traits, such as cooking loss and juiciness (Allen *et al.*, 1998). According to Husak *et al.* (2008), higher pH values are more favorable for maintaining desirable color and improving the moisture retention capacity. Quiao *et al.* (2001) categorized chicken breast meat into three color groups: light (L > 53), normal (48 < L < 53), and dark (L* < 48). In our study, ducks reared on all three water sources had pH and L values within the range of normal-quality meat. Only the breast meat exhibited a darker color.

Sex influenced several specific meat quality traits. Male ducks exhibited higher pH15 values in their thigh meat compared to females, indicating a better ability to maintain meat conditions immediately post-mortem. Breast meat from female ducks showed a higher drip loss, suggesting a lower water holding capacity than that of males.

The study results indicated that duck meat quality is significantly affected by the interaction between water source and sex, with distinct responses observed in different muscle parts. In the thigh, the a* value was highest in male ducks supplied with filtered water and lowest in male ducks provided with tap water; meanwhile, the L* value was higher in ducks (both sexes) given pond water and in male ducks supplied with tap water, but lower in male ducks raised with filtered water. In contrast, in the breast, the interaction mainly influenced pH15 and b*. The pH15 value was higher when ducks were supplied with tap water, particularly in females, while other combinations showed lower values, and the b* value was highest in male ducks receiving filtered or pond water, but lowest in male ducks provided with tap water. The results highlight that meat quality management should take into account both sex and water source simultaneously, rather than analyzing each factor in isolation. Monitoring pH15 and meat color according to each sex–water source combination will allow for better control of sensory uniformity and commercial value.

Conclusions

This study showed that ducks can grow normally using different water sources (pond, filtered, and tap), as the physicochemical properties of the water were within the acceptable limits of drinking water quality standards. However, as pond water typically exhibits higher TDS and pH levels, its long-term use requires regular monitoring to prevent potential adverse effects. The water sources had no significant effect on meat yield except for thigh weight, but meat quality varied notably. Ducks given pond water produced lighter thigh meat and darker breast meat, while tap water increased breast redness (a*). Sex significantly influenced the growth and meat traits, as males grew faster with higher yield, whereas females had higher thigh pH and breast drip loss. Different combinations of sex and water source altered the pH and color parameters (L*, a*, b*) of the thigh and breast muscles in different directions, indicating that both factors should be considered together in meat quality evaluations. This study did not include a microbiological analysis of the pond water, which should be considered a limitation. Future research should incorporate microbiological assessments of different water sources to better understand their potential effects on duck health and performance.

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