ARCHIVES OF AGRICULTURE SCIENCES JOURNAL

Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

Volume 8, Issue 1, 2025, Pages 86–98

Available online at https://aasj.journals.ekb.eg

DOI: https://dx.doi.org/10.21608/aasj.2025.374509.1187

Effect of dietary Betaine, L-glutamine supplementation and cold water on productive performance and physiological responses of Japanese quail under heat stress conditions

Galal M. S.[a], Ahmed S. F.[b], Refaie M. S.[c*]

[a]*Department of Poultry Breeding Research, Animal Production Research Institute, Agricultural Research Center, Egypt*
[b]*Department of Animal Production Faculty of Agriculture, Al-Azhar University (Assiut Branch), Assiut, Egypt*
[c]*Department of Poultry Production, Faculty of Agriculture, New Valley University, New Valley, Egypt*

Abstract

This study aimed to investigate the impact of dietary betaine (Bet), L-glutamine (L-Gln), and cold water supplementation on productive performance and physiological responses of Japanese quail under heat stress conditions. A total of 225 quail chicks aged 14 days were assigned to five dietary treatments: a basal diet (control), and a basal diet supplemented with betaine, L-glutamine, a combination of both, or cold water. Growth performance, carcass traits, blood parameters, and economic efficiency were evaluated during the growing periods. The results revealed that quails receiving cold water exhibited the highest growth performance, feed conversion efficiency, and carcass yield, outperforming dietary supplementation groups. While betaine and L-glutamine individually improved nutrient utilization and physiological resilience to heat stress, their combination demonstrated synergistic effects, enhancing growth and carcass traits further. Blood analyses indicated improved metabolic profiles, with reduced hepatic stress and enhanced protein metabolism in supplemented and cold water-treated groups. Moreover, cold water proved to be the most cost-effective intervention, significantly boosting economic efficiency compared to feed additives. These findings highlight the practicality of cold water supplementation as an economical and effective strategy to mitigate heat stress in quails, providing a sustainable approach for enhancing productivity and profitability in poultry farming.

Keywords: Betaine, L-glutamine, cold water, performance, quails.

*Corresponding author: Refaie, M. S.,
E-mail address: kelani1990@agr.nvu.edu.eg

1. Introduction

Japanese quail (*Coturnix coturnix japonica*) has proven to be a suitable alternative for meat and eggs production (Runjaić-Antić *et al.*, 2010). In the tropical regions, thermal stress may hinder protein synthesis and harmfully affect poultry production (Rashid *et al.*, 2012). Several characteristics such as feed intake, egg production and reproduction in the chickens are negatively affected by heat stress (Attia *et al.*, 2011), and also imparted welfare issues, such as increased mortality, discomfort and dermatitis (Nawab *et al.*, 2018). The high ambient temperature harmfully affects growth performance, physiological status and decreased economic efficiency of Japanese quails (Alagawany *et al.*, 2017; Mehaisen *et al.*, 2017; Niu *et al.*, 2009). Moreover, it decreases production performance due to reduced feed consumption (Abuoghaba *et al.*, 2021). Several feed additives have been studied to manipulate boosting performance during heat stress. Betaine (Bet) is a trimethyl derived of the amino acid glycine and is considered as a methyl group donor (Metzler-Zebeli *et al.*, 2009). It's absent in most animal feedstuffs and dietary supplementations which enhances productivity and resistance to heat stress (Wang *et al.*, 2004). The betaine has the ability to increase non enzymatic antioxidant defenses via the methionine–homo cysteine cycle and form a protective membrane around cells (Zhang *et al.*, 2016) and protecting cells against osmotic inactivation which helps in maintaining cell volume under heat stress conditions (Saeed *et al.*, 2017). Additions of betaine in laying hen diets succeed to improve egg production (Gudev *et al.*, 2011), fertility, hatchability and chick weight at hatch (Tollba and El-Nagar, 2008), egg weight and egg mass (Park *et al.*, 2006). L-glutamine (L-Gln) is considered a non-essential amino acid (AA) due to most animal cells can produce it (Murakami *et al.*, 2007). It is synthesized in the liver and skeletal muscle under physiological conditions; however, its concentrations in the tissues decrease under heat and oxidative stress (Hu *et al.*, 2016). Survival rate, growth performance and gut-barrier function in livestock were improved under heat stress when adding L-Gln (Dai *et al.*, 2011; Zhong *et al.*, 2012). Incorporating 0.8% L-Gln in the diets of laying hens could improve egg production, egg mass, feed intake, and feed conversion efficiency (Dong *et al.*, 2010). L-Gln plays role in cellular immunity (Francis and Griffiths., 2002), and fertility. Furthermore, it improved hatchability by lowering blood urea nitrogen levels and oxidation activity (Suchner *et al.*, 2000). On one hand, at high ambient temperatures water consumption increases, on the other hand the rise in water temperature also harmfully affects poultry performance (Jones and Watkins, 2009). Cold water supports poultry in heat dissipation and body temperature regulation (Abioja *et al.*, 2011), cold water improved weight gain, final live body weight and relative weight of spleen of poultry during hot-dry season. Another study by Puma *et al.* (2001) reported that birds prefer cold to warm water during both winter and summer, respectively. The application of a suitable feed additive system has been suggested as a suitable tool to efficiently adjust body temperature to obtain optimum good performance. Therefore, the main objective of this study was to investigate the effect of dietary betaine, L- glutamine and cold water supplementation on productive performance and physiological responses of Japanese quail under heat stress conditions.

2. Materials and methods

The present study was performed at the poultry production farm, Faculty of Agriculture, New Valley University, Egypt. The experiment was carried out lasting 42 days in summer season from July to August 2021.

2.1 Experimental design and diet

At day 14 of age, a total of 225 unsexed Japanese quail chicks an average body weight 60 g, were randomly divided into five treatments each comprising 45 chicks. Each treatment was further subdivided into 3 replicates of 15 chicks. The first group received a basal diet and served as the control. The second, third and fourth groups received the basal diet supplemented with; 2 g /kg betaine, 5 g/kg L-glutamine and a combination 2 g/kg betaine + 5 g/kg L-glutamine; respectively. The fifth group received the basal diet and was provided with cold water (5-10c) without any additives. Betaine and glutamine powder were purchased from El-Gomhorya Company, Assiut, Egypt. Cold water was offered to birds twice daily, 8:00 AM and 4:00 PM. The basal diet in this study was formulated according to the recommendations NRC (1994), the composition and chemical analysis of the diet are shown in Table (1). Feed and water were offered *ad libtum* throughout the entire experiment.

Table (1): Composition and calculated analysis of basal diet for growing Japanese quail

Ingredients	%
Yellow corn 44%	55
Soybean meal	33.50
Gluten 60%	7
Oil	1
Limestone	1
Di-calcium phosphate	1.90
NACL	0.20
Premix[1]	0.30
Dl-Methionine	0.10
Calculated analysis	
Metabolizable energy	2942
Crude protein	23.98
Ether extract	3.53
Crude fiber	3.75
Calcium	0.96
Phosphorus	0.45
Methionine	0.56
Lysine	1.18
Sodium	0.11

[1]Each kg of vitamin mineral premix: contains: vit A, 12000IU; vit D3, 3000ICU; vit E, 200 mg; vit K3, 400 mg; vit B1, 450 mg; vit B2, 250 mg; vit B6, 650 mg; vit B12, 300 mg; folic acid, 25mg; choline chloride, 1000 mg; Niacin, 1000 mg; Biotin, 600 mg; panathonic acid, 670 mg; Mn, 90 mg; Fe, 50 mg; Zn, 80 mg; Cu, 70 mg; I, 1.8 mg; Co, 30 mg; selenium, 1.8 mg

2.2. Housing and management

Environmental and managerial conditions were maintained for all tested tested birds during the experimental period. All birds were wing banded and housed in floor pens during the growing period. The ambient temperature and relative humidity were recorded daily in Table (2). The light regime used was 23 hours light: 1 hour dark during growing.

Table (2): The ambient temperature and relative humidity measured during the experiment weeks.

Week	Temperature (ºC)	Humidity (%)
1st	38	55
2nd	39	59
3rd	40	60
4th	39	54
5th	38	56
6th	41	58

2.3. Growth performance data

The weekly live body weight (LBW) was weighed from two to six weeks of age. The body weight gain (BWG) and feed intake (FI) were determined. Additionally, feed conversion ratio (FCR) was calculated according to the following formula:

$$\text{FCR} = \frac{\text{F.I (g)}}{\text{BWG (g)}}$$

Where FCR is feed conversion ratio, FI is feed intake (g) and BWG is body weight gain (g).

2.4. Carcass characteristics

At the end of the experimental 42 days, randomly 6 quails per treatment were selected then fasted for 12 hours, individually weighted and slaughtered to evaluate the dressing percentage beside edible giblets (liver, heart, and gizzard) thereafter each organ was individually separated and weighed then estimated for each organ relative to pre-slaughtered weight. The length of the small intestine was also measured. The dressing percentages were calculated as follows:

$$\text{Dressing \%} = \frac{\text{Dressing weight}}{\text{pre-slaughter live body weight}} \times 100$$

2.5. Blood measurements

During slaughtering blood samples per treatment were withdrawn in non-heparinized tubes. The collected blood was centrifuged at 3500 RPM for 15 minutes to separate the serum. The collected blood serum samples were frozen then kept on –20° until analysis. Plasma glucose, total protein, albumin, globulin, cholesterol, AST, ALT, creatinine and uric acid were measured by using commercial kits (spectrum Diagnostics, Egypt) by means of spectrophotometer.

2.6. Economic efficiency

Economic efficiency was estimated according to average costs of feed consumed and litter quantities used as well as the average income/bird were calculated. The net revenue per bird was calculated as the difference between the total sale price (LE), and the costs (LE) of feeds consumed and litter used, according to the prevailing prices in the local Egyptian market during the experimental period.

$$\text{Net Revenue (NR)} = \text{TR} - \text{TC}$$

Where TR = Total revenue, TC = Total costs.

$$\text{Economic efficiency \%} = \frac{\text{Net Revenue (NR)}}{\text{Total Costs (TC)}} \times 100$$

$$\text{Relative Economic efficiency} = \frac{\text{Economic efficiency of treatment}}{\text{Economic efficiency of control}} \times 100$$

2.7. Statistical analysis

The obtained results were statistically analyzed using Analysis of Variance (ANOVA), moreover, using the General Liner Model (GLM) Procedure, by (SAS, 2009) Version 9.2. Percentage values were transformed using arcsine before statistical analysis. Significant differences among treatment means were separated by Duncan's multiple range test (Duncan, 1955). All experiment results obtained were analyzed using the following model:

$$Yij = \mu + Ti + eij$$

Where Yij = observation, μ = the overall mean, Ti = the effect of treatment, i (1-5), eij = random error.

3. Results and Discussion

3.1. Growth performance

Data in Table (3) showed that quails fed a basal diet had the lowest final body weight (209 g) and weight gain (149 g). This indicates that under heat stress, the basal diet alone is insufficient to support optimal growth performance, while quails supplemented with betaine exhibited improvement in final body weight (225 g) and weight gain (154 g) compared to the control group. Betaine acts as an osmolyte, regulating cellular hydration and improving nutrient absorption during heat stress (Attia *et al.*, 2016). Also, adding glutamine further enhanced growth performance (229 g final weight and 158 g gain). Glutamine plays a key role in intestinal health, improving nutrient absorption, and enhancing protein metabolism (Yi *et al.*, 2005). The combination of betaine and glutamine yielded one of the highest body weights (230 g) and gain (159 g) compared with each individual additive of betaine and glutamine, indicating a synergistic effect of betaine and glutamine mitigating heat stress. This combination optimizes both cellular hydration and gut health, allowing for better nutrient utilization. However, the cold water treatment produced the best weight gain (160 g) and final body weight (231 g) compared to all groups. Cold water likely reduces heat stress directly by lowering body temperature and enhancing feed intake efficiency, which aligns with findings by Sahin *et al.* (2003), who reported that cold water mitigates the physiological impact of heat stress. The improvements in FBW reflect enhanced growth performance due to reduced heat stress and improved nutrient utilization. Betaine's role in osmoprotection and glutamine's intestinal benefits synergize in the combination betaine + L-glutamine group, while cold water provides direct thermoregulatory effects (Eklund *et al.*, 2005; Wu *et al.*, 2011). Feed intake did not differ significantly across treatments (463-469 g), indicating that the additives and cold water did not directly alter appetite but rather improved nutrient utilization. Heat-stressed quails tend to reduce feed intake to minimize metabolic heat, but dietary supplementation and cold water likely improved their physiological ability to manage heat stress, maintaining consistent intake (Attia *et al.*, 2011). Feed conversion ratio was improved in the cold water group (2.91) compared to the control (3.15), betaine, L-glutamine, and betaine- glutamine combination groups showed intermediate but significantly better values than the control. Improved FCR in supplemented groups and the cold water group indicates more efficient feed utilization, attributed to the combined effects of reduced heat stress and enhanced nutrient absorption (Windmueller, 1982; Sahin *et al.*, 2003).

Table (3): Effect of dietary betaine, L-glutamine supplementation and cold water on Productive performance.

Variables	Groups					SEM	*P*-Value
	Control	Beta 2g	Gluta 5g	Beta + Glut	Water		
IBW 14 d, g	60.74	61.27	61.05	60.99	61.62	0.38	0.17
FBW 42 d, g	209[c]	225[b]	229[ab]	230[a]	231[a]	1.17	<.0001
BWG14-42 d, g	149[b]	154[ab]	158[a]	159[a]	160[a]	1.62	0.002
FI 14-42 d, g	469	465	468	465	463	2.89	0.66
FCR 14-42 d, g	3.15[a]	3.02[b]	2.97[b]	2.92[b]	2.91[b]	0.03	0.001

Beta 2g: Quails fed basal diet plus Betaine 2 g/kg diet, Gluta 5 g: Quails fed basal diet plus L-glutamine 5 g/kg diet, Beta + Glut: Quails fed basal diet plus Betaine 2 g/kg + L-glutamine 5 g diet and Water: Quails received cold water without any additive, IBW: Initial body Weight, FBW: Final body weight, BWG: body weight gain, FI: Feed intake, FCR: Feed conversion ratio. [a-c] Means within the same row with different superscripts are significantly different ($P \leq 0.05$), SEM=Standard error of means

3.2 Carcass characteristics

Table (4) summarizes the effects of betaine and L-glutamine supplementation and giving cold water as a managerial treatment on various carcass characteristics observed in our experiment. Quail chicks receiving dietary betaine (76.64%) or L-glutamine (77.54%) had significantly higher carcass yields compared to the control (73.08%). The combination of betaine and glutamine (77.70%) and cold water treatment (78.65%) further enhanced the yield. Similarly, breast percentage increased significantly in all treatment groups compared to the control, with cold water treatment yielding the highest value (41.97%). Betaine is an osmolyte that enhances cellular water retention and supports protein metabolism, reducing the negative effects of heat stress on growth performance (Eklund *et al.*, 2005). L-glutamine supports intestinal integrity, protein synthesis, and immune responses during stress conditions, which positively influence carcass traits (Newsholme *et al.*, 2003). Cold water likely reduces heat stress by directly lowering body temperature, improving feed intake, and nutrient utilization efficiency (Teeter and Smith, 1986). Dietary treatments and cold water significantly increased rump percentage compared to control, with the highest improvement noted in the cold water group (23.71%). The increase can be attributed to better energy and nutrient utilization under reduced stress conditions. Betaine's role in lipid metabolism and glutamine's impact on energy production contribute to higher muscle deposition in stressed quails (Eklund *et al.*, 2005; Wu, 2011). No significant changes were observed across groups, indicating that these treatments do not negatively affect internal organs (liver, heart, and gizzard) development. Betaine and glutamine primarily affect muscle tissues and not visceral organs. Additionally, these treatments do not impose extra metabolic loads that could alter liver or heart weights (Wu, 2011).

Cold water (53.50%) led to the highest increase in small intestine weight compared to other groups. The betaine + glutamine group also showed improvement (47.75%), albeit lower. Enhanced intestinal integrity and villus height from L-glutamine and improved hydration from betaine likely improve intestinal health and weight (Eklund *et al.*, 2005; Newsholme *et al.*, 2003). Cold water reduces thermal stress, enhances intestinal functionality and nutrient absorption. Betaine and glutamine showed additive effects in improving carcass traits, likely due to their complementary roles in osmoregulation and gut health (Yi *et al.*, 2005). Cold water was the most effective, as it directly reduces heat stress by influencing body temperature and improving feed consumption efficiency. This is consistent with findings that water cooling effectively mitigates heat stress in poultry (Teeter and Smith, 1986).

Table (4): Effect of dietary betaine, L-glutamine supplementation and cold water on carcass characteristics.

Variables	Groups					SEM	*P*-Value
	Control	Beta 2g	Gluta 5g	Beta + Glut	Water		
Carcass yield %	73.08^{b}	76.64^{a}	77.54^{a}	77.70^{a}	78.65^{a}	1.15	0.02
Breast %	38.15^{b}	41.18^{a}	41.36^{a}	41.61^{a}	41.97^{a}	0.62	0.001
Rump %	21.67^{b}	23.56^{a}	23.49^{a}	23.44^{a}	23.71^{a}	0.43	0.02
Liver %	2.41	2.45	2.41	2.43	2.47	0.09	0.99
Heart %	0.87	0.90	0.87	0.88	0.90	0.04	0.90
Gizzard%	2.51	2.64	2.65	2.56	2.61	0.05	0.28
Small intestine length (cm)	45.25^{b}	44.25^{b}	45.75^{b}	47.75^{ab}	53.50^{a}	2.22	0.05

Beta 2 g: Quails fed basal diet plus Betaine 2 g/kg diet, Gluta 5 g: Quails fed basal diet plus L-glutamine 5 g/kg diet, Beta + Glut: Quails fed basal diet plus Betaine 2 g/kg + L-glutamine 5 g diet and Water: Quails received cold water without any additive. a--c Means within the same row with different superscripts are significantly different ($P \leq 0.05$), SEM= Standard error of means.

3.3. Blood parameters.

Results of blood parameters are presented in Table 5, showing that glucose levels increased significantly in the cold water group (223 mg/dL) compared to the control group (187 mg/dL). The combination of betaine and glutamine (220 mg/dL) also showed an increase, though slightly lower than cold water group. Both betaine and L-glutamine had intermediate glucose levels. Increased glucose levels may indicate improved energy metabolism under heat stress due to supplementation and cold water. Betaine, known for its osmoprotective properties (Kettunen *et al.*, 2001), helps maintain cellular integrity, while glutamine enhances intestinal health and nutrient absorption (Newsholme, 2001). Cholesterol levels were highest in the cold water group (211 mg/dL) and lowest in the control group (168 mg/dL). Betaine and a combination of betaine and L-glutamine showed intermediate levels. Cold water likely reduces heat stress, which positively influences lipid metabolism. Betaine also aids lipid metabolism by functioning as a methyl donor (Eklund *et al.*, 2005), explaining the moderate cholesterol levels in betaine and betaine and L-glutamine combination groups. Both ALT and AST levels were significantly reduced in the cold water and betaine and L-glutamine combination groups compared to the control, with the lowest levels in the betaine and L-glutamine combination group. Betaine and L-glutamine groups also showed likewise improvements. Reduced transaminase levels suggest lower hepatic stress, a common issue in heat-stressed quails. Betaine and glutamine's protective roles against oxidative stress (Wu *et al.*, 2011) and their capacity to stabilize cellular structures might explain these findings. Total protein levels were highest in the cold water group (5.46 g/dL), followed by the combination of betaine and glutamine (5.11 g/dL). Betaine and L-glutamine also outperformed the control. Albumin levels peaked in cold water group, whereas globulin levels were similar among the betaine, L-glutamine and cold water groups but highest in the betaine and glutamine combination group. Improved protein levels reflect enhanced nutrient absorption and utilization, possibly due to glutamine's role in intestinal development (Windmueller, 1982). The synergistic effect in the betaine and glutamine combination group suggests that combining betaine and glutamine optimizes protein metabolism under stress. Creatinine levels were lowest in the cold water (0.31 mg/dL) and highest in the betaine (0.47 mg/dL) groups.

Table (5): Effect of dietary betaine, L-glutamine supplementation and cold water on blood parameters.

Variables	Groups					SEM	*P*-Value
	Control	Beta 2g	Gluta 5g	Beta+Glut	Water		
Glucose (mg/dl)	187[c]	212[ab]	208[b]	220[ab]	223[a]	7.13	<.0001
Cholesterol (mg/dl)	168[b]	172[b]	191[ab]	180[ab]	211[a]	17.26	0.049
ALT (u/ml)	22.46[a]	16.27[ab]	15.13[b]	12.71[b]	12.34[b]	2.85	0.024
AST (u/ml)	313[a]	223[b]	179[bc]	161[c]	169[c]	20.74	<.0001
Total protein (g/dl)	3.70[b]	4.80[a]	4.84[a]	5.11[a]	5.46[a]	0.44	0.003
Albumin (g/dl)	1.42[cd]	1.66[b]	1.57[bc]	1.30[d]	2.13[a]	0.10	<.0001
Globulin (g/dl)	2.28[b]	3.14[a]	3.27[a]	3.80[a]	3.32[a]	0.39	0.006
Creatinine (mg/dl)	0.35[bc]	0.47[a]	0.40[ab]	0.40[ab]	0.31[c]	0.04	0.002
Uric acid (mg/dl)	4.26[b]	5.78[a]	5.56[a]	4.40[b]	5.54[a]	0.51	0.006

ALT: Alanine transaminase, AST: Aspartate transaminase. Beta 2 g: Quails fed basal diet plus Betaine 2 g/kg diet, Gluta 5 g: Quails fed basal diet plus L-glutamine 5 g/kg diet, Beta + Glut: Quails fed basal diet plus Betaine 2 g/kg + L-glutamine 5 g diet and water: Quails received cold water without any additive. [a-c] Means within the same row with different superscripts are significantly different ($P \leq 0.05$), SEM=Standard error of means.

Uric acid levels were lowest in the control and betaine and glutamine combination groups but highest in betaine and glutamine groups. Lower creatinine and uric acid levels in cold water and combination of betaine and glutamine groups indicate improved renal function and reduced protein catabolism. Betaine's osmoregulatory effects and glutamine's support for nitrogen metabolism contribute to these results (Kettunen *et al.*, 2001; Newsholme, 2001). Betaine's osmoprotective properties alleviate cellular dehydration caused by heat stress. It also improves lipid metabolism and reduces hepatic stress (Eklund *et al.*, 2005). Enhances intestinal integrity, improves nutrient absorption, and supports antioxidant defenses (Wu *et al.*, 2011). The combination of betaine and glutamine demonstrated synergistic effects, leading to improved metabolic and productive performance. Cold water group consistently showed the best performance in reducing heat stress markers, likely due to direct thermoregulatory effects on the birds.

3.4. Economic efficiency.

Economic efficiency was the highest in the cold water group (132.66%) and the lowest in the betaine + L-glutamine combination group (50.47%). The control group exhibited moderate efficiency (107.81%), while betaine (88.17%) and L-glutamine (71.26%) showed reduced efficiency. The diminished economic efficiency in supplemented groups reflects the imbalance between their high costs and the resulting revenue gains. In contrast, cold water demonstrated outstanding efficiency by enhancing productivity without additional feed costs. Eklund *et al.* (2005) supported the use of cost-effective, non-dietary interventions for improving livestock resilience to stress. The cold water group exhibited the highest REE (1.23), outperforming all other groups. Betaine (0.82) and L-glutamine (0.66) showed moderate efficiency, while the betaine + L-glutamine combination (0.47) had the lowest relative performance. The REE confirms that cold water is the most cost-effective intervention for alleviating heat stress, delivering better economic returns compared to dietary supplements. This finding corroborates Wu *et al.* (2011), who advocated prioritizing low-cost strategies to maximize profitability under stress conditions.

Table (6). Effect of dietary betaine, L-glutamine supplementation and cold water on economical efficiency rate.

Variables	Groups				
	Control	Beta 2g	Gluta 5g	Beta+Glut	Water
Feed intake (Kg/bird)	0.469	0.465	0.468	0.465	0.463
Price/kg feed (LE)	15	18	20	23	15
Total cost (LE)	7.04	8.37	9.36	10.70	6.95
BW(kg)	0.209	0.225	0.229	0.230	0.231
Price(kg) L.E	70	70	70	70	70
Total Revenue (TR)	14.63	15.75	16.03	16.10	16.17
Net Revenue (ER)	7.59	7.38	6.67	5.40	9.22
Economic efficiency %	107.81	88.17	71.26	50.47	132.66
Relative Economic efficiency	1.00	0.82	0.66	0.47	1.23

Beta 2 g: Quails fed basal diet plus Betaine 2 g/kg diet, Gluta 5 g: Quails fed basal diet plus L-glutamine 5 g/kg diet, Beta + Glut: Quails fed basal diet plus Betaine 2 g/kg + L-glutamine 5 g diet and water: Quails received cold water without any additive.

In practical applications, we can recommend that cold water is a low-cost and highly effective solution for enhancing productivity in growing quails during heat stress conditions. While betaine and glutamine improve growth, their economic feasibility depends on the cost of inputs and expected market prices. From a sustainable agriculture perspective, implementing cost-effective strategies like cold water can improve profitability while maintaining animal welfare.

4. Conclusion

From our findings, it can be concluded that cold water stands out as the most effective and economical managerial treatment for alleviating heat stress in quails, directly reducing body temperature and enhancing feed intake efficiency, nutrient utilization, growth performance, feed conversion, and carcass traits. Compared to nutritional interventions like betaine and L-glutamine supplementation, which indirectly address heat stress by improving cellular hydration, gut health, and nutrient absorption, cold -water provides superior results with significantly lower costs and ease of implementation. While betaine and L-glutamine enhance stress resilience, their high costs limit economic viability. Combining cold water with targeted supplementation offers a synergistic approach, optimizing growth, welfare, and profitability, making it a practical and sustainable solution for managing heat stress in poultry production.

References

Abioja, M. O., Osinowo, O. A., Smith, O. F., Eruvbetine, D. and Abiona, J. A. (2011), "Evaluation of cold water and vitamin c on broiler growth during hot-dry season in swnigeria", *Archivos de zootecnia*, Vol. 60 No. 232, pp. 1095–1103.

Abuoghaba, A. A., Ali, F., Ismail, I. I. and Saleh, M. (2021), "Impact of acute short term high thermal stress during early embryogenesis on hatchability, physiological body reaction and ovarian follicles development of quails", *Poultry Science*, Vol. 100 No. 2, pp. 1213–1220.

Alagawany, M., Farag, M., Abd El-Hack, M. and Patra, A. (2017), "Heat stress: effects on productive and reproductive performance of quail", *World's Poultry Science Journal,* Vol. 73 No. 4, pp. 747–756.

Attia, Y. A., Abd El-Hamid, A. E. H. E., Abedalla, A. A., Berika, M. A., Al-Harthi, M. A., Kucuk, O., Sahin, K. and Abou-Shehema, B. M. (2016), "Laying performance, digestibility and plasma hormones in laying hens exposed to chronic heat stress as affected by betaine, vitamin C, and/or vitamin E supplementation", *Springer Plus*, Vol. 5, pp. 1–12.

Attia, Y., Ahmed, A. A., Mervat, A. B., Abdelhamid, E. A. and Bahaa, M. A. (2011), "Effect of betaine with or without two antioxidants on the performance of dual purpose breeding hens exposed to heat stress", *Journal of Agricultural and*

Environmental Sciences, Vol. 10 No.1, pp. 73–107.

Dai, S. F., Gao, F., Zhang, W. H., Song, S. X., Xu, X. L. and Zhou, G. H. (2011), "Effects of dietary glutamine and gamma-aminobutyric acid on performance, carcass characteristics and serum parameters in broilers under circular heat stress", *Animal Feed Science and Technology*, Vol. 168 No. 1-2, pp. 51–60.

Dong, X. Y., Yang, C. F., Tang, S. Q., Jiang, Q. Y. and Zou, X. T. (2010), "Effect and mechanism of glutamine on productive performance and egg quality of laying hens", *Australasian Journal of Animal Sciences*, Vol. 23 No. 8, pp. 1049–1056.

Duncan's, D. B. (1955), "Multiple range and multiple F tests", *Biometrics*, Vol. 11, pp. 1–42.

Eklund, M., Bauer, E., Wamatu, J. and Mosenthin, R. (2005), "Potential nutritional and physiological functions of betaine in livestock", *Nutrition Research Reviews*, Vol. 18 No.1, pp. 31–48.

Francis, J. A. and Griffiths, R. D. (2002), "Glutamine: essential for immune nutrition in the critically ill", *British Journal of Nutrition*, Vol. 87 No. 3-8, pp. S3–S8.

Gudev, D., Popova-Ralcheva, S., Yanchev, I., Moneva, P., Petkov, E. and Ignatova, M. (2011), "Effect of betaine on egg performance and some blood constituents in laying hens reared indoor under natural summer temperatures and varying levels of air ammonia", *Bulgarian Journal of Agricultural Science*, Vol. 17 No. 6, pp. 859–866.

Hu, H., Bai, X., Shah, A. A., Dai, S. F., Wang, L. K., Hua, J. L., Che, C. Y., He, S. J., Wen, A. Y. and Jiang, J. P. (2016), "Interactive effects of glutamine and gamma-amino butyric acid on growth performance and skeletal muscle amino acid metabolism of 22–42-day-old broilers exposed to hot environment", *International Journal of Biometeorology*, Vol. 60, pp. 907–915.

Jones, F. and Watkins, S. (2009), "How does taste influence water consumption in broilers", *Avian Advice*, Vol. 11 No. 1, pp. 8–11.

Kettunen, H., Tiihonen, K., Peuranen, S., Saarinen, M. T. and Remus, J. C. (2001), "Dietary betaine accumulates in the liver and intestinal tissue and stabilizes the intestinal epithelial structure in healthy and coccidia-infected broiler chicks", *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, Vol. 130 No. 4, pp. 759–769.

Mehaisen, G. M., Ibrahim, R. M., Desoky, A. A., Safaa, H. M., El-Sayed, O. A. and Abass, A. O. (2017), "The importance of propolis in alleviating the negative physiological effects of heat stress in quail chicks", *PLOS ONE*, Vol. 12 No. 10, Article No. e0186907.

Metzler-Zebeli, B. U., Eklund, M. and Mosenthin, R. (2009), "Impact of osmoregulatory and methyl donor functions of betaine on intestinal health and performance in poultry", *World's Poultry Science Journal*, Vol. 65 No. 3, pp. 419–441.

Murakami, A. E., Sakamoto, M. I., Natali, M. R. M., Souza, L. M. G. and Franco, J. R. G. (2007), "Supplementation of L-glutamine and vitamin e on the morphometry of the intestinal mucosa in broiler chickens", *Poultry Science*, Vol. 86 No. 3, pp. 488–495.

NRC: National Research Council (1994), *Nutrient requirement of poultry*, 9th Edn., National Academy Press, Washington, D.C., USA.

Nawab, A., Ibtisham, F., Li, G., Kieser, B., Wu, J., Liu, W., Zhao, Y., Nawab, Y., Li, K., Xiao, M. and An, L. (2018), "Heat stress in poultry production: Mitigation strategies to overcome the future challenges facing the global poultry industry", *Journal of Thermal Biology*, Vol. 78, pp.131–139.

Newsholme, P. (2001), "Why is L-glutamine metabolism important to cells of the immune system in health, postinjury, surgery or infection?", *The Journal of Nutrition*, Vol. 131 No. 9, pp. 2515–2522.

Newsholme, P., Procopio, J., Lima, M. M. R., Pithon-Curi, T. C. and Curi, R. (2003), "Glutamine and glutamate their central role in cell metabolism and function", *Cell Biochemistry and Function*, Vol. 21 No. 1, pp. 1–9.

Niu, Z., Liu, F., Yan, Q. and Li, W. (2009), "Effects of different levels of vitamin E on growth performance and immune responses of broilers under heat stress", *Poultry Science*, Vol. 88 No. 10, pp. 2101–2107.

Park, J. H., Kang, C. W. and Ryu, K. S. (2006), "Effects of feeding betaine on performance and blood hormone in laying hens", *Korean Journal of Poultry Science*, Vol. 33 No. 4, pp. 323–328.

Puma, M. C., Xin, R. S., Gates, R. S. and Ahn, D. U. (2001), "Effects of drinking water temperature on laying hens subjected to warm cyclic environmental conditions", In: Stowell, R. R., Bucklin, R. and Bottcher, R. W. (eds.) *Livestock environment*, Proceedings of 6th International Symposium, pp. 235–243.

Rashid, H. O., Huwajda, E. E. and Ibrahim, A. Y. (2012), "Effect of dietary protein level and strain on growth", *International Journal of Poultry Science*, Vol. 11 No. 10, pp. 649–653.

Runjaić-Antić, D., Pavkov, S., Lević, J., (2010), "Herbs in a sustainable animal nutrition", *Biotechnology in Animal Husbandry*, Vol. 26 No. 3-4, pp. 203–214.

Saeed, M., Babazadeh, D., Naveed, M., Arain, M. A., Hassan, F. U. and Chao, S. (2017), "Reconsidering betaine as a natural anti-heat stress agent in poultry industry: A review", *Tropical Animal Health and Production*, Vol. 49 No.7, pp. 29–38.

Sahin, N., Sahin, K. and Onderci, M. (2003), "Vitamin E and selenium supplementation to alleviate cold-stress-associated deterioration in egg quality and egg yolk mineral concentrations of Japanese quails", *Biological Trace Element Research*, Vol. 96, pp.179–189.

SAS Institute (2009), *SAS Users Guide Statistics' (Release 9.2)*, SAS Institute, Cary, NC, USA.

Suchner, U. K, Kuhn, S. and Furst, P. (2000), "The scientific basis of immuno nutrition", *Proceedings of the Nutrition Society*, Vol. 59 No. 4, pp. 553–563.

Teeter, R. and Smith, M. O. (1986), "High chronic ambient temperature stress effects on broiler acid-base balance and their response to supplemental ammonium chloride, potassium chloride, and potassium carbonate", *Poultry Science*, Vol. 65 No. 9, pp. 1777–1781.

Tollba, A. A. and El- Nagar, A. H. (2008), "Increasing stocking density of Egyptian laying hens by using: 3 - increasing protein level betaine supplementation", *Egyptian Poultry Science Journal*, Vol. 28 No. 3, pp. 745–766.

Wang, Y., Xu, Z. and Feng, J. (2004), "The effect of brotaine an methionine on growth performance and carcass characteristics in meat duck", *Animal Feed Science and Technology*, Vol. 116 No. 1-2, pp.151–159.

Windmueller, H. G. (1982), "Glutamine utilization by the small intestine", *Adv Enzymol Relat Areas Mol Biol*, Vol. 53 No. 201, pp. 201–237.

Wu, G., Bazer, F. W., Johnson, G. A., Knabe, D. A., Burghardt, R. C., Spencer, T. E. and Wang, J. J. (2011), "Triennial growth symposium: Important roles for L-glutamine in swine nutrition and production", *Journal of Animal Science*, Vol. 89 No. 7, pp. 20–30.

Yi, G. F., Allee, G. L., Knight, C. D. and Dibner, J. J. (2005), "Impact of glutamine and oasis hatchling supplement on growth performance, small intestinal morphology, and immune response of broilers vaccinated and challenged with Eimeria maxima", *Poultry Science*, Vol. 84 No. 2, pp. 283–293.

Zhang, M., Zhang, H., Li, H., Lai, F., Li, X., Tang, Y., Min, T. and Wu, H. (2016), "Antioxidant mechanism of betaine without free radical scavenging ability", *Journal of Agricultural and Food Chemistry*, Vol. 64 No. 42, pp. 7921–7930.

Zhong, X., Li, W., Huang, X., Wang, Y., Zhang, L., Zhou, Y. and Wang, T. (2012), "Effects of glutamine supplementation on the immune status in weaning piglets with intrauterine growth retardation", *Archives of Animal Nutrition*, Vol. 66 No. 5, pp. 347–356.