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# EFFECT OF SUPPLEMENTING NON-CHLORIDE SODIUM SOURCES AND LEVELS ON PERFORMANCE OF LAYING JAPANESE QUAIL THAT FED DIETS VARYING IN THEIR PROTEIN CONTENT

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## SUMMARY

The experimental work was conducted in a Poultry Research Station, El-Azab, Fayoum, Egypt, to study the dietary effects of supplementing different non-chloride (Cl) sodium (Na) sources and levels with different levels of dietary protein on the productive and reproductive performance of laying Japanese quail. The experiment was designed in a 2 x 2 x 3 factorial arrangement of treatments with crude protein (CP) level, type and level of non-chloride Na addition as main effects. Corn-soybean meal basal diets were formulated with two CP levels (20 and 18%), two types of non-chloride Na addition (sodium sulfate, $Na_2SO_4$ and sodium bicarbonate, $NaHCO_3$) and three levels of non-chloride Na addition% (0.00, 0.05 and 0.10%). According to the nutrient requirements of NRC (1994), the minimum dietary Na levels of all treatments groups were 0.15, and the Cl level of all diets were set to be 0.25% which were provided by supplemental level of sodium chloride (NaCl) at 0.35% to satisfy nutrient requirements. Then raising the Na level above the minimum requirement by adding $Na_2SO_4$ or $NaHCO_3$. These diets were fed from 39 to 88 days. The dietary amino acid levels were adjusted by adding DL-methionine and L-lysine-HCl. Results obtained can be summarized in the subsequent: Quails fed diet containing 18% CP had higher values of egg number, egg production% and the best crude protein conversion value. Quails fed diet containing $NaHCO_3$ had significantly the best values of feed conversion ratio and caloric efficiency ratio. Quails fed diet containing 18% CP supplemented with 0.05% Na from $Na_2SO_4$ at dietary electrolyte balance (DEB) 208.4 mEq/kg had higher values of egg weight (g) and yolk color. Quails fed diet containing 20% CP supplemented with 0.05% Na from $NaHCO_3$ at DEB 233.8 mEq/kg or 18% CP supplemented with 0.05% Na from $Na_2SO_4$ at DEB 208.4 mEq/kg had higher values of yolk index%.

Quails fed diet containing 18 CP% had higher value of hatchability (lower value of average chick weight (g) and late embryonic mortality%) and those fed diet containing 20% CP had higher value of average chick weight (g) and late embryonic mortality%. Quails fed diet containing 0.00% non-chloride Na had significantly higher value of early embryonic mortality% (lowest hatchability%), while, those fed diet containing 0.10% non-chloride Na had significantly higher value of hatchability% (lower value of early embryonic mortality%). Quails fed diet containing 20% CP supplemented with 0.05% Na from $Na_2SO_4$ had higher value of fertility%. Quails fed diet containing 18% CP supplemented with 0.10% Na from $NaHCO_3$ at DEB 231.0 mEq/kg had higher value of hatchability% (lower values of average chick weight (g) and early embryonic mortality%). Generally, all of the dietary treatments significantly surpassed the control in hatchability. While, quails fed diet containing 18% CP at DEB 187.4 mEq/kg with 0.00% $Na_2SO_4$ or $NaHCO_3$ had lower values of early and late embryonic mortality%. Values of economical and relative efficiency during the laying period (from 46 to 88 days) were improved in quails fed all experimental diets except those fed diet containing 20% CP plus any level of $Na_2SO_4$ supplementation, as compared with those fed the control and other treatments. Hens fed diet containing 18% CP supplemented with 0.10% Na from NaHCO3 at DEB 231.0 mEq/kg had the best economical and relative efficiency values, followed by hens fed diet containing 18% CP supplemented with 0.10% Na from $Na_2SO_4$ at DEB 230.7 mEq/kg, then hens fed diet containing 18% CP at DEB 187.4 mEq/kg, followed by hens fed diet containing 18% CP supplemented with 0.05% Na from $NaHCO_3$ at DEB 208.6 mEq/kg.

***Keywords:*** *Japanese quail, crude protein, dietary electrolyte balance, non-chloride sodium, sodium sulfate, sodium bicarbonate, performance, fertility, hatchability.*

## INTRODUCTION

Sodium (Na), potassium (K) and chloride (Cl) play a vital role) as synergetic action of all three elements) in preserving acid-base balance of body so, regulating osmotic pressure in body fluids of poultry. Also, the role of each element is difficult to define with no taking and knowing into consideration the other two components. On the other hand, the biological role of these three components is necessary in normal metabolism during poultry production. Some researchers stated that dietary Na and Cl affect acid-base balance (Patience, 1990), synthesis of tissue protein (Borges *et al.,* 2003), feed intake (Adedokun and Applegate, 2014), and digestibility of amino acids (Chrystal *et al.,* 2020). Dietary Na, K and Cl can adjust dietary electrolyte balance (DEB) values. The three elements (Na, K and Cl) are a relatively harmless elements that is vital in relatively large quantities to sustain life. Disorders in metabolism of three elements can result in they being toxic.

Chloride is one of the critical minerals for poultry nutrition, it plays a significant role in keeping fluid and electrolyte balance in the kidney (Wang *et al.*, 2020). It is generally accepted by nutritionists that the physiological ratio between Na and Cl is less than one. Hence, it is imperative to use a Cl-free source of Na and reduce NaCl to sustain this ratio. This has the effect of rising DEB about the optimum values from 240 to 250 mEq/kg to avoid difference in acid-base balance. However, requirements for Na, Cl and K have been clearly established, there is now an understanding of the need to balance the supply of cations and anions (Leeson and Summers, 2001). Most often, electrolyte balance is described via the simple formula Na+K-Cl and expressed by the term of milli equivalent (mEq)/kg or 100g of diet (Ahmad and Sarwar, 2006). They also noted that the reaction to DEB depends on ambient temperature, age of bird and extent of exposure to great temperature. Dietary electrolyte balance affects the performance of bird. An amount of 250 mEq/kg is an optimal requirement for usual physiological role. Electrolyte imbalance is very rare, since body’s buffer system provides keep of usual physiological pH rate. Conservation of this rate is determined by three main factors – the balance and proportion of electrolytes in diet, production of endogenous acid and the level of renal activity (Zivkov-Balos *et al.* (2016).

Hooge (2003) noted that broiler and breeder feeds typically have DEB indices of 100 - 250 mEq/kg. A very high of DEB being 340 and 360 mEq and a very low being 0 mEq/kg DEB can affect metabolic alkalosis and acidosis, respectively. Likewise, deficiency or excess of any particular mineral necessity avoid however maintaining the DEB. When adjusting DEB for the optimal performance, care must be taken that total levels of $Na^+$, $K^+$ and $Cl^-$ are within acceptable ranges, and not deficient or toxic (Mongin, 1981).

The supplementary Na source in poultry diets is commonly NaCl, approximately 0.3% NaCl is usually supplemented to the diet to meet the Cl and Na needs of laying hens. It should be noted that the Na and Cl content of NaCl is 59 and 39.5%, respectively. Poultry producers, as they switch the source of Na, can make feed cost savings at the same time improving performance. All poultry feeds need to be added with Na, an element vital for several physiological functions. This is mostly provided through NaCl plus a Cl-free Na source for example, sodium bicarbonate ($NaHCO_3$), sodium sulfate ($Na_2SO_4$), or sodium sesquicarbonate ($Na_3H(CO_3)_2 \cdot 2H_2O$). Stephens *et al.* (1974) compared to $NaHCO_3$ or sodium carbonate ($Na_2CO_3$), $Na_2SO_4$ has a much lower acid binding capacity which means that the use of $Na_2SO_4$ limits the effect of feed storage in the upper gastrointestinal tract. Low buffering capacity of feed improves protein digestibility and increases the efficiency of any organic acid used.

The synergistic result of increased levels of Na and Cl in the diets leads to an increase in water intake and due to the humidity content of excreta there has been cumulative interest to substitute Na sources in broiler diets (Kidd *et al.,* 2003 and Mushtaq *et al.,* 2005). High excreta humidity, may be accompanied by functional disorders of gastrointestinal (Jankowski *et al.,* 2011a, b).

Sodium sulfate (Glauber’s salt) which used as a cathartic, has been tested as an substitute Na source in a little researches (Hooge *et al.,* 1999 and Ahmad *et al.,* 2006). Sulphate is included in small quantities by way of the anion for necessary trace element, or to avoid methionine breakdown (Ahmad *et al.,* 2005). Though, different studies exhibited that the divalent ions excepted from the equation of DEB too exert important effects on poultry performance.

In a laying hen's diet typically range from 0.40 to 0.45% NaCl, these levels provide approximately 0.16% Na and 0.24% Cl. According to N.R.C. (1994), the nutrient requirement of laying Japanese quail for Na is 0.15% and Cl 0.14%. Sherwood (1975) reported that a Cl level of 0.10% was necessary to maintain adequate production and eggshell quality. Faria *et al.* (2000) found that replacing $Na_2SO_4$ with NaCl in laying diet enhance eggshell quality. High Na consumption also affects the balance of dietary cations and anions (known as $Na^{+}$+ $K^{+}$- Cl), which controls blood pH and thus affects amino acid metabolism and enzymatic efficiency.

Similar formulation principles have been applied in other experiments with laying hens and the similar conclusions were reached. Wei (2015); Fu (2019) and Wang *et al.* (2020) noted that $Na_2SO_4$ is a Cl-free source of Na for laying hens which can be used to decrease NaCl to keep the ratio between Na and Cl in diets. But, this substitution, which significantly reduced the dietary level of Cl, may have potentially harmful effects on performance of poultry.

Furthermore, the use of $Na_2SO_4$ significantly reduces $NH_3$ emissions from waste compared to $NaHCO_3$. This result has benefits for both the performance and health of poultry, as well as the working conditions of livestock owners. Stephens *et al.* (1974) reported in general that, the use of $Na_2SO_4$ provides poultry producers with a wide range of opportunities without compromising performance.

A number of researches (Balnave and Oliva, 1991 and Gorman and Balnave, 1994) have shown helpful responses to $NaHCO_3$ addition of the diet or drinking water. Sullivan and Njoku (1979) stated that 0.16% Na was essential in the diet of a laying hen for satisfactory performance. Sauver and Mongin (1978) reported that correlations with K were equally significant, and that this could not be disregarded in determining Na and Cl levels. The need for NaCl in all animals diets has been documented throughout the ages. Because NaCl does not have the Na and Cl ratio that best suits the desired levels, it has been hypothesized that excess Cl could contribute to decrease egg shell quality. Several scientists have stated a response to Na addition in the form of $NaHCO_3$ (Howes, 1966). Because of the negative relationship between blood pH and calcification of eggshell (Hall and Helbacka, 1959 and Wideman and Buss, 1985), laying hens require a source of alkaline substances, especially bicarbonate, to compensate for metabolic acidosis.

Zivkov-Balos *et al.* (2016) reported that as high levels of salt increased water consumption, a quota of dietary salt nearly 30% can be substituted with $NaHCO_3$ without harmful effects on production performance of poultry, somewhat dry excreta can be observed in these cases. Dietary electrolyte balance calculation factors are based on the total nutrient contents of chicken diets, nevertheless in the fact, the bioavailability of nutrients affects the actual quantities of nutrients absorbed via the intestines into the bloodstream (Hooge, 1995). Ahmad and Sarwar (2006) found that increasing DEB increased FI (regardless of ambient temperature), which may perhaps due to increasing Na+ contents in diets from 0.15 to 0.45%.

Regarding nutritional requirements, two critical factors that limit poultry production are protein and energy (Ashour *et al.,* 2020 and El-Hindawy *et al.,* 2021). The above nutrients are the primary determinants of the cost of chicken feed. Sources of protein in poultry diets are made from the costliest raw materials or ingredient. Consequently, producers tend to reduce production costs by lowering the level of CP in the diets or using the optimalCP level (Ashour *et al.* 2020; El-Hindawy *et al.* 2021 and Alagawany *et al.,* 2022) without seeing the imports of this experimental on the poultry production and reproduction performance. On the other hand, Latshaw and Zhao (2011) and Chalova *et al.* (2016) reported that increased CP in diets can cause emission of undigested odor, increased excretion of nitrogen (N) and unabsorbed CP as well as uric acids as the end product of CP metabolism which is simultaneously excreted in fecal droplets. It is estimatedthat more than 50% of the N consumed by the laying hen is ousted in the manure (Latshaw and Zhao, 2011).The gaseous pollutants accountable for global warming in the livestock production are odors emitted from waste (Blanes-Vidal *et al.,* 2012). Toward solve this problem, several techniques are being developed via poultry producers that can be divided into two categories: nutritional intervention and technological strategy (Patterson and Adrizal, 2005). Thus the strategy of using a low CP diet balanced by supplemental essential amino acids in poultry production has been extensively accepted (Abdel-Hafeez *et al.,* 2016). Parenteau *et al.* (2020) indicate that CP can be decreased by 2% in laying hen diets if supplemented with synthetic amino acids.

Both too much or too little protein will have adverse financial and health impacts. According to Pinto *et al.* (2002), optimal laying quail performance was attained when diets contained 22.42% CP and 2850 kcal ME/kg. However, ideal protein and caloric needs vary by strain, season and environment. Subsequently, an effort was made to ascertain the optimal protein and calorie requirements of Japanese quail during the egg-laying phase.

Japanese quail has become an important research poultry for the reason that sexual maturity befalls around six to seven weeks, rapid growth, potential for three to four offspring per year. Advances in genetics, nutrition, health, management and facilities have improved the productivity and development of poultry production, allowing production costs to be reduced and the quality of the final product improved. Developments require continuous monitoring of nutritional requirements of birds during breeding and differences in climatic and other environmental conditions (Abdul Hafeez *et al.,* 2021 and Qureshi *et al.,* 2021).

Therefore, the aim of this research was to set whether a substantial increase in Na content in the diets above the recommendations (re-evaluate Na requirements) of N.R.C. (1994), affects positively on laying Japanese quail performance, and also to determine the best DEB for obtaining maximum productive and reproductive performance, this by addition of different sources and levels of non-chloride sodium like $NaHCO_3$ and $Na_2SO_4$ in the diets varying in their protein content.

## MATERIALS AND METHODS

The experimental work was conducted in a Poultry Research Station, El-Azab, Fayoum, Egypt, this study was undertaken to assess the dietary effects of supplementation of different non-chloride Na sources and levels with different dietary protein levels on the productive and reproductive performance of laying Japanese quail.

The experiment was designed in a 2 x 2 x 3 factorial arrangement of treatments with CP level, type and level of non-chloride Na addition as main effects. Corn-soybean meal basal diets (Tables 1and 2) were formulated with two CP levels (20 and 18% CP), two types of non-chloride Na addition ($Na_2SO_4$ and $NaHCO_3$) and three levels of non-chloride Na addition% (0.00, 0.05 and 0.10%). According to the nutrient requirements of NRC (1994), the minimum dietary Na levels of all treatments groups were 0.15, and the Cl level of all diets were set to be 0.25% which were provided by supplemental level of NaCl at 0.35% to satisfy nutrient requirements. Then raising the Na level above the minimum requirement by adding $Na_2SO_4$ or $NaHCO_3$ (Tables 1and 2).

The basal experimental diets (control) were formulated to satisfy nutrient requirements (iso-caloric) of laying Japanese quail (2900 Kcal ME/Kg diet) according to the NRC (1994). These diets were fed from 39 to 88 days (feed and water were provided *ad libitum*). The amino acid levels were adjusted by adding DL-methionine and L-lysine-HCl. The composition and calculated analyses of the experimental diets are shown in Tables 1 and 2. The requirements of nutrients are calculated according to NRC (1994). The experimental diets were weighed daily and their residues left in troughs were weighed at the end of each 7 days.

The experiment started at the age of 46 days (50% egg production) preceded by an adaptation period of one week (from 39 to 45 days of age) after growing period (knowing that the birds were fed the same treatments during the growth period) and ended at the age of 88 days (lasted for 6 weeks). A total number of 288 laying hens plus 144 males of Japanese quail at 46 days of age were allocated randomly into 12 equal dietary treatments groups, each treatment containing 24 hens with 12 males. Each group was subdivided equally into 3 replicates (experimental units) of 8 hens with 4 males each.

The experimental groups were housed in galvanized wire cage batteries and provided with the feeders (manual feed distribution) and stainless steel nipples with plastic cups for each cage. For calculated FI during the laying period, generally females consume 13% more feed than the males according to Ragab *et al.* (2002). This figure was used to correct the FI of the females to calculate the FCR. Also, every hen that died was weighed, FI at the same time was noted, and these numbers were used for adjustment of FCR. The quails were reared in the normal environmental conditions of Poultry Research Station, El-Azab, Fayoum, Egypt farms and received the same management.

Extra artificial light source was used, 100-watt lamps with 3 m distance from each other and in 2.30 m height from the ground were considered for lighting giving a total of 16 hours of light per day (16 L:8 D lighting program), throughout the experimental period (6 weeks).

***The next parameters were estimated and/or calculated:***

Egg number (EN), average egg weight (EW), egg production (EP%), daily feed intake (FI), feed conversion ratio (FCR), crude protein conversion (CPC), caloric conversion ratio (CCR) and mortality rate (MR).

***Egg quality:***

Total number of 252 eggs (21 eggs from each treatment) were randomly collected (at the end of 88 days of age) and individually weighed and broken out on a flat glass plate to determine the following egg quality traits: According to equation of Carter (1968) egg shape index (ESI) was calculated, albumen weight (AW)%, yolk weight (YW)%, shell weight (SW)%, shell thickness (ST) (measured (including shell membranes) by using a micrometer as an average of three locations on the egg (air cell, equator, and sharp end)), thick albumen and yolk heights (AH and YH), yolk diameter (YD), yolk index (YI)% (according to Well (1968) as the following formula: YI% = (YH/YD) X 100). Around the world the yolk color (YC) is very important to consumers satisfaction and usually prefer the YC that ranges from orange to golden yellow, therefore, YC was determined by Roche yolk color scale as described by Vuilleumiller (1969).

**Table (1): Composition and calculated analysis of the experimental diets (20%) during the laying period.**

| Items % | | Crude protein level % 20 | | | | | |
|---|---|---|---|---|---|---|---|
| | | Type of non-chloride Na addition | | | | | |
| | | $Na_2SO_4$ | | | $NaHCO_3$ | | |
| | | Level of non-chloride Na addition % | | | | | |
| | | 0.00 | 0.05 | 0.10 | 0.00 | 0.05 | 0.10 |
| Feed ingredients | Yellow corn, ground | 54.26 | 53.93 | 53.64 | 54.26 | 53.90 | 53.51 |
| | Soybean meal (44%CP[1]) | 34.80 | 34.86 | 34.91 | 34.80 | 34.86 | 34.94 |
| | Calcium carbonate | 5.60 | 5.60 | 5.60 | 5.60 | 5.60 | 5.60 |
| | Sodium chloride | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| | Vit. and Min. premix[2] | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| | Dicalcium phosphate | 1.20 | 1.20 | 1.20 | 1.20 | 1.20 | 1.20 |
| | Vegetable oil[3] | 3.35 | 3.46 | 3.55 | 3.35 | 3.47 | 3.59 |
| | DL–Methionine | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| | L-Lysine HCl | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | $Na_2SO_4$ | 0.00 | 0.16 | 0.31 | 0.00 | 0.00 | 0.00 |
| | $NaHCO_3$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.37 |
| | Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Calculated analysis[4]: | | | | | | | |
| ME, kcal./Kg | | 2900.4 | 2900.6 | 2900.1 | 2900.4 | 2900.5 | 2900.0 |
| Protein and amino acids | Crude protein | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 |
| | Lysine | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 |
| | Methionine | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| | Methionine + Cystine | 0.78 | 0.78 | 0.78 | 0.78 | 0.78 | 0.78 |
| | Arginine | 1.30 | 1.30 | 1.30 | 1.30 | 1.30 | 1.30 |
| | Threonine | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |
| | Valine | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 |
| Minerals | Calcium | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| | Available phosphorus | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| | Potassium | 0.84 | 0.85 | 0.85 | 0.84 | 0.84 | 0.85 |
| | Sodium | 0.15 | 0.20 | 0.25 | 0.15 | 0.20 | 0.25 |
| | Chloride | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| | EB(electrolyte balance) | 212.6 | 234.9 | 255.8 | 212.6 | 233.8 | 256.2 |
| Crude fiber | | 3.63 | 3.63 | 3.62 | 3.63 | 3.63 | 3.62 |
| Crude fat | | 5.69 | 5.79 | 5.87 | 5.69 | 5.80 | 5.90 |
| Cost (£.E./ton)[5] | | 1875.7 | 1884.3 | 1891.7 | 1875.7 | 1885.1 | 1894.9 |

[1]*Crude protein* [2]*Each 3.0 Kg of the vitamin and mineral premix manufactured by Egy. Phar. Co. and contains: Vit. A 10000000 IU; Vit. $D_3$ 2500000 IU; Vit. E 10000 mg; Vit. $K_3$ 1000 mg; Vit. B1 1000 mg; Vit. B2 5000 mg; Vit. B6 1500 mg; Vit. B12 10 mg; biotin 50 mg; folic acid 1000 mg; niacin 30000 mg; pantothenic acid 10000 mg; Zn 50000 mg; Cu 4000 mg; Fe 30000 mg; Co 100 mg; Se 100 mg; I 300 mg; Mn 60000 mg, choline chloride 300000 mg and complete to 3.0 Kg by calcium carbonate.* [3] *Mixture from 25% sunflower oil and 75% soybean oil.* [4]*According to NRC, 1994.*
[5] *According to the local market price at the experimental time.*

**Table (2): Composition and calculated analysis of the experimental diets (18%) during the laying period.**

| Items % | | Crude protein level % 18 | | | | | |
|---|---|---|---|---|---|---|---|
| | | Type of non-chloride Na addition | | | | | |
| | | $Na_2SO_4$ | | | $NaHCO_3$ | | |
| | | Level of non-chloride Na addition % | | | | | |
| | | **0.00** | **0.05** | **0.10** | **0.00** | **0.05** | **0.10** |
| Feed ingredients | **Yellow corn, ground** | 61.47 | 61.16 | 60.82 | 61.47 | 61.10 | 60.70 |
| | **Soybean meal (44%CP[1])** | 28.60 | 28.66 | 28.73 | 28.60 | 28.67 | 28.75 |
| | **Calcium carbonate** | 5.61 | 5.61 | 5.61 | 5.61 | 5.61 | 5.61 |
| | **Sodium chloride** | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| | **Vit. and Min. premix[2]** | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| | **Dicalcium phosphate** | 1.26 | 1.26 | 1.26 | 1.26 | 1.26 | 1.26 |
| | **Vegetable oil[3]** | 2.14 | 2.24 | 2.35 | 2.14 | 2.26 | 2.39 |
| | **DL–Methionine** | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| | **L-Lysine HCl** | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| | **$Na_2SO_4$** | 0.00 | 0.15 | 0.31 | 0.00 | 0.00 | 0.00 |
| | **$NaHCO_3$** | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.37 |
| | **Total** | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| **Calculated analysis[4]:** | | | | | | | |
| **ME, kcal./Kg** | | 2900.5 | 2900.4 | 2900.5 | 2900.5 | 2900.4 | 2900.5 |
| Protein and amino acids | **Crude protein** | 18.00 | 18.00 | 18.00 | 18.00 | 18.00 | 18.00 |
| | **Lysine** | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 |
| | **Methionine** | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| | **Methionine + Cystine** | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| | **Arginine** | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 | 1.13 |
| | **Threonine** | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 |
| | **Valine** | 0.83 | 0.83 | 0.83 | 0.83 | 0.83 | 0.83 |
| Minerals | **Calcium** | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| | **Available phosphorus** | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| | **Potassium** | 0.74 | 0.75 | 0.75 | 0.74 | 0.75 | 0.75 |
| | **Sodium** | 0.15 | 0.20 | 0.25 | 0.15 | 0.20 | 0.25 |
| | **Chloride** | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| | **EB(electrolyte balance)** | 187.4 | 208.4 | 230.7 | 187.4 | 208.6 | 231.0 |
| **Crude fiber** | | 3.35 | 3.35 | 3.35 | 3.35 | 3.35 | 3.35 |
| **Crude fat** | | 4.70 | 4.79 | 4.89 | 4.70 | 4.81 | 4.93 |
| **Cost (£.E./ton)[5]** | | 1734.1 | 1742.1 | 1750.8 | 1734.1 | 1743.6 | 1753.9 |

*[1]Crude protein* *[2]Each 3.0 Kg of the vitamin and mineral premix manufactured by Egy. Phar. Co. and contains: Vit. A 10000000 IU; Vit. $D_3$ 2500000 IU; Vit. E 10000 mg; Vit. $K_3$ 1000 mg; Vit. B1 1000 mg; Vit. B2 5000 mg; Vit. B6 1500 mg; Vit. B12 10 mg; biotin 50 mg; folic acid 1000 mg; niacin 30000 mg; pantothenic acid 10000 mg; Zn 50000 mg; Cu 4000 mg; Fe 30000 mg; Co 100 mg; Se 100 mg; I 300 mg; Mn 60000 mg, choline chloride 300000 mg and complete to 3.0 Kg by calcium carbonate.* *[3] Mixture from 25% sunflower oil and 75% soybean oil.* *[4]According to NRC, 1994.*
*[5] According to the local market price at the experimental time.*

Haugh units (HU) are found by determining the logarithm of albumen height corrected to a standard EW, the log values are then expressed in convenient whole number by multiplying by 100 (Haugh, 1937). For since albumen height is influenced by the pull of gravity, the gravitational constant 32.2 is introduced into the calculation, (Card and Nesheim, 1976). The original HU formula is: $HU = 100 \log (H + 7.57 - 1.7 W^{0.37})$. Where: HU = Haugh units, H = observed albumen height in millimeters, W = observed weight of an egg in grams.

***Hatch characteristics:***

Settable eggs were weighed to determine the average daily EW. Settable eggs (separated from dirty, deformed, broken, cracked and excessively small) were stored in a cold room at 18˚C until its set for incubation. Eggs were collected daily for all replicates, and weighed individually. Sixty settable eggs per treatment were set for incubation (88 days of age). Eggs were incubated in an automatic incubator (pas reform model). Incubator was set at 37.8˚C dry bulb temperatures and 70% relative humidity, eggs turning every one hour (0-15 days).

All infertile eggs were opened and inspected for evidence of embryonic mortality. All unhatched eggs were examined for developmental stage of dead embryos. The time of embryonic death was assigned to one of two categories: early dead (≤10 days) when blood islet or very small embryo with very large yolk sac was detected, late dead (11-17 days) when medium sized or fully formed embryo was detected. Fertility was expressed as the rate of fertile eggs to total eggs set. On day 16, eggs were relocated to baskets which were sited randomly into the hatcher cabinets dry bulb temperatures at 36.8˚C and relative humidity of 85%. The number of eggs that hatched was recorded at 17 days of incubation. Within 2 hours after hatching, each chick was weighed, the body weights of chicks were determined using mean of individual chick weight (g).

Fertility and hatchability% were expressed as the following formulas:

Fertility%= (number of fertile eggs/number of total set eggs) X 100.

Hatchability%= (number of hatched chicks/numbers of fertile eggs) X 100.

***Economical efficiency (E.EF):***

EP was calculated from the input-output analysis by data from feeding expenses, from eggs selling incomes, finally achieving the absolute revenue. The E.EF values were calculated as the net revenue per unit of total costs. The total feed cost (pounds/quail) was calculated at the end of the experiment for each treatment based on the local market prices of the ingredients used in formulating the experimental diet. Prices of supplementations ($Na_2SO_4$ or $NaHCO_3$) were 30.0 LE/Kg, The total income (LE/hen) were calculated depending on the average market price of both table eggs (1.75 L.E).

***Statistical analysis:***

Results was performed using the General Linear Models procedure of the SPSS software (SPSS, 2007), according to the follow general model:

$Y_{ijkl}= \mu+C_i+T_j +L_k+CT_{ij}+TL_{ik}+CL_{jk}+CTL_{ijk}+e_{ijkl.}$ Where:

$Y_{ijkl}$: observed value. µ: overall mean. $C_i$: crude protein (CP) level effect (i: 20 and 18%)

$T_j$: Type of non-chloride Na addition effect (j: $Na_2SO_4$ and $NaHCO_3$)

$L_k$: Level of non-chloride Na addition effect % (k: 0.00, 0.05 and 0.10%).

$CT_{ij:}$ Interaction effect of CP level by type of non-chloride Na addition.

$TL_{ik:}$ Interaction effect of type of non-chloride Na addition by level of non-chloride Na addition%.

$CL_{jk}$: Interaction effect of CP level by level of non-chloride Na addition%.

$CTL_{ijk:}$ Interaction effect of CP level by type of non-chloride Na addition by level of non-chloride Na addition% (treatments). $e_{ijkl}$: random error.

Statistically significant differences between treatment means were determined by Duncan's multiple range test (Duncan, 1955).

## RESULTS AND DISCUSSION

***Laying hens productive performance:***

Effect of supplementation of different non-chloride sodium sources and levels with different levels of dietary protein on laying Japanese quail performance are shown in Tables 3.a and 3.b. The results of the present study indicate that the main effects of CP level% had significantly (P≤0.05) affected EN, EP%

and CPC,g. Quails fed diet containing 18% CP had higher values of EN, EP% and the best CPC values (Table 3.a). However, insignificant differences were detected in other productive parameters. Type of non-chloride Na addition had significantly (P≤0.05) affected FCR and CCR (Table 3.a). Quails fed diet containing $NaHCO_3$ had significantly the best values of FCR and CCR, while, chicks fed diet containing $Na_2SO_4$ had significantly the worest values. However, insignificant differences were detected in other productive parameters.

Level of non-chloride Na addition% had insignificantly affected productive parameters (Table 3.a). Numerically, quails fed diet containing 0.10% non-chloride Na surpassed the control for all the productive parameters, except EW, g. Interaction due to CP levels%, type and level of non-chloride Na addition (experimental treatments) had significantly (P≤0.01) affected CPC (Table 3.b). However, insignificant differences were detected in other productive parameters as compared to the control diet. Quails fed diet containing 20% CP supplemented with 0.05% or 0.10 Na from Na2SO4 had the worest value of CPC (the difference is not significant between quails fed the control diet or those fed diet containing 20% CP supplemented with 0.05% or 0.10% Na from $Na_2SO_4$).

**Table (3.a): Effect of different non-chloride sodium sources and levels with different levels of dietary protein on productive performance of laying Japanese quail (main effects).**

| Items | EW,g[1] | EN[2] | EP[3], % | FI[4],g | FCR[5] | CPC[6] | CCR[7] |
|---|---|---|---|---|---|---|---|
| **Crude protein level %** | | | | | | | |
| 20 | 12.98 | 31.08[b] | 73.99[b] | 43.92 | 4.62 | 0.91[a] | 13.26 |
| 18 | 12.83 | 33.13[a] | 78.87[a] | 44.22 | 4.34 | 0.78[b] | 12.59 |
| SEM[8] | 0.11 | 0.66 | 1.57 | 0.54 | 0.09 | 0.02 | 0.25 |
| P-value | 0.351 | 0.042 | 0.042 | 0.703 | 0.051 | 0.000 | 0.070 |
| **Type of non-chloride Na addition** | | | | | | | |
| $Na_2SO_4$ | 12.97 | 31.50 | 74.99 | 44.49 | 4.63[a] | 0.87 | 13.27[a] |
| $NaHCO_3$ | 12.81 | 32.86 | 78.25 | 43.66 | 4.31[b] | 0.82 | 12.49[b] |
| SEM | 0.12 | 0.80 | 1.91 | 0.66 | 0.10 | 0.03 | 0.25 |
| P-value | 0.382 | 0.249 | 0.249 | 0.393 | 0.037 | 0.196 | 0.045 |
| **Level of non-chloride Na addition%** | | | | | | | |
| 0.00 | 13.00 | 31.79 | 75.69 | 44.03 | 4.52 | 0.86 | 13.10 |
| 0.05 | 12.85 | 30.93 | 73.65 | 43.56 | 4.53 | 0.85 | 13.03 |
| 0.10 | 12.93 | 33.43 | 79.59 | 44.60 | 4.41 | 0.84 | 12.72 |
| **SEM** | 1.29 | 0.74 | 1.76 | 0.60 | 0.12 | 0.03 | 0.31 |
| **P-value** | 0.785 | 0.081 | 0.081 | 0.429 | 0.777 | 0.860 | 0.701 |

*[a–b] Means in a column with different superscripts differ significantly (P≤0.05).*
*[1]Average egg weight, [2]Egg number/hen, [3]Egg production, [4]Daily feed intake, [5]Feed conversion ratio,*
*[6]Crude protein conversion,[7]Caloric conversion ratio, and[8] Pooled SEM*

Similar results were reported by Hassan and Ragab (2007a) and Heo *et al.* (2023) who noted that no differences in FI were found due to reducing CP levels in diets, most likely because energy was constant in all diets, and laying hens manage their FI principally to meet their energy requirements for best EP. Also, results obtained corroborates with Alagawany *et al.* (2020) and Heo *et al.* (2023) as they reported that lowering CP levels did not affect FCR and EM in laying hens.

On the contrary to our results, Alagawany *et al.* (2020) and Heo *et al.* (2023) as they reported that reducing CP levels in diets decreased EW. Also, Gunawardana *et al.* (2008) establishes that increasing the CP level can improve laying performance. Jesuyon *et al.* (2021) recommend the EW increase as a result of the level of CP increase in the diet. Increasing the CP level in the diet resulted in improved EP, EM, and FCR (El-Hindawy *et al.*, 2021 and Ashour *et al.*, 2024), increased EP, EW, EM, and FCR of laying quail (Salih *et al.*, 2021) and enhance EP of quails (Macelline *et al.*, 2021 and Mnisi *et al.*, 2022). Moreover, Hassan and Ragab (2007b) found that Hy-Line W-36 laying hens fed diet contains high level of CP (14.75%) had significantly higher values of EW, EP%, EM, FI and better FCR, and CCR than the other treatments. But it not differs in CPC with laying hens fed diet contains 13.25% CP, however, CCR were improved by decreasing CP level. However, Ji *et al.* (2014) reported that low CP levels did not affect EP.

**Table (3.b): Effect of different non-chloride sodium sources and levels with different levels of dietary protein on productive performance of laying Japanese quail (treatments).**

| Crude protein level % | Type of non-chloride Na addition | Level of non-chloride Na addition% | EW,g[1] | EN[2] | EP[3], % | FI[4],g | FCR[5] | CPC[6] | CCR[7] |
|---|---|---|---|---|---|---|---|---|---|
| 20 | $Na_2SO_4$ | 0.00 | 12.80 | 30.34 | 72.24 | 43.69 | 4.76 | 0.95[a] | 13.81 |
| | | 0.05 | 12.98 | 30.43 | 72.45 | 43.87 | 4.84 | 0.94[a] | 13.66 |
| | | 0.10 | 13.15 | 30.36 | 72.28 | 45.11 | 4.86 | 0.95[a] | 13.80 |
| | $NaHCO_3$ | 0.00 | 12.80 | 30.34 | 72.24 | 43.69 | 4.76 | 0.95[a] | 13.81 |
| | | 0.05 | 12.91 | 30.73 | 73.16 | 42.72 | 4.38 | 0.88[ab] | 12.70 |
| | | 0.10 | 13.07 | 33.53 | 79.83 | 44.20 | 4.25 | 0.85[ab] | 12.32 |
| 18 | $Na_2SO_4$ | 0.00 | 13.19 | 33.24 | 79.14 | 44.36 | 4.27 | 0.77[b] | 12.38 |
| | | 0.05 | 12.87 | 30.99 | 73.79 | 45.08 | 4.57 | 0.82[b] | 13.24 |
| | | 0.10 | 12.86 | 34.20 | 81.42 | 43.90 | 4.26 | 0.77[b] | 12.37 |
| | $NaHCO_3$ | 0.00 | 13.19 | 33.24 | 79.14 | 44.36 | 4.27 | 0.77[b] | 12.38 |
| | | 0.05 | 12.62 | 31.57 | 75.17 | 42.57 | 4.32 | 0.78[b] | 12.53 |
| | | 0.10 | 12.62 | 35.63 | 84.83 | 45.17 | 4.28 | 0.77[b] | 12.41 |
| **SEM[8]** | | | 0.28 | 1.31 | 3.13 | 1.39 | 0.20 | 0.04 | 0.55 |
| **P-value** | | | 0.857 | 0.133 | 0.133 | 0.879 | 0.241 | 0.008 | 0.319 |

*[a–b] Means in a column with different superscripts differ significantly ($P \leq 0.05$).*
*[1]Average egg weight, [2]Egg number/hen, [3]Egg production, [4]Daily feed intake, [5]Feed conversion ratio, [6]Crude protein conversion,[7]Caloric conversion ratio, and[8] Pooled SEM*

In this respect, Edi and Andri (2023), noted that feeding diets containing 21% CP and 2900 kcal/kg ME is essential to give laying quail the best possible performance. Ashour *et al.* (2024) recommended that laying Japanese quail between 8 and 20 weeks of age be fed diets containing an protein level of 20% CP with 2900 kcal ME/kg for optimal performance, the best egg quality and increasing nutrient digestibility.

The results partially confirmed previous findings of Wang *et al.* (2020) who indicate that $Na_2SO_4$ can partially replace NaCl in the diets of laying hens during the period from 43 to 54 weeks of age at a dietary Cl level of 0.10 to 0.25% without detrimental effects on performance with maintaining the total dietary Na level at 0.15%) no significant difference between treatments in performance) . But our findings differ from those reported by Liu *et al.* (2021) who found that dietary addition with 0.3 or 0.6% $Na_2SO_4$ significantly increased EP during the pre-peak period. Similar results were reported by Wei *et al.* (2015). Liu *et al.* (2021) noted that short-term feeding (3 weeks) of high-dose $Na_2SO_4$ being 1.5% and 3.0% also resulted in a significant increase in EP.

***Egg quality:***

Effect of supplementation of different non-chloride sodium sources and levels with different levels of dietary protein on egg quality of laying Japanese quail are shown in Tables 4.a and 4.b. It is clear that, the main effects of CP level% had significantly ($P \leq 0.01$) affected YC and YI. Hens fed diet containing 18% CP had higher values of YC and YI as shown in Table 4.a (this effect was secondary to the increase in yellow corn inclusion in low CP diets), as yellow corn is known to be rich in natural pigments, such as xanthophyll.

However, insignificant differences were detected in other egg quality parameters as compared to the control diet. Numerically, quails fed diet containing 18% CP had insignificantly higher value of HU, this result may be demonstrate that protein synthesis of albumin throughout egg formation in the oviduct was not lessened by dietary CP levels. In this respect, Shim *et al.* (2013) and Heo *et al.* (2023) reported that decreasing dietary CP levels improved HU at the early phase of laying hens. Similarly, Hassan and Ragab (2007b) found that reducing dietary CP levels enhanced HU at 61 weeks of age of Hy-Line W-36 laying hens. This might be partly related to higher supplementation of crystalline AA leading to higher systemic availability for synthesis of albumen through decreasing dietary CP levels.

Type of non-chloride Na addition had significantly ($P \leq 0.05$) affected EW, g and yolk% (Table 4.a). Quails fed diet containing $Na_2SO_4$ had significantly higher value of EW, while, chicks fed diet containing $NaHCO_3$ had significantly the higher value of yolk%. However, insignificant differences were detected in other egg quality parameters.

**Table (4.a): Effect of different non-chloride sodium sources and levels with different levels of dietary protein on egg quality of laying Japanese quail (main effects).**

| Items | Egg weight, g | Yolk color | Shell thickness, mm | Albumen % | Yolk% | Shell% | Yolk index | Shape index% | Haugh unit |
|---|---|---|---|---|---|---|---|---|---|
| **Crude protein level %** | | | | | | | | | |
| 20 | 13.27 | 5.49[b] | 0.202 | 60.41 | 31.80 | 9.44 | 0.408[b] | 78.83 | 77.89 |
| 18 | 13.63 | 6.20[a] | 0.209 | 57.93 | 32.87 | 9.20 | 0.445[a] | 78.95 | 78.07 |
| SEM[1] | 0.15 | 0.12 | 0.010 | 0.92 | 0.58 | 0.18 | 0.010 | 0.44 | 0.90 |
| P-value | 0.092 | 0.000 | 0.966 | 0.055 | 0.191 | 0.334 | 0.006 | 0.850 | 0.886 |
| **Type of non-chloride Na addition** | | | | | | | | | |
| $Na_2SO_4$ | 13.66[a] | 5.87 | 0.205 | 60.42 | 31.46[b] | 9.43 | 0.431 | 79.04 | 77.18 |
| $NaHCO_3$ | 13.05[b] | 5.80 | 0.210 | 57.83 | 33.70[a] | 9.32 | 0.410 | 78.60 | 78.08 |
| SEM | 0.18 | 0.14 | 0.010 | 1.18 | 0.66 | 0.20 | 0.010 | 0.46 | 1.02 |
| P-value | 0.013 | 0.742 | 0.155 | 0.110 | 0.024 | 0.699 | 0.224 | 0.513 | 0.551 |
| **Level of non-chloride Na addition %** | | | | | | | | | |
| 0.00 | 13.65 | 5.87 | 0.203 | 59.13 | 31.77 | 9.10 | 0.447[a] | 79.08 | 79.49 |
| 0.05 | 13.21 | 5.91 | 0.205 | 60.32 | 31.79 | 9.31 | 0.448[a] | 79.04 | 77.13 |
| 0.10 | 13.56 | 5.77 | 0.211 | 58.12 | 33.20 | 9.46 | 0.394[b] | 78.62 | 78.07 |
| **SEM** | 0.17 | 0.15 | 0.010 | 1.04 | 0.65 | 0.20 | 0.010 | 0.49 | 0.98 |
| **P-value** | 0.209 | 0.790 | 0.721 | 0.332 | 0.247 | 0.573 | 0.001 | 0.788 | 0.395 |

*[a–b] Means in a column with different superscripts differ significantly ($P \leq 0.05$).* *[1] Pooled SEM*

**Table (4.b): Effect of different non-chloride sodium sources and levels with different levels of dietary protein on egg quality of laying Japanese quail (treatments).**

| Crude protein level % | Type of non-chloride Na addition | Level of non-chloride Na addition % | Egg weight, g | Yolk color | Shell thickness, mm | Albumen % | Yolk% | Shell% | Yolk index | Shape index% | Haugh unit |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | $Na_2SO_4$ | 0.00 | 13.41[abc] | 5.36[c] | 0.200 | 59.19 | 31.20 | 9.61 | 0.435[a] | 79.24 | 80.97 |
| | | 0.05 | 13.18[abc] | 5.20[c] | 0.205 | 62.53 | 31.01 | 9.04 | 0.424[a] | 80.54 | 76.92 |
| | | 0.10 | 13.51[abc] | 5.33[c] | 0.211 | 61.22 | 31.97 | 9.48 | 0.410[a] | 78.59 | 76.64 |
| | $NaHCO_3$ | 0.00 | 13.41[abc] | 5.36[c] | 0.200 | 59.19 | 31.20 | 9.61 | 0.435[a] | 79.24 | 80.97 |
| | | 0.05 | 12.62[c] | 5.67[abc] | 0.209 | 60.76 | 31.87 | 10.02 | 0.461[a] | 78.41 | 74.34 |
| | | 0.10 | 13.69[ab] | 5.90[abc] | 0.208 | 57.93 | 33.11 | 8.96 | 0.300[b] | 77.10 | 81.12 |
| 18 | $Na_2SO_4$ | 0.00 | 13.90[ab] | 6.33[a] | 0.203 | 59.06 | 32.35 | 8.60 | 0.459[a] | 78.92 | 77.81 |
| | | 0.05 | 14.08[a] | 6.50[a] | 0.206 | 60.79 | 29.96 | 9.24 | 0.461[a] | 77.54 | 78.26 |
| | | 0.10 | 13.89[ab] | 6.33[a] | 0.209 | 57.12 | 32.91 | 9.97 | 0.425[a] | 79.50 | 76.91 |
| | $NaHCO_3$ | 0.00 | 13.90[ab] | 6.33[a] | 0.203 | 59.06 | 32.35 | 8.60 | 0.459[a] | 78.92 | 77.81 |
| | | 0.05 | 12.90[bc] | 6.22[ab] | 0.207 | 56.13 | 35.09 | 8.79 | 0.439[a] | 79.91 | 79.63 |
| | | 0.10 | 13.06[abc] | 5.44[bc] | 0.210 | 55.50 | 35.19 | 9.31 | 0.440[a] | 79.18 | 78.15 |
| **SEM[1]** | | | 0.31 | 0.25 | 0.010 | 1.95 | 1.21 | 0.37 | 0.020 | 0.93 | 1.88 |
| **P-value** | | | 0.028 | 0.001 | 0.677 | 0.269 | 0.113 | 0.133 | 0.000 | 0.338 | 0.334 |

*[a–c] Means in a column with different superscripts differ significantly ($P \leq 0.05$).* [1]*Pooled SEM*

Level of non-chloride Na addition% had significantly ($P \le 0.01$) affected YI% (Table 4.a). Quails fed diet containing 0.05% non-chloride Na had significantly higher value of YI%, while, those fed diet containing 0.10% non-chloride Na had significantly lower value (the difference is not significant between quails fed the control diet and those fed 0.05% non-chloride sodium). However, insignificant differences were detected in other egg quality parameters as compared to the control diet.

Interaction due to CP level%, type of non-chloride Na addition and level of non-chloride Na addition% (experimental treatments) had significantly ($P \le 0.05$ and $P \le 0.01$) affected EW(g), YC and YI% (Table 4.b). Quails fed diet containing 18% CP supplemented with 0.05% Na from $Na_2SO_4$ at DEB 208.4 mEq/kg had higher values of EW (g) and YC. Quails fed diet containing 20% CP supplemented with 0.05% Na from $NaHCO_3$ at DEB 233.8 mEq/kg or 18% CP supplemented with 0.05% Na from $Na_2SO_4$ at DEB 208.4 mEq/kg had higher values of YI%. Quails fed diet containing 20% CP supplemented with 0.05% Na from $NaHCO_3$ at DEB 233.8 mEq/kg had lower value of EW (g), and those fed diet containing 20% CP supplemented with 0.05% Na from $Na_2SO_4$ at DEB 234.9 mEq/kg had lower value of YC, however, quails fed diet containing 20% CP supplemented with 0.10% Na from $NaHCO_3$ at DEB 256.2 mEq/kg had lowest value of YI%. However, insignificant differences were detected in other egg quality parameters as compared to the control diet.

These finding verifies with earlier studies of Stephens *et al.* (1974) who reported that no significant differences between NaCl, $NaHCO_3$ and $NaSO_4$ on eggshell quality or laying performance were recognized. On the contrary to our results, Wei *et al.* (2015) and Liu *et al.* (2021) found that hens fed diet supplemented with 0.6% $Na_2SO_4$ had the highest eggshell%, but those fed diet containing 3.0% $Na_2SO_4$ had the lowest value of eggshell%. Furthermore, Hammershøj and Qvist (2001) demonstrated that HU is considered an index of egg freshness and is affected by CP levels in diets as it relates to protein synthesis at the time of egg formation. Heo *et al.* (2023) reported that decreasing dietary CP levels in the diets of laying hens linearly increased the HU at 26 weeks while partially increasing it at 22 weeks.

Similar to the present results, Heo *et al.* (2023) found that YC improved as CP levels decreased in the diets of laying hens. Also, Hassan and Ragab (2007b) found that reducing dietary CP levels improved YI at 61 weeks of age of Hy-Line W-36 laying hens. Liu *et al.* (2021) found that no significant differences were created between treatments due to dietary addition of 0.3 or 0.6% $Na_2SO_4$ for albumen%, YC and HU. Hassan and Ragab (2007a) found that CP% non-significantly affected all external and internal egg quality traits, except YI. Also, Heo *et al.* (2023) noted that dietary CP levels did not affect eggshell strength and eggshell color. On the contrary to our results Wang *et al.* (2020) reported that better eggshell quality can be obtained when NaCl was partly substituted by $Na_2SO_4$ in diets of laying hen with continuing Cl level at 0.10 to 0.15%. However, no differences were observed in other egg quality components between the treatments during the blanket feeding period, except for a temporary quadratic change in YC at 48 weeks of age (Wang *et al.,* 2020).

***Fertility and hatchability%:***

Effect of supplementation of different non-chloride sodium sources and levels with different levels of dietary protein on fertility and hatchability are shown in Tables 5.a and 5.b. It is clear that, the main effects of CP level% had significantly ($P \le 0.05$ and $P \le 0.01$) affected hatchability%, average chick weight (g) and late embryonic mortality%. Quails fed diet containing 18% CP had higher value of hatchability (lower value of average chick weight (g) and late embryonic mortality%) and those fed diet containing 20% CP had higher value of average chick weight (g) and late embryonic mortality% (lower value of hatchability) as shown in Table 5.a.

Type of non-chloride Na addition had insignificantly affected fertility%, hatchability%, average chick weight (g) and early and late embryonic mortality% (Table 5.a). Numerically, quails fed diet containing $NaHCO_3$ had significantly higher values of fertility and hatchability%, while, chicks fed diet containing $Na_2SO_4$ had significantly higher values of average chick weight (g) and early embryonic mortality%.

Level of non-chloride Na addition% had significantly ($P \le 0.01$) affected hatchability% and early embryonic mortality% (Table 5.a). Quails fed diet containing 0.00% non-chloride Na had significantly higher value of early embryonic mortality% (lowest hatchability%), while, those fed diet containing 0.10%

non-chloride Na had significantly higher value of hatchability% (lower value of early embryonic mortality%), the difference is not significant between quails fed diet containing 0.05% non-chloride Na and those fed 0.10% non-chloride Na in hatchability%.

**Table (5.a): Effect of different non-chloride sodium sources and levels with different levels of dietary protein on fertility%, hatchability%, average chick weight,g and embryonic mortality% of laying Japanese quail(main effects).**

| Items | Fertility% | Hatchability% | Average chick weight, g | Embryonic mortality% | |
|---|---|---|---|---|---|
| | | | | Early | Late |
| **Crude protein level %** | | | | | |
| 20 | 92.07 | $67.59^{b}$ | $8.89^{a}$ | 11.91 | $11.51^{a}$ |
| 18 | 89.31 | $84.30^{a}$ | $8.60^{b}$ | 9.96 | $5.74^{b}$ |
| SEM[1] | 1.31 | 2.10 | 0.06 | 1.69 | 1.15 |
| P-value | 0.149 | 0.013 | 0.001 | 0.424 | 0.001 |
| **Type of non-chloride Na addition** | | | | | |
| $Na_2SO_4$ | 90.57 | 82.37 | 8.85 | 10.80 | 6.83 |
| $NaHCO_3$ | 91.36 | 83.57 | 8.72 | 8.02 | 8.41 |
| SEM | 1.39 | 2.04 | 0.07 | 1.67 | 1.08 |
| P-value | 0.696 | 0.685 | 0.203 | 0.254 | 0.316 |
| **Level of non-chloride Na addition%** | | | | | |
| 0.00 | 89.36 | $71.30^{b}$ | 8.60 | $16.85^{a}$ | 11.85 |
| 0.05 | 91.05 | $80.05^{a}$ | 8.82 | $13.35^{a}$ | 6.60 |
| 0.10 | 90.90 | $86.21^{a}$ | 8.74 | $4.99^{b}$ | 8.80 |
| **SEM** | 1.56 | 2.27 | 0.07 | 1.72 | 1.34 |
| **P-value** | 0.789 | 0.002 | 0.179 | 0.000 | 0.081 |

*a–b Means in a column with different superscripts differ significantly ($P \leq 0.05$)* *[1]Pooled SEM.*

However, insignificant differences were detected in fertility%, average chick weight (g) and late embryonic mortality% as compared to the control diet. Numerically, all the dietary levels of non-chloride Na insignificantly surpassed the control in fertility% and average chick weight (g) (lower late embryonic mortality%). On the other hand, quails fed diet containing 0.05% non-chloride Na had insignificantly higher value of fertility% and average chick weight, g (lower late embryonic mortality%).

Interaction due to CP level%, type and level of non-chloride Na addition% (experimental treatments) had significantly ($P \leq 0.01$) affected fertility%, hatchability%, average chick weight (g) and early and late embryonic mortality% (Table 5.b). Quails fed diet containing 20% CP supplemented with 0.05% Na from $NaHCO_3$ at DEB 233.8 mEq/kg had higher value of fertility%, while, those fed diet containing 18% CP at DEB 208.6 mEq/kg supplemented with 0.05% Na from $NaHCO_3$ had lower value. Quails fed diet containing 18% CP supplemented with 0.01% Na from $NaHCO_3$ at DEB 231.0 mEq/kg had higher value of hatchability% (lower values of average chick weight (g) and early embryonic mortality%), while, quails fed diet containing 20% CP at DEB 212.6 mEq/kg with 0.00% $Na_2SO_4$ or $NaHCO_3$ had lower values of hatchability% (higher values of early and late embryonic mortality%). While, quails fed diet containing 18% CP at DEB 187.4 mEq/kg with 0.00% $Na_2SO_4$ or $NaHCO_3$ had lower value of late embryonic mortality%.

Generally, all the dietary treatments significantly ($P \leq 0.01$) surpassed the control in hatchability% (lower values of early and late embryonic mortality%).

As occurred with the current study, Hocking and Bernard (1997) found that no significant differences in fertility (hatching eggs) between males fed diets containing 12 or 16% CP. However, Hocking (1990) noted that the broiler- breeder males fed diets containing 11% CP had higher fertility than those that fed diets containing 16% CP. This may be due to many factors that affect the poultry productivity as the environmental conditions, age and breed which have been identified to effect the growth rate of poultry (Murawska, 2017).

**Table (5.b): Effect of different non-chloride sodium sources and levels with different levels of dietary protein on fertility%, hatchability%, average chick weight, g and embryonic mortality% of laying Japanese quail(treatments).**

| Crude protein level % | Type of non-chloride Na addition | Level of non-chloride Na addition% | Fertility% | Hatchability% | Average chick weight, g | Embryonic mortality% Early | Embryonic mortality% Late |
|---|---|---|---|---|---|---|---|
| 20 | $Na_2SO_4$ | 0.00 | 85.56$^{bcd}$ | 55.56$^{c}$ | 8.70$^{bc}$ | 22.59$^{a}$ | 21.85$^{a}$ |
| | | 0.05 | 96.97$^{a}$ | 74.24$^{b}$ | 9.00$^{ab}$ | 16.36$^{abc}$ | 9.39$^{bc}$ |
| | | 0.10 | 90.20$^{abc}$ | 84.46$^{ab}$ | 8.60$^{c}$ | 8.81$^{cde}$ | 6.73$^{bcd}$ |
| | $NaHCO_3$ | 0.00 | 85.56$^{bcd}$ | 55.56$^{c}$ | 8.70$^{bc}$ | 22.59$^{a}$ | 21.85$^{a}$ |
| | | 0.05 | 97.78$^{a}$ | 88.10$^{a}$ | 8.63$^{c}$ | 7.14$^{cde}$ | 4.76$^{cd}$ |
| | | 0.10 | 92.69$^{abc}$ | 80.71$^{ab}$ | 9.01$^{ab}$ | 5.77$^{de}$ | 13.52$^{b}$ |
| 18 | $Na_2SO_4$ | 0.00 | 93.16$^{abc}$ | 87.04$^{a}$ | 8.50$^{cd}$ | 11.11$^{bcd}$ | 1.85$^{d}$ |
| | | 0.05 | 88.25$^{bcd}$ | 84.52$^{ab}$ | 8.69$^{bc}$ | 10.71$^{bcd}$ | 4.76$^{cd}$ |
| | | 0.10 | 85.00$^{cd}$ | 88.19$^{a}$ | 9.26$^{a}$ | 5.56$^{de}$ | 6.25$^{cd}$ |
| | $NaHCO_3$ | 0.00 | 93.16$^{abc}$ | 87.04$^{a}$ | 8.50$^{cd}$ | 11.11$^{bcd}$ | 1.85$^{d}$ |
| | | 0.05 | 81.21$^{d}$ | 73.33$^{b}$ | 8.97$^{ab}$ | 19.17$^{ab}$ | 7.50$^{bcd}$ |
| | | 0.10 | 93.75$^{ab}$ | 92.16$^{a}$ | 8.25$^{d}$ | 0.00$^{e}$ | 7.84$^{bcd}$ |
| **SEM[1]** | | | 2.54 | 3.61 | 0.11 | 3.22 | 2.15 |
| **P-value** | | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

*$^{a–e}$ Means in a column with different superscripts differ significantly ($P\leq0.05$)* [1]*Pooled SEM*

***Economical efficiency (EEf):***

Values of economical and relative efficiency during the laying period (from 46 to 88 days) were improved in quails fed all experimental diets except, those fed diet containing 20% CP plus any level of $Na_2SO_4$ supplementation, as compared to those fed the control diet and other experimental diets (Table 6). Hens fed diet containing 18% CP supplemented with 0.10% Na from $NaHCO_3$ at DEB 231.0 mEq/kg had the best economical and relative efficiency values being 0.8739 and 161.06%, respectively, followed by hens fed diet containing 18% CP supplemented with 0.10% Na from $Na_2SO_4$ at DEB 230.7 mEq/kg being, 0.8540 and 157.39%, respectively, then hens fed diet containing 18% CP at DEB 187.4 mEq/kg, followed by hens fed diet containing 18% CP supplemented with 0.05% Na from $NaHCO_3$ at DEB 208.6 mEq/kg.

## CONCLUSION

It can be recommending the diet with 18% CP supplemented with 0.10% Na from $NaHCO_3$ at DEB 231.0 mEq/kg for laying Japanese quail, without negative effect on the productive and reproductive performance of the quails and/or the economic efficiency. Further studies are required to study the effect of applying dies with more quantities of $NaHCO_3$ (more than those added in the present work) for feeding laying Japanese quail and the possibility to consume beneficial feed additives to reduce cost of production and environmental pollution. The benefits of DEB necessity should be considered carefully, and further studies are needed to estimate DEB benefits especially in low CP diets with added synthetic EAA.

In general, from present study, low dietary CP can be used without harmfully affecting the performance of layingJapanese quail. Moreover, it is considered beneficial as manifested by increased EP, hatchability and economic efficiency in laying Japanese quail.

**Table (6): Effect of different non-chloride sodium sources and levels with different levels of dietary protein on economic efficiency of laying Japanese quail (EEf).**

| Items | Crude protein level % | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | | | | | | 18 | | | | | |
| | Type of non-chloride Na addition | | | | | | | | | | | |
| | $Na_2SO_4$ | | | $NaHCO_3$ | | | $Na_2SO_4$ | | | $NaHCO_3$ | | |
| | Level of non-chloride Na addition % | | | | | | | | | | | |
| | **0.00** | **0.05** | **0.10** | **0.00** | **0.05** | **0.10** | **0.00** | **0.05** | **0.10** | **0.00** | **0.05** | **0.10** |
| **a** | 30.34 | 30.43 | 30.36 | 30.34 | 30.73 | 33.53 | 33.24 | 30.99 | 34.2 | 33.24 | 31.57 | 35.63 |
| **b** | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 |
| **c = a × b** | 53.10 | 53.25 | 53.13 | 53.10 | 53.78 | 58.68 | 58.17 | 54.23 | 59.85 | 58.17 | 55.25 | 62.35 |
| **d** | 43.69 | 43.87 | 45.11 | 43.69 | 42.72 | 44.2 | 44.36 | 45.08 | 43.9 | 44.36 | 42.57 | 45.17 |
| **e** | 1.835 | 1.843 | 1.895 | 1.835 | 1.794 | 1.856 | 1.863 | 1.893 | 1.844 | 1.863 | 1.788 | 1.897 |
| **f** | 18.76 | 18.84 | 18.92 | 18.76 | 18.85 | 18.95 | 17.34 | 17.42 | 17.51 | 17.34 | 17.44 | 17.54 |
| **g = e × f** | 34.42 | 34.72 | 35.84 | 34.42 | 33.82 | 35.18 | 32.31 | 32.98 | 32.28 | 32.31 | 31.17 | 33.27 |
| **h = c - g** | 18.68 | 18.53 | 17.29 | 18.68 | 19.95 | 23.50 | 25.86 | 21.25 | 27.57 | 25.86 | 24.07 | 29.08 |
| **E.E.f. = h / g** | 0.5426 | 0.5338 | 0.4824 | 0.5426 | 0.5900 | 0.6680 | 0.8005 | 0.6442 | 0.8540 | 0.8005 | 0.7722 | 0.8739 |
| **Relative (E.E.f.)** | 100.00 | 98.38 | 88.91 | 100.00 | 108.73 | 123.12 | 147.52 | 118.73 | 157.39 | 147.52 | 142.31 | 161.06 |

*a ……. egg number/hen.*

*b …… price/ egg (L.E.), according to the local market price.*

*c ……. total price of eggs /hen (L.E.).*

*d……..daily feed intake (g).*

*e…….. total feed intake/hen, kg = (FI (g/hen/day) /1000) X 42 days ( Experiment period, days ).*

*f……..price/ Kg feed (L.E.), based on average price of diets.*

*g……..total feed cost/hen (L.E.)*

*h……..net revenue / hen (L.E.)*

*E.E.f. .....economical efficiency(net revenue per unit feed cost).*

*Relative (E.E.f.)……assuming that economical efficiency of the control groups equals 100.*

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## تأثير إضافة مصادر ومستويات مختلفة من الصوديوم غير الكلوريدي على أداء طيور السمان الياباني البياض التي تتغذى على علائق مختلفة في محتواها من البروتين

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أجريت التجربة في محطة بحوث الدواجن، العزب، الفيوم، مصر، لتقييم التأثيرات الغذائية لمكملات مصادر الصوديوم غير الكلوريد المختلفة ومستوياتها مع مستويات مختلفة من البروتين في العليقة على الأداء الإنتاجي والتناسلي للسمان الياباني البياض. تم تصميم التجربة في ترتيب عاملي 2×2 ×3 للمعاملات مع مستوى البروتين الخام ونوع ومستوى إضافة الصوديوم غير الكلوريدي كتأثيرات رئيسية. إستخدمت علائق تتكون أساسا من الذرة وكسب فول الصويا بمستويين من البروتين الخام (20 و 18%)، ونوعين من إضافة الصوديوم غير الكلوريدي (كبريتات الصوديوم أو بيكربونات الصوديوم) وثلاثة مستويات من إضافة الصوديوم غير الكلوريدي (0,00 و0,05 و0,10٪). ووفقًا للإحتياجات الغذائية لـ NRC (1994)، كانت المستويات الغذائية الدنيا للصوديوم لجميع المعاملات هي 0.15%، وتم ضبط مستوى الكلوريد لجميع العلائق ليكون 0,25٪ والتي تم توفيرها من خلال إضافة 0,35٪ كلوريد الصوديوم لتغطية الاحتياجات الغذائية. تم رفع مستوى الصوديوم فوق الحد الأدنى من المتطلبات عن طريق إضافة كبريتات الصوديوم أو كربونات الصوديوم. تم تغذية هذه العلائق من عمر 39 إلى 88 يومًا ، وتم تعديل مستويات الأحماض الأمينية عن طريق إضافة المثيونين والليسين.

**يمكن تلخيص اهم النتائج التي تم الحصول عليها فيما يلي:**

كان للسمان الذي تغذى على عليقة تحتوي على 18% بروتين قيم أعلى من عدد البيض ونسبة انتاج البيض وأفضل قيمة لكفاءة تحويل البروتين. سجل السمان الذي تغذى على عليقة تحتوي على بيكربونات الصوديوم أفضل القيم المعنوية لكفاءة تحويل الغذاء والطاقة . كان للسمان الذي تغذى على عليقة تحتوي على 18% بروتين مع 0,05% صوديوم من كبريتات الصوديوم على اتزان معدني 208,4 مللي مكافئ/كجم عليقة أعلى القيم لوزن البيض (جم) ولون الصفار. أظهر السمان المغذى على عليقة تحتوي على 20% بروتين مع 0,05% صوديوم من بيكربونات الصوديوم على اتزان معدني 233,8 مللي مكافئ/كجم عليقة أو 18% بروتين مع 0,05% صوديوم من كبريتات الصوديوم على اتزان معدني 208,4 مللي مكافئ/كجم عليقة أعلى القيم لدليل الصفار%.

كان للسمان الذي تغذى على عليقة تحتوي على 18% بروتين أعلى قيمة لنسبة الفقس (أقل قيمة لمتوسط وزن الكتاكيت (جم) ونسبة النفوق الجنيني المتأخر) وتلك التي تغذت على عليقة تحتوي على 20% بروتين أعلى قيمة لمتوسط وزن الكتاكيت (جم) ونسبة النفوق الجنيني المتأخر. كان للسمان الذي تغذى على عليقة تحتوي على 0,00% صوديوم غير كلوريدي أعلى قيمة معنويا لنسبة النفوق الجنيني المبكر (اقل نسبة فقس)، في حين أن تلك التي تغذت على عليقة تحتوي على 0,10% صوديوم غير كلوريدي أعلى قيمة معنوية لنسبة الفقس (أقل قيمة لنسبة النفوق الجنيني المبكر). وكانت نسبة الخصوبة أعلى بالنسبة للسمان الذي تغذى على علائق تحتوي على 20% بروتين مع 0,05% صوديوم من كبريتات الصوديوم وكانت نسبة الفقس أعلى بالنسبة للسمان الذي تغذى على علائق تحتوي على 18% بروتين مع 0,10% صوديوم من بيكربونات الصوديوم على اتزان معدني 231,0 مللي مكافئ/كجم عليقة (قيم أقل لمتوسط وزن الكتاكيت (جم) ونسبة النفوق الجنيني المبكر) .

وبشكل عام، تفوقت جميع المعاملات التجريبية معنوياً على المجموعة الضابطة في نسبة الفقس. بينما كانت نسبة النفوق الجنيني المبكر والمتأخر بالنسبة للسمان الذي تغذى على علائق تحتوي على اتزان معدني 187,4 مللي مكافئ/كجم مع 18% بروتين ، 0,00% كبريتات أو بيكربونات صوديوم (قيم أقل لنسبة النفوق الجنيني المبكر والمتأخر).

تحسنت قيم الكفاءة الاقتصادية والنسبية خلال فترة وضع البيض (من 46 إلى 88 يومًا) في السمان الذي تغذى على جميع المعاملات التجريبية باستثناء تلك التي تغذت على عليقة تحتوي على 20% بروتين مع إضافة أي مستويات من الكبريتات، مقارنة بتلك التي تغذت على عليقة المقارنة والمعاملات التجريبية الأخرى. كان للدجاج الذي تغذى على عليقة تحتوي على 18% بروتين مع 0,10% صوديوم من بيكربونات الصوديوم واتزان معدني 231,0 مللي مكافئ/كجم عليقة أفضل قيم للكفاءة الاقتصادية والنسبية، تليها الدجاجات التي تغذت على عليقة تحتوي على 18% بروتين مع 0,10% صوديوم من كبريتات الصوديوم واتزان معدني 230.7 مللي مكافئ/كجم عليقة ، ثم الدجاجات التي تغذت على عليقة تحتوي على 18% بروتين واتزان معدني 187,4 مللي مكافئ/كجم عليقة ، تليها الدجاجات التي تغذت على عليقة تحتوي على 18% بروتين مع 0,05 %صوديوم من بيكربونات الصوديوم واتزان معدني 208,6 مللي مكافئ/كجم عليقة .