

DIETARY HYDROPONIC WHEAT SPROUTS IMPROVE FEED EFFICIENCY AND EGG PRODUCTION IN LAYING JAPANESE QUAIL WITHOUT ALTERING EGG QUALITY

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Abstract

Food security has become a major concern in recent decades, largely due to the growing competition between human and animal food needs. This challenge has prompted the search for alternative, affordable feed resources that do not compromise human food supplies. One promising approach is hydroponic cultivation, where grains and legumes are grown in water-based systems without soil. Hydroponically sprouted grains provide enhanced protein levels and improved bioavailability of both macro- and micronutrients, making them a valuable feed supplement. Their higher protein content, demonstrated in several studies, suggests that they could serve as a cost-effective replacement for expensive feed ingredients such as soybean. For this purpose, this study was performed to evaluate the effects of hydroponic wheat sprouts on the laying performance of Japanese quail. A total of 600 Japanese quails (510 hens and 90 males) at 8 weeks of age were randomly assigned to five treatment groups in a completely randomized design (CRD). Each treatment consisted of 6 replicates, with 17 hens and 3 males per replicate (20 birds per cage). All treatments were provided a basal diet in a common feeder. In addition, Treatments 2, 3, 4, and 5 were offered fresh hydroponic wheat sprouts (HWS) in a separate feeder at respective inclusion levels of 5, 10, 15, and 20 g HWS per kg of total basal diet offered daily. The control group (Treatment 1) received only the basal diet without sprouts. The experiment lasted for 49 days. The current research found that feeding HWS to laying Japanese quail had a significant ($p < 0.05$) impact on feed intake and FCR. However, the weight across all the treatments remained the same ($p > 0.05$). Furthermore, it was evident that the supplemented groups showed more egg production than the control, and the highest egg collection was recorded in T5, where HWS levels were 20 g/kg of basal diet ($p < 0.05$). The results of hatchability and fertility showed no significance compared to the control ($p > 0.05$). Furthermore, egg morphology parameters such as egg weight, egg mass and egg shape index were not significantly different ($p > 0.05$) from those of the control and showed no effects when supplemented with HWS. Eggshell quality, albumen and yolk quality were not affected by supplementation with HWS ($p > 0.05$). In terms of HWS supplementation, the research studied limited parameters, and further research is needed to deeply explore the impact of supplementation on Japanese quails.



Graphical abstract for dietary hydroponic wheat sprouts improve feed efficiency and egg production in laying Japanese quail without altering egg quality

INTRODUCTION

The human population, which was 7.9 billion in 2022, is expected to reach 8.6 billion, with an average growth rate of 9.8%. Most of this population is centered in developing countries (OECD & FAO, 2022). With this significant increase, the demand for total global food is expected to reach 56% by 2050 (van Dijk, Morley, Rau, & Saghai, 2021). Animal-derived products and byproducts are an integral part of food security (Godfray, Aveyard, Garnett, Hall,

Key, Lorimer, Pierrehumbert, Scarborough, Springmann, & Jebb, 2018). According to the FAO (2012), 13% of calories and 28% of protein consumed derive from livestock, accounting for 40% of the total cost of agricultural produce (McLeod, 2011). Pakistan's poultry bird population is estimated to reach 2.26 billion, including 2.17 billion broiler birds, 83.9 million layers, and other birds of economic importance. The data show that 2.6 million tons of poultry meat were

produced during 2024-25, including 2.4 million tons of broiler meat and 137,720 tons of domestic chicken meat. Egg production was 26.7 billion, including 21.9 billion commercial and 4.8 billion domestic eggs (Economic Survey of Pakistan, 2024-25). Per capita egg consumption in Pakistan is 51%, which is much lower than that in developed countries, where it is 300 eggs per year (Hussain *et al.*, 2024).

The quail is a wild domesticated bird found in most parts of the earth, but the Middle East is believed to be its origin, from where it spread to the other parts of the planet. Quail has been domesticated and transformed from a wild bird to a life completely controlled by humans, who control its breeding, habitat, food, and reproduction. Quail is a small bird that is slightly larger than a pigeon; its weight changes from species to species, ranging from 160 to 250 grams (Cahyadi *et al.*, 2019). The first ever genetic selection program focused on modifying Japanese quails (*Coturnix japonica*) for efficient egg production dates back to 1907 in Japan. The process of domestication and genetic selection led to changes in bird morphology, behavior, productivity, egg weight, and body weight. Quails serve two functions

because they produce two types of products. The birds demonstrate exceptional egg-laying abilities because they produce between 200 and 300 eggs each year. The female quail begins her egg-laying activities after she reaches 35 to 42 days of age (Abdul-Majeed & Al-Krad, 2023), and she becomes sexually mature after she turns 50 days old. The production process experiences a sudden rise that achieves maximum output between 12 and 15 weeks of life (Abdul-Majeed & Al-Krad, 2023; Ratriyanto *et al.*, 2018).

Feed efficiency (FE) represents a key factor in poultry farming because feed expenses constitute 60 to 70% of total costs throughout the entire layer of production systems (Willems *et al.*, 2013). The traditional method of poultry feeding depends on corn and soybean meal, which creates both supply and demand problems while delivering multiple sustainability problems that include deforestation, biodiversity decrease and major

greenhouse gas emissions from production and transportation (Siddiqui *et al.*, 2024).

Given that feed accounts for 60-70 % of layer-production costs and conventional corn-soybean diets raise not only cost but also sustainability and availability concerns, exploring cost-effective substitute feedstuffs that lessen dependence on traditional ingredients and support poultry health without antibiotic growth promoters is a strategic next step. The use of diverse, novel and substitute feed ingredients, which could be legume waste, oilseed meals, fruit waste, leaves or plants and other agricultural by/coproducts, but are not limited to just these in poultry diets, offers promising ways to reduce the current challenges in poultry industries (Seidavi *et al.*, 2021). There is one recent trend that is becoming popular among farmers: the use of hydroponic grain sprouts as feed, which is not only cost-effective, easy to grow, and sustainable but also high in nutrients. This method of growing seed sprouts involves producing nutrient-rich feed in a controlled environment without soil, using minimal water and space (Rajendran *et al.*, 2024).

The cultivation of hydroponic fodder offers a novel method to alleviate feed deficits in the poultry and livestock sector. This technique cultivates nutrient-dense forage in a soil-free system, relying on water and precisely managed surroundings to boost growth productivity, and is becoming increasingly favoured because it can supply fresh, good quality forage year-round, unaffected by weather or seasonal cycles (Dutta *et al.*, 2023). The process of sprouting grains leads to changes in their chemical and physical properties, which results in the conversion of complex substances into simpler components and the decreased presence of antinutritional elements, which simultaneously improves the overall nutritional value of the grains (Sugiharto, 2021). Wheat protein content varies greatly depending on factors such as cultivar and growing conditions, with nitrogen fertilization playing a crucial role, especially during the heading stage, influencing the final protein levels. (Duncan *et al.*, 2018).

The crude protein content of HWS increases during sprouting due to the loss of dry matter resulting from the hydrolysis and metabolism

of carbohydrates and fats as energy sources for microorganisms. Even when the crude protein content does not increase, germination enhances the biological value of proteins. The activation of proteases during seed germination breaks down complex proteins into simple peptides, albumens, globulins, and amino acids (Chavan, Kadam, & Beuchat, 1989).

Limited research has explored the use of hydroponically sprouted wheat for laying performance of quail in Pakistan. Existing studies mainly address ruminants and broiler chickens, leaving quail nutrition underexplored. Because quails have distinct dietary needs, specific investigations are required to assess how Hydroponic Wheat Sprouts influence their growth, feed consumption, laying performance and overall output. Additionally, the economic practicality of substituting commercial feed with hydroponic wheat sprouts in quail production remains an open question that needs further study. Therefore, the present study will examine the effects of feeding hydroponic wheat sprouts (HWS) on quail egg production performance (egg number, egg weight, and egg mass), assess the influence on internal and external egg quality parameters (Haugh unit, shell thickness, yolk index), and analyse the effects on reproductive performance (fertility and hatchability rates).

Materials and Methods

Trial Location and Duration

The experiment was conducted at the Poultry Research Unit, Department of Animal Sciences, College of Agriculture, University of Sargodha, Sargodha, Pakistan. The trial lasted for 8 weeks, from 8 to 15 weeks of age of the birds, covering the early to peak laying phase.

Preparation of Hydroponic Wheat Sprouts (HWS)

Wheat seeds (*Triticum aestivum*) were procured from the Fodder Research Institute, Sargodha. Hydroponic sprouting was carried out in the hydroponic facility of the College of Agriculture, University of Sargodha. Cleaned galvanized trays (22" × 14" × 2.5") were sterilized with a mild bleach solution, rinsed thoroughly, and sun-dried. Wheat seeds were washed 3-5 times with tap water to remove dust

and debris; floating and defective seeds were discarded. To prevent fungal contamination, seeds were soaked in tap water containing 5-10 drops of bleach solution per liter for 15 minutes, followed by thorough rinsing. Seeds were then soaked in clean water for 3-4 hours. After soaking, seeds were drained and kept in moist gunny bags for 24 hours for presprouting. They were then spread uniformly on prepared trays. Trays were kept in the dark by covering with moist gunny bags for 24 h. During this period, seeds were watered three times daily with 250-350 mL tap water per tray to maintain moisture. After 24 h, the covers were removed, and watering continued until harvest. Sprouts were harvested at 7 days of growth to ensure tender, nutrient-rich biomass. The harvested wheat sprouts, dosed at a calculated rate, were then offered alongside the basal quail diet.

Preparation of Research Facility

The environmentally controlled quail shed was thoroughly cleaned and disinfected before the arrival of the birds. All cages, feeders, and drinkers were washed with detergent, rinsed, and fumigated with a formalin and potassium permanganate mixture (35 mL formalin + 17.5 g KMnO₄ per 100 ft²) for 24 hours. After fumigation, the house was aerated, and the equipment was rinsed with clean water before use.

Experimental Birds and Housing

A total of 600 Japanese quails (510 hens and 90 males) at 8 weeks of age were acquired from the poultry research and development center of the College of Agriculture, University of Sargodha. The birds were healthy, vaccinated, and of uniform weight. They were randomly assigned to five treatment groups in a completely randomized design (CRD). Each treatment consisted of 6 replicates, with 17 hens and 3 males per replicate (20 birds per cage). Cages measured 90 × 40 × 40 cm per replicate and were equipped with separate feeders and drinkers. The birds had ad libitum access to feed and water throughout the trial. Lighting was provided for 14 hours per day initially and increased by 15 minutes each week until reaching 16 hours of light by the end of the trial to stimulate laying performance (Table 1).

Experimental Diets and Treatments

All treatments were provided a basal diet in a common feeder. In addition, Treatments 2, 3, 4, and 5 were offered fresh hydroponic wheat sprouts (HWS) on a dry matter basis in a separate feeder at respective inclusion levels of

5, 10, 15, and 20 g HWS per kg of total basal diet offered daily. The control group (Treatment 1) received only the basal diet without sprouts (Table 2).

Table 1: Experimental setup

Sr. No	Treatment	HWS Level (g/kg feed)	Description
1	T1	0	Control
2	T2	5	Low level
3	T3	10	Medium level
4	T4	15	High level
5	T5	20	Very high level

Table 2: Ingredient and nutrient composition of the basal diet for laying quails

Ingredients	% in Diet Maize
Corn	62
Soybean meal	23.5
Canola meal	1
Calcium carbonate	2
Limestone	8.1
Oil	1.2
DCP*	1
Soda	0.27
Premix**	0.4
Lysine HCL	0.02
Salt	0.2
DL-Methionine	0.21
Threonine	0.1
Calculated nutrients	
ME (kcal/kg)	2850
Crude Protein%	18.5
Dig. Lysine%	0.78
Crude fibre %	2.47
Calcium%	4.42
Available phosphorus %	0.3
Sodium %	0.18
Chloride %	0.20
Potassium %	0.71

*DCP stands for dicalcium phosphate,

**Premix provided per kg diet: Vit A 12,000 IU; Vit D3 3000 IU; Vit E 80 mg; Vit K 3 mg; Thiamine 3 mg; Riboflavin 8 mg; Niacin 60 mg; Pantothenic acid 15 mg; Pyridoxing 4 mg; Folic acid 2 mg; Vit B12 0.02 mg; Choline 600 mg; Zn 80 mg; Fe 60 mg; Cu 10 mg; Mn 80 mg; I mg; Se 0.2 mg.

Proximate Analysis of Hydroponic Wheat Sprouts

Fresh hydroponic wheat sprouts (HWS) were harvested after a 7-day growth cycle from the hydroponic production unit. Spring wheat (*Triticum aestivum* L.) seeds were used, with a seeding density of approximately $1.72 \text{ kg}\cdot\text{m}^{-2}$ on a dry seed basis. At the end of each cycle, representative samples were taken from the

growth trays. Fresh samples were weighed immediately, so moisture loss could be calculated without delay. The samples were then oven dried until constant mass, ground through a 1 mm sieve and kept in airtight containers until additional analysis. Every analysis was performed following the respective ISO and AOAC standards listed below.

Determination of Moisture and Dry Matter

Dry matter (DM) content was measured gravimetrically, according to the LST ISO 712:2010 standard. The mean dry matter content of the HWS in this trial was 13.82%, while the related moisture content was 86.18% (which was calculated by difference). These results show the average moisture and solid fractions of the sprouts as they were fed to the quails.

Determination of Crude Protein

The crude protein CP content was measured using the Kjeldahl method, mainly for total nitrogen estimation, using ISO 20483:2006. Then, crude protein was calculated as $CP(\%) = \text{Nitrogen}(\%) \times 6.25$. Overall, the mean CP for the HWS was 18.26% on a dry matter basis.

Determination of Ether Extract

Ether extract (EE) was measured via Soxhlet extraction using petroleum ether as the solvent, and we followed AOAC 920.39-1920/LST ISO 1443. The mean EE content in the HWS reached 2.37% when set on a dry-matter basis. This lipid fraction remained fairly steady from batch to batch, suggesting stable biological regulation in early-stage wheat sprouts.

Determination of Crude Fibres

The crude fibre (CF) content was calculated using sequential acid alkali digestion following ISO 6865:2000. The average crude fibre content in the HWS was 3.22% on a dry matter basis. This structural carbohydrate fraction supports the dietary fibre that ends up being supplied to the birds, so it matters more than it actually sounds.

Determination of Ash Content

The total ash content (mineral residue) was determined by burning dried samples in a muffle furnace following ISO 5984:2022(E). The mean ash content of the HWS was 10.29% on a dry-matter basis, indicating a rich mineral profile that can enhance eggshell quality and overall bird health.

Calculation of Nitrogen-Free Extract (NFE)

The nitrogen-free extract (NFE), which represents the soluble carbohydrate fraction, was measured by the formula: $NFE(\%) = 100 - (CP\% + EE\% + CF\% + \text{Ash}\%)$. Using the mean values: $NFE = 100 - (18.26 + 2.37 + 3.22 + 10.29) = 65.86\%$. This fraction provides the primary energy source derived from the sprout carbohydrates.

Analytical Replication

All chemical analyses for qualitative parameters (CP, EE, CF, Ash) were performed in triplicate per sample batch. The results are expressed as the mean values, with analytical precision maintained throughout the measurements (Table 3).

Table 3: Proximate analysis of Hydroponic Wheat Sprouts (HWS) at different dietary inclusion levels

Parameter	T2	T3	T4	T5
HWS inclusion (g/kg feed)	5	10	15	20
Dry matter (g/kg feed)	0.69	1.38	2.07	2.76
Moisture (g/kg feed)	4.31	8.62	12.93	17.24
Crude protein (g/kg feed)	0.13	0.25	0.38	0.51
Ether extract (g/kg feed)	0.02	0.03	0.05	0.07
Crude fibre (g/kg feed)	0.02	0.04	0.07	0.09
Ash (g/kg feed)	0.07	0.13	0.22	0.29
Nitrogen free extract (g/kg feed)	0.46	0.91	1.37	1.83

Note: Dry matter and moisture values are shown on an as-fed basis (i.e., the actual weight of solids and water contributed by the fresh sprouts). All nutritional parameters (CP, EE, CF, Ash, NFE) are calculated from the

dry-matter fraction and reported as g per kg of complete feed (as-fed diet). Calculations are based on the average proximate composition of the HWS: DM = 13.82%, CP = 18.26%, EE = 2.37%, CF = 3.22%, Ash = 10.29%, and NFE

= 65.86% (all on DM basis). Values are rounded to two decimal places.

Growth parameters

Initial body weight was recorded at 8 weeks of age. Birds were weighed individually at weekly intervals using a digital balance (± 0.1 g). Final body weight was recorded at 15 weeks of age. Feed offered and refused was recorded daily for each replicate. Weekly feed intake (g/bird/day) was calculated as:

$$\text{Feed intake} = \frac{\text{Feed offered} - \text{Feed refused}}{\text{Number of bird} \times \text{days}}$$

Feed conversion ratio (FCR)

The FCR was calculated weekly as follows:

$$\text{FCR} = \frac{\text{Total feed intake (g)}}{\text{Total egg mass produced (g)}}$$

Laying performance parameters

Eggs were collected twice daily, first in the morning and later in the evening. Hen-day egg production was calculated as follows:

$$\text{Hen day production} = \left(\frac{\text{Total eggs laid}}{\text{Number of hen} \times \text{days}} \right)$$

Egg mass was calculated as follows:

$$\text{Egg mass} = \text{Number of eggs} \times \text{Average egg weight}$$

Fertility and Hatchability

A total of 900 eggs (30 from each replicate) were collected during the third week of the trial and stored at 14°C and 15-16% relative humidity until incubation. Once eggs were collected, they were then incubated at 37.8°C and 60% relative humidity until chicks hatched. After the hatching of all the chicks, all unhatched eggs were cracked to identify the unfertilized eggs to calculate fertility and hatchability percentages using the following formulas:

$$\text{Fertility} = \frac{\text{fertile eggs}}{\text{total incubated eggs}} \times 100$$

$$\text{Hatchability} = \frac{\text{number of hatched chicks}}{\text{total incubated eggs}} \times 100$$

Egg Quality Parameters

Every week, 30 eggs per treatment (5 eggs per replicate) were randomly selected for quality assessment. Eggs were weighed individually

using a digital balance (± 0.01 g). Egg mass was calculated as follows:

$$\text{Egg mass} = \text{Number of eggs} \times \text{Average egg weight}$$

Egg Shape Index

Egg length and width were measured using a digital Vernier calliper (± 0.01 mm). The shape index was calculated as:

$$\text{Shape index} = \left(\frac{\text{Length (mm)}}{\text{Width (mm)}} \right) \times 100$$

Egg shell quality parameters

The shells were washed, dried at 65 °C for 24 h, and weighed using an electronic weighing balance. The shell percentage was calculated as follows:

$$\text{Shell weight \%} = \frac{\text{Shell weight (g)}}{\text{Egg weight (g)}} \times 100$$

Wet eggshell (g)

A damp egg is one that has not been stored properly. Each egg was cracked on a sheet of glass. The eggshell was wiped off with a tissue towel before being placed on an automated scale for measurement.

Dry eggshell (g)

After drying the eggshell in an oven at 105°C for at least 24 hours, we measured each one precisely.

Shell thickness

The shell thickness (mm) was measured at three points, the blunt end, equator and sharp end, using a micrometer screw gauge after removing the shell membrane. The average was recorded.

Albumen quality parameters

A digital Haugh tester was used to measure the albumen's height in millimeters. The entire height of the albumen was determined from the thick albumen's middle section. The egg white was separated from the yolk with the help of a spoon. Then, with the help of a weighing scale, albumen weight was measured. The albumen ratio shows the proportion of egg white in a whole egg. The formula calculated the albumen ratio.

$$\frac{\text{egg white}}{\text{whole egg weight}} \times 100$$

The Haugh unit was calculated by using the following formula:

$$HU = 100 \times \log (H+7.57-1.7 \times W^{0.37})$$

where

H = height

W = weight

Yolk quality parameters

An egg was carefully cracked into a bowl, being mindful not to break the yolk. Submerge a ruler or calliper with millimeter (mm) markings vertically into the egg white, up to the yolk's surface, without piercing it. Read the measurement, which represents the yolk's height in millimeters (mm). A spoon was used to separate the egg yolk from the albumen. The separated yolk was then measured on a weighing scale. To determine the diameter of an egg's yolk, an egg was carefully broken into a dish while being careful not to break the yolk. Then, by laying the calliper horizontally over the broadest area of the yolk, making sure it was perpendicular to the long axis of the yolk, the egg yolk was measured in millimeters (mm) where the calliper crossed the surface of the yolk. The yolk proportion in the whole egg is represented by the yolk ratio. The yolk ratio was calculated by using the following formula.

$$\frac{\text{Egg yolk weight}}{\text{whole egg weight}} \times 100$$

Yolk index

The yolk index was calculated through the following equation:

$$I = YH/YD$$

where YH = Yolk height

YD = Yolk diameter

Statistical Analysis

Data were analysed using one-way analysis of variance (ANOVA) with appropriate statistical software in a completely randomized design. Treatment means were compared to identify significant differences between groups. Significant differences between treatment means were isolated using Duncan's Multiple Range test and judged significant when the P value was less than

Results and Discussion

Growth characteristics

Body weight of Japanese quails ($p > 0.05$) was not affected when HWS was included as a part of the diet of the laying quails. The supplementation with 10 g/kg and 15 g/kg and 20 g/kg of HWS significantly affected the daily Average FI and the total FI ($p < 0.05$) as shown in Table 4.1. The F.C.R in the HWS supplemented groups was better than that of the control group and the best F.C.R. was obtained in T5 ($p < 0.05$). The results of this study are similar with Abouelezz et al. (2019) which used Japanese quail as a model to be laid on HWS rather than on hydroponic barley sprouts (HBS) (Table 4).

The conclusion of this study corroborates with the findings of Sultana et al. (2022) who also reported that broiler chickens on HWS with 50 g/kg improved their FCR and WG without affecting FI. Similarly, the findings of the current study corroborate the findings of Ali et al. (2019) which reported similar findings on FCR. There was also an improved weight gain with 5% HWS inclusion in diet when compared to the control, but no effect was seen on FI.

A slight difference in weight gain was observed among the supplemented groups but the difference was not significant with the control group (Table 4). Optimized weight gain shown by Alinaitwe et al. (2019) when 25% hydroponic barley fed to growing Kuroiler birds differed from our results which may be because of difference in bird species or different nutritional profile of hydroponic barley.

As the level of HWS in the diet was raised, the results of our study indicate that as these levels increased, so did the average feed intake throughout the trial. This may be because the HWS is made up of higher fibre. The data show that the mean feed intake for the control group (quails not fed the HWS supplement) was higher than for the other four treatments. This may be due to the relatively high level of fibre and moisture in the HWS, which can fill the quails' gut and thus decrease the voluntary FI of the quails.

These findings are consistent with Abouelezz et al. (2019) study of laying Japanese quails fed 15% hydroponic barley sprouts plus a restricted

diet (15% less than the control) that showed reduced weight gain compared to the control and similar reductions in FI, but no effect of the hydroponic barley sprouts with restricted diet on the FCR was seen. Opposing to Baye et al. (2024) who reported improved weight gain, FI and FCR of Cobb-500 broilers fed 10% hydroponic barley sprouts and basal feed, the

results of our study revealed that broilers did not get better performance. The increased BWG in dairy cows reported by Zang et al. (2024) when 10% of the total conventional concentrates was replaced with HWS may be due to the ability of ruminants to digest fibre better than nonruminants.

Table 4: Effects of hydroponic wheat sprouts on growth parameters of Japanese quail

Parameters	T1	T2	T3	T4	T5	SEM
Body weight (g)	219	217.33	218.42	217.83	220.67	0.9893
Average daily feed intake (g/bird/day)	26.057 ^a	23.768 ^b	23.845 ^b	23.848 ^b	22.098 ^c	0.1590
Feed intake per bird (49 days) (g)	1276.8 ^a	1164.7 ^b	1168.4 ^b	1168.4 ^b	1082.8 ^c	7.7990
FCR (g fed intake/g egg mass)	2.9583 ^a	2.6750 ^b	2.7000 ^b	2.6750 ^b	2.4667 ^c	0.0220

Treatments T1, T2, T3, T4, and T5 indicate diets containing 0, 5, 10, 15 and 20 g/kg HWS of basal diet, respectively, SEM= Standard error of the mean Means sharing different superscripts (a, b, c) differ significantly ($p < 0.05$)

Laying characteristics

Dietary inclusion of varying levels of HWS in the quail diet showed significant effects on egg production ($p < 0.05$), as shown in Table 5. The results of fertility and hatchability were efficient in the supplemented groups but were not statistically significant ($p > 0.05$). Egg production, fertility, and hatchability are all parameters on which a bird's laying performance is judged. As the level of HWS in the diet increased, egg production increased. The best results regarding egg production percentage were recorded in T3 and T4, where HWS inclusion was 10 g/kg and 15 g/kg of the basal diet, respectively. The egg production of T5 outperformed the rest of the groups, and the lowest percentage was recorded in the control. The highest hatchability percentage was recorded in T5, and the rest of the treatments showed similar results (Table 5).

Similar results in terms of fertility were noted. The results of this study are similar to those of Abouelezz et al. (2019), where the egg laying rate increased when hydroponic barley sprouts were added to the diet of laying quail. The study

showed that fertility and hatchability results also improved with the addition of HBS to the diet of laying quail.

The results of our study are opposite to the study of Hibebo and Heliso (2025), where no results on egg production were seen when 5% HWS of the commercial feed was added to the dual-purpose chickens. The difference in the outcomes of both studies can be attributed to the fact that the mentioned study was on dual-purpose chickens, while our study was on laying quails; the results may be different because of the different physiological needs of both species. However, in that same study, 5% HBS showed significant effects on egg production when added to the diet of laying chickens. Another study by Khaziev et al. (2021) found that dietary inclusion of 25-30% hydroponic green herbage in the parent flock geese's diet considerably improved egg production and hatchability, which aligns with our research.

The results of the study by Sathiaganeshan et al. (2024) are contradictory to our research; the study found that dietary inclusion of varying levels of wheatgrass fodder improves weight gain and FI in growing Japanese quail. However, the same study showed improved FCR, which aligns with our research. The difference between the two studies can be explained by the fact that the study used wheatgrass fodder harvested after the 8th day of

sprouting, whereas our study used whole sprouted grain on the 3rd day post-sprouting. Gadiev *et al.* (2023) found that supplementing parent flock Ross-300 hens with crushed

sprouted barley improved egg production, hatchability, and fertility, findings similar to those of our study.

Table 5: Effects of hydroponic wheat sprouts on the laying parameters of Japanese quail

Parameters	T1	T2	T3	T4	T5	SEM
Egg collection (49 days)	432.33 ^a	434.75 ^b	434.17 ^b	433.75 ^b	440.08 ^a	0.9242
Hatchability (%)	70.750	73.417	72.833	72.250	75.083	1.1742
Fertility (%)	77.250	78.833	78.167	77.583	80.583	0.9812

Treatments T1, T2, T3, T4, and T5 indicate diets containing 0, 5, 10, 15 and 20 g/kg HWS of basal diet, respectively, SEM= Standard error of the mean Means sharing different superscripts (a, b, c) differ significantly ($p < 0.05$)

Egg morphology parameters

The weight and shape of the quail eggs were not affected by the dietary inclusion of varying levels of HWS in the diets of Japanese quail ($p > 0.05$), as shown in Figure 1. A similar trend was observed in egg mass values, and no effect on egg mass was observed when the groups were supplemented with HWS ($p > 0.05$). No significant effect on egg length, egg width or ultimately on the egg shape index was observed in the supplemented groups when HWS was offered to the laying Japanese quails (Figure 1). The current study aligns with the findings of Abouelezz *et al.* (2019), where egg weight was not affected, but in that study, egg mass was

considerably affected by the supplementation of HBS to laying quails. The results of our study are contradicted by the findings of Hibebo and Heliso (2025), where egg weight was considerably affected by HWS supplementation in laying sasso chickens. The difference in outcomes between the two studies can be explained by the inclusion levels. Hibebo and Heliso (2025) included 5% HWS in chicken diets, whereas our inclusion levels were much lower (0.5-2%), which may explain why we did not observe the same effects on egg weight. Opposite results were observed in the study by Gadiev *et al.* (2023), where improved egg weight gain was observed when crushed sprouted barley was fed to laying Ross 308 chickens. A study by Sandilands *et al.* (2026) showed the same results, where no effects of HBS were observed on egg weight, but the study did show effects on the egg mass of laying Lohmann Brown hens.

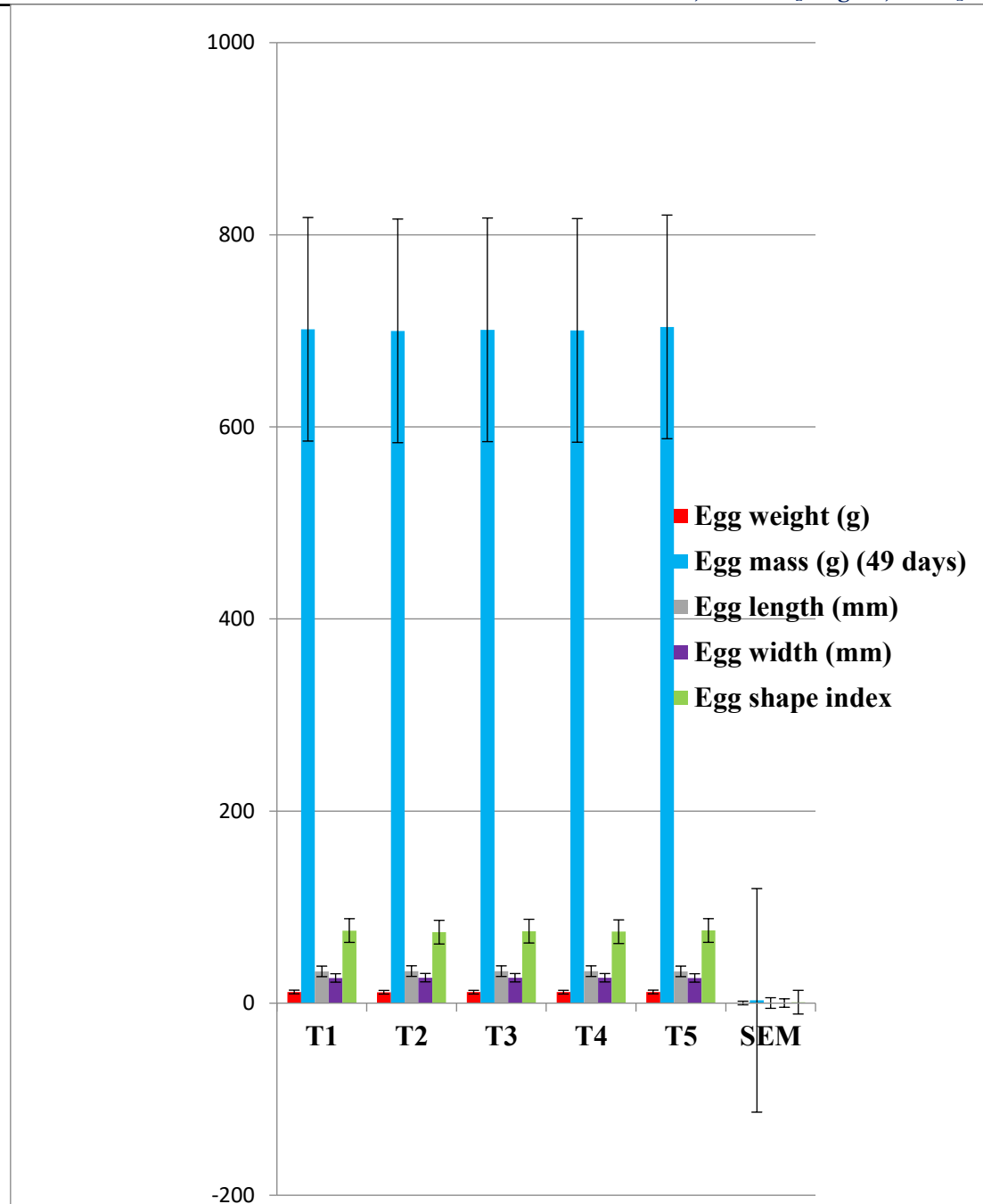


Figure 1: Effects of hydroponic wheat sprouts on Japanese quail egg morphology

Egg shell quality characteristics

No significant effect ($p > 0.05$) was observed in eggshell weight, eggshell percentage or eggshell thickness in the laying Japanese quails supplemented with different levels of HWS. Throughout the research trial, the results regarding the abovementioned characteristics remained consistent among all groups. Similar results were reported by Abouelezz *et al.* (2019); in that study, no significant difference in eggshell percentage and shell thickness was

observed among all groups when laying quails were fed HBS.

Eggshell thickness was considerably improved in the study by Hibebo & Heliso (2025), but eggshell weight was not affected by the supplementation of HWS in the diets of laying Sasso chickens. However, in the same study, HBS supplementation in laying sasso chickens showed superior results compared to HWS. No significant effects were observed on dry eggshell

and wet eggshell weights when HWS was added to the laying quails ($p>0.05$), (Figure 2).

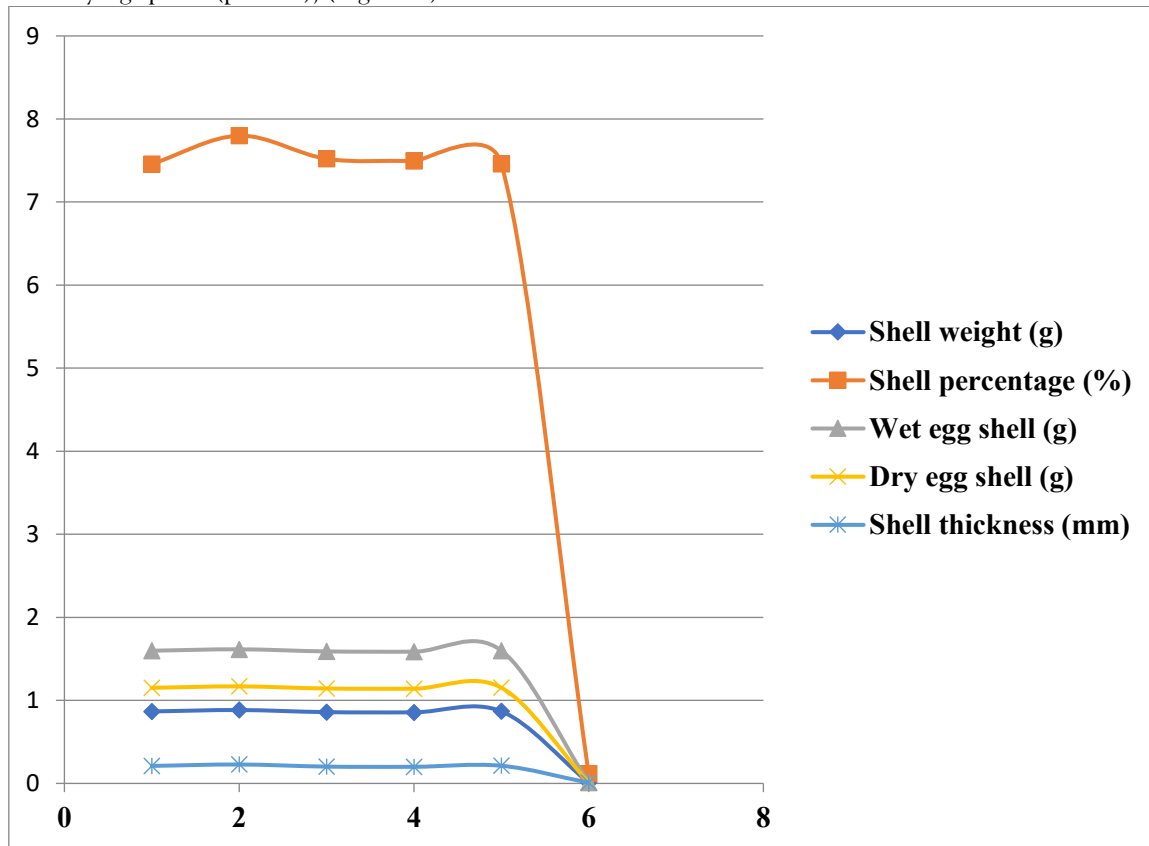


Figure 2: Effects of hydroponic wheat sprouts on Japanese quail eggshell quality

Albumen and yolk parameters

Albumen characteristics

In laying Japanese quail eggs, the addition of HWS to the bird's diet did not show any significant effects ($p>0.05$) on the albumen height, albumen weight, albumen ratio or Haugh unit under various conditions (Figure 3). The study indicates that the HWS-supplemented groups showed apparently better results on albumen height and albumen weight but were not significantly different from the control. The albumen ratio and Haugh unit of the supplemented groups showed no significant differences from those of the control.

The results of this study are aligned with Hibebo & Heliso (2025), where albumen height and weight were considerably better than the control when different levels of hydroponic sprouts were added to laying Sasso

chicken's diet. They reported that HBS had the best results regarding the weight and height of the albumen, followed by HWS, which has considerably more efficient results than control but not superior to HBS. Hydroponic maize has comparable results with the control diet. This could be due to the improved protein and amino acid profiles of both HBS and HWS after germination.

A study by Luo *et al.* (2025) concluded that replacing corn with an aged brown rice-wheat mixture at levels up to 37.5% did not negatively affect laying performance and, notably, resulted in a quadratic improvement in albumen height and Haugh units in weeks 4 and 8. However, in that study, aged brown rice was used along with whole wheat in an 85:15 ratio.

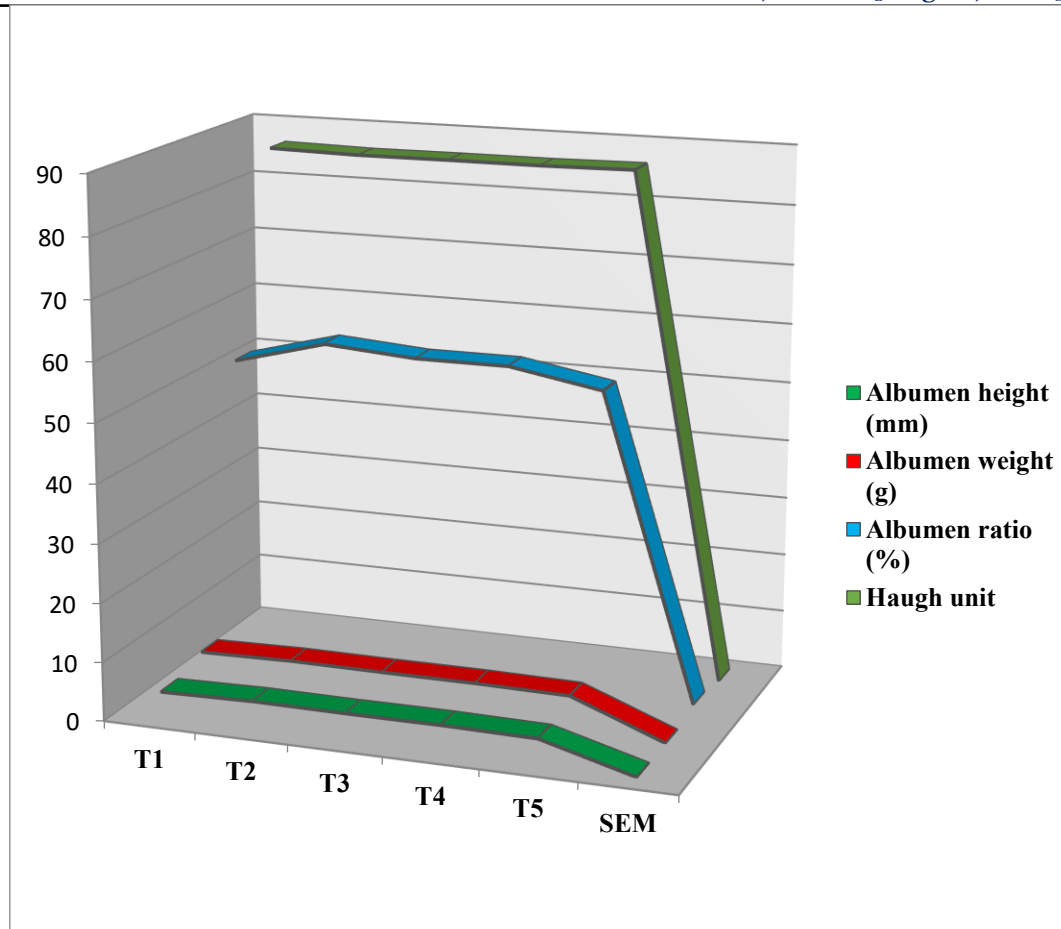


Figure 3: Effects of hydroponic wheat sprouts on albumen characteristics of Japanese quail eggs

Yolk characteristics

The results indicated that there were no significant differences ($p > 0.05$) between the yolk height of the quail laying birds fed a diet supplemented with HWS (Figure 4). The HWS supplemented groups had relatively good results but were not statistically significant. The weight of yolk did not differ ($p > 0.05$) between the different treatments of HWS supplementation as presented in Table 9. Laying Japanese quails fed with different diet levels of HWS did not show any significant difference ($p > 0.05$) in yolk diameter (Figure 4). Somewhat better results were observed in T2 and T4, but they were not statistically significant compared to the control.

No significant difference ($p < 0.05$) was found among the laying quail fed different levels of HWS in the yolk ratio. The control had the lowest values, the highest were recorded in T3, followed by T2, T4 and T5 (Figure 4). The egg

yolk index of Japanese quail did not differ significantly ($p < 0.05$) due to different levels of HWS added to the diets. The highest values were found in T3, T4 and T2. T5 values were very much alike to the control.

The results of this study are consistent with those of Sandilands et al. (2026), where no effect on yolk diameter and height was found on the laying Lohmann Brown hens when fed HBS. Our findings differ from those of Abouelezz et al. (2019) as they did not find any significant difference in yolk index and yolk proportion when the laying Japanese quails were fed HBS. Our research is in agreement with Hibebo and Heliso (2025) as they reported that feeding HWS to laying Sasso hens resulted in an increase in yolk weight. That study added HBS, HWS and hydroponic maize sprouts to the birds and the HBS was found to be superior to all the supplemented ingredients.

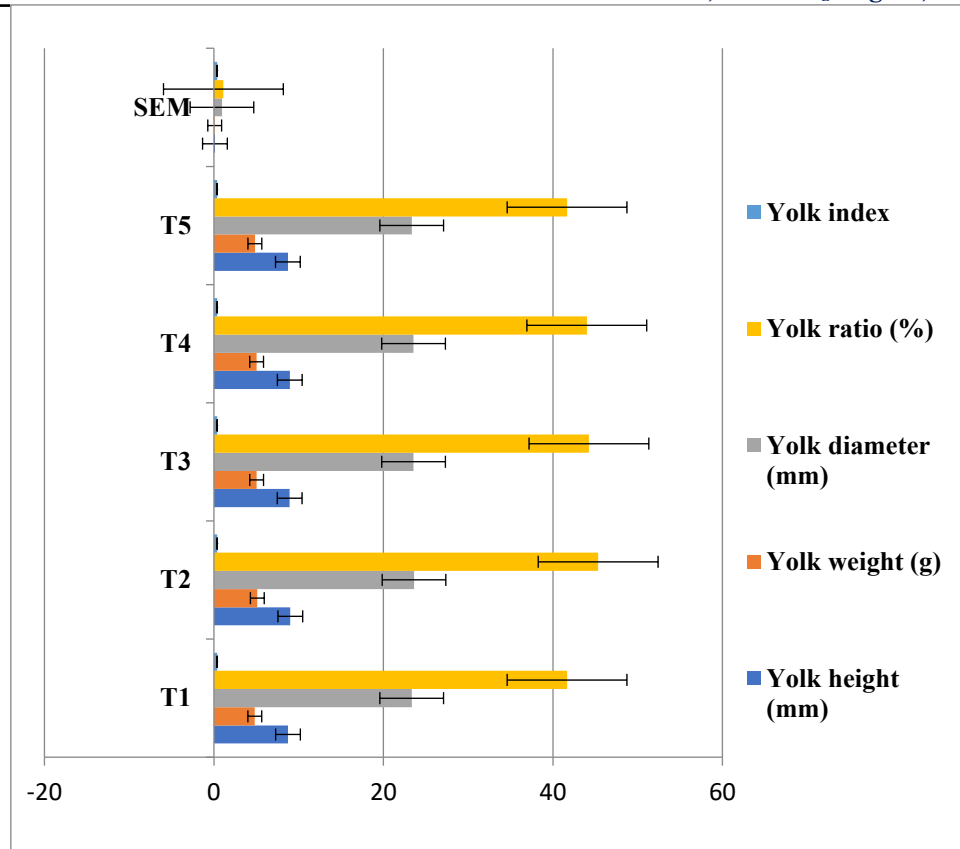


Figure 4: Effects of hydroponic wheat sprouts on yolk characteristics of Japanese quail eggs

Conclusion

The current research demonstrates that feeding HWS to laying Japanese quail significantly affected feed intake and FCR, and the FI decreased as the level of HWS in the quail diet increased without negatively affecting the productive and reproductive characteristics of the birds. However, there was no significant effect of HWS supplementation on the laying parameters of quail, and the hatchability and fertility rates showed no significance over the control treatments. Egg production results were better in the supplemented groups, particularly in T5, but the rest of the treatments showed comparable results with the control. All the egg morphological parameters were nonsignificant. The supplementation of laying quails with HWS showed no impact on egg quality parameters; including egg weight, egg mass, albumen and yolk quality characteristics.

Declarations

Consent for publication

All subjects gave their “informed consent” for the publication of details within the text (“informed consent”) to be published in the above Journal and Article. Written “informed consent” was obtained from all authors for the publication of this manuscript.

Availability of data and materials

Data are provided within the manuscript or supplementary information files.

Competing Interest

All authors declare that there are no competing interests.

Conflict of interest

All the authors declare no conflicts of interest.

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