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Comparison of egg laying behaviour and production performance between 'conventional nest box' and 'novel roll away egg nest' system in backyard poultry rearing

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ABSTRACT

A specially designed "Novel Roll Away Nest" was compared with the conventional (made up of brick and soil) to find out the production performance and egg laying behaviour for backyard poultry. The experiment was conducted using a total of 60 commercial BV 300-layer birds, aged 60-76 weeks, during 2024. The behaviour (egg eating, floor laying, broken eggs, and dirty eggs) and performance (hen day and hen housed egg production, feed conversion ratio (FCR) based on dozen of eggs produced and egg mass) of experimental laying birds with novel roll-away egg nests and once daily egg collection was comparied to the laying birds with the conventional nest (T_C, made up of brick and soil) with different daily egg collection frequencies (1, 2, 3 or 4 times/day i.e. T_C^1, T_c^2, T_c^3 and T_C^4) for the period of 4-month (i.e. P1, P2, P3 and P4). In the roll-away egg nest group, the egg laying on the floor was almost 9.44 times and egg-eating behaviour was 11.47 times lower than the conventional egg nest group. Whereas, the hen day egg production (based on total saleable eggs) and FCR in the roll-away egg nest group were comparable to the conventional egg nest group with 4 times daily egg collection frequency. Also, the conventional egg nest group, having a 4 times daily egg collection frequency, required more labour. The majority of the hens displayed a preference for the roll-away nest box over the conventional nest. In conclusion, the improved parameters in the novel roll way rollaway plausibly attributable nest were achieved due to its novel design, which provided a cosy and confined space for birds to lay eggs and allows the rolling back of the egg to the rear end once it is laid and making it inaccessible to birds, thereby preventing egg-eating habits.

Keywords: Backyard rearing, Egg eating, Laying behaviour, Nest box, 'Novel Roll Away Nest', Production loss

Backyard poultry production accounts for 15.18 % of total egg production, Backyard poultry has grown at a much higher rate (45.48%) over the recent years during the last census period (20th Livestock Census 2019). Backyard poultry farming is characterized by "production by mass" and practiced by the majority of the poor and marginalized rural households all over India, thus ensuring their socioeconomic and nutritional security.

Backyard poultry, primarily reared in a deep litter system, possess managemental challenges in egg production viz. floor laying, egg eating, egg breaking and soiling resulting in poor economic returns associated with production losses, poor egg quality and increased labour requirements in egg collection (Campbell 2023). Most hens in commercial flocks perceive the nest boxes as suitable nesting places and prefer to lay (Christina *et al.* 2014; Lentfer *et al.* 2013; Tine *et al.* 2011). But still, in the commonly used conventional nest box, birds lay more floor eggs and develop egg-eating habits. Considering these constraints, a low-cost "Novel Roll Away Nest" with the potential to address the above-discussed problem has been developed at the Department of Livestock Farm Complex, COVS, Rampura Phul, which will keep laid eggs away from the reach of chickens. The name "Novel Roll Away Nest" was due to its triangular shape and slanting floor, which makes it to fit in the corner of the shed and makes eggs inaccessible to birds once it is laid. This Roll-away egg nest can be a valuable technology input for backyard poultry farmers. The present study was planned to find out the comparative performance and egg laying behaviour between 'Novel Roll Away' and 'Conventional' nest box under backyard poultry rearing system.

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MATERIALS AND METHODS

Location of the study: Study was conducted at the Poultry unit, Department of Livestock Farm Complex, College of Veterinary Science, Rampura Phul (GADVASU, Ludhiana). Its latitude is 30.29° North, longitude is 75.24° West, height from sea level is 814 feet, ambient maximum temperature is 45°C and minimum temperature is 4°C, humidity varies from 11 to 92 %, and annual rainfall varies from 6.89 cm to 0 cm.

Animal Ethics Committee Approval: The ethical permission for the experiment was duly granted by IEAC vide GADVASU/2024 /IAEC/72/05), dated 13.03.2024.

Experimental birds- 60 commercial BV 300-layer birds from 60-76 weeks of age.

Period of study: 4 months

Management of birds: The experimental birds were kept in an open-sided conventional shed on the deep litter system, with a floor area allowance of 2.0 square feet per bird as per BIS housing standards (IS 2725 1985). Sufficient number of round-hanging feeders and drinkers were placed to ensure the required feeding and drinking space per bird in accordance with BIS housing standards (IS 2725 1985). The birds were offered twice daily, a weighed amount of feed as per ICAR (2013) feeding standards and ensured round-the-clock availability of drinking water. Each group was allotted an equal amount of feed daily.

Experimental design: The shed was partitioned into two equal pens with a wire mesh partition frame. Each corner of one pen was installed with one roll-away egg nest box (Fig. 1 and Fig. 2), while another pen was provided with one conventional egg nest, made of bricks, soil and rice husk bedding material (Fig. 3). Further, the behaviour and performance of experimental laying birds with conventional egg nest with different daily egg collection frequencies (1, 2, 3 or 4) during the entire experimental period of 4 months, were studied in relation to birds with roll away egg nest with daily once egg collection frequency as per following treatment details:

T_C^1: Conventional egg nest with daily once-egg collection

T_C^2: Conventional egg nest with daily twice-egg collection

T_C^3: Conventional egg nest with daily thrice egg collection

T_C^4: Conventional egg nest with daily four times egg collection

T_{RAN}^5: Roll away egg nest with daily once-egg collection

Roll Away Egg Nest Design: The roll-away egg nest was made of 0.5-inch-thick plywood with the following design details:

Shape: Isosceles triangle

1. Sides: Front: 38", lateral: 26.5"
2. Inside height of nest (floor to roof) 12.5 inches
3. Total area: 350 square inches
4. Area for egg collection: 45 square inches
5. Sitting area for birds: 306 square inches
6. Sitting capacity of nest: 3 birds at a time
7. Area for one bird: 101.60 square inches
8. Floor height from the ground (front side): 3.25"
9. Floor height to depth ratio: 3.35: 18.50 inches
10. Slope of nest floor (front to rear): 1: 5.70 inches

Recording of parameters: The data on the number of eggs laid on the floor, and in the nest, cracked eggs, eggs with consumed yolk and albumen and dirty eggs were recorded daily for the assessment of egg-laying behaviour of birds. The daily egg produced, egg weight and feed intake were recorded to calculate hen house egg production (HHEP), hen day egg production (HDEP), feed conversion ratio(FCR) per dozen eggs and kilogram egg mass production. Daily income from saleable eggs, expenditure on feed consumed and time for egg collection were recorded to assess the economic and labour use efficiency of egg production. The economics of all the treatment groups were estimated at the end of the trial. The price of feed remained the same throughout the experiment period, and labour use efficiency was calculated on a rupee-per-minute basis for each treatment.

Statistical analysis: The SPSS 20 software was used for statistical analysis. To assess the effect of different treatments over different periods, various parameters like egg production and behaviour data were subjected to analysis of variance using the following general linear model:

$$E = \mu + Ti + Pj + T*Pij$$

Where Ti is the effect of i^{th} treatment

Pj is the effect of j^{th} different egg collection period (Age of bird)

T*Pij is the effect of treatment and period interaction

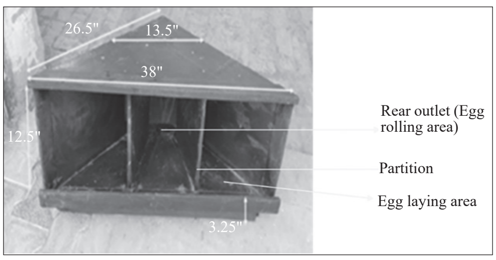

Fig. 1 Front view of the novel roll-away egg nest

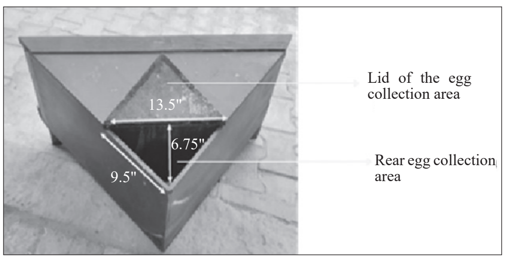

Fig. 2 Rear and top view of the novel roll-away egg nest

Fig. 3 Conventional egg nest

Table 1. Effect of treatment, period, and their interaction on various egg-laying behaviour parameters.

Treatment (T)	% Floor eggs	% Broken egg	% Egg eating	% Dirty eggs
T_C^4	23.09±1.52^a	0.13±0.17b	19.32±1.30^{ab}	10.59±1.89^b
T_C^3	24.57±1.52^a	3.703E-17±0.17^c	22.02±1.30^a	11.01±1.89^b
T_C^2	19.48±1.52^b	0.63±0.17^a	20.59±1.30^a	21.48±1.89^a
T_C^1	23.23±1.52^a	-1.162E-17±0.17^d	11.44±1.30^c	13.81±1.89^b
Average (T_c): Convention nest	22.59 ± 1.52	0.84±0.17	18.34±1.30	14.22±1.89
T_{RAN}^5: Novel roll-away nest	2.46±0.76^c	0.12±0.08^b	4.20±0.65^d	18.49±0.95^a
P Value	0.01	0.04	0.01	0.01
		Period (P)		
P1	20.41±1.25^a	0.47±0.14^a	14.56±1.07^b	13.41±1.57^b
P2	15.88±1.25^b	3.256E-17±0.14^c	15.76±1.08^b	9.95±1.57^c
P3	16.50±1.25^b	1.983E-17±0.14^d	21.09±1.07^a	17.79±1.57^a
P4	21.47±1.25^a	0.24±0.14^b	10.64±1.07^c	19.17±1.57^a
P Value	0.01	0.05	0.01	0.01
		Interaction (Treatment*period)		
T_C^4*P1	27.63±3.03^a	0.529±0.33	15.95±2.60^{bc}	13.59±3.80^{bc}
T_C^4*P2	17.64±3.03^{ab}	1.952E-17±0.33	24.23±2.60^b	6.13±3.80^c
T_C^4 *P3	20.44±3.03^{ab}	5.941E-17±0.33	18.28±2.60^{bc}	8.41±3.80^{bc}
T_C^4*P 4	26.63±3.03^a	-1.076E-16±0.33	18.79±2.60^{bc}	14.27±3.80^{bc}
T_C^3*P1	22.65±3.03^{ab}	-3.569E-17±0.33	15.71±2.60^{bc}	7.47±3.80^{bc}
T_C^3*P2	18.02±3.03^{ab}	4.077E-17±0.33	19.41±2.60^{bc}	9.85±3.80^{bc}
T_C^3*P3	28.74±3.03^a	2.807E-17±0.33	39.70±2.60^a	14.94±3.80^{bc}
T_C^3*P4	28.85±3.03^a	8.327E-17±0.33	13.25±2.60^c	11.79±3.80^{bc}
T_C^2 *P1	21.99±3.03^{ab}	1.323±0.33	26.10±2.60^b	20.00±3.80^b
T_C^2*P2	17.55±3.03^{ab}	7.534E-17±0.33	24.45±2.60^b	11.71±3.80^{bc}
T_C^2*P3	11.17±3.03	0.000±0.33	22.00±2.60^b	31.53±3.80^a
T_C^2 *P4	27.19±3.03^a	1.190±0.33	9.82±2.60^c	22.67±3.80^b
T_C^1*P1	27.97±3.03^a	-1.071E-16±0.33	11.54±2.60^c	14.48±3.80^{bc}
T_C^1*P2	22.40±3.03^{ab}	4.775E-17±0.33	6.64±2.60^{cd}	8.55±3.80^{bc}
T_C^1*P3	21.23±3.03^{ab}	6.438E-17±0.33	21.72±2.60^b	13.18±3.80^{bc}
T_C^1*P4	21.34±3.03^{ab}	-5.155E-17±0.33	5.87±2.60^{cd}	19.04±3.80^b
T_{RAN}^5*P1	1.80±1.52^c	0.477±0.17	3.50±1.30^{cd}	11.50±1.90^{bc}
T_{RAN}^5*P2	3.77±1.54^c	5.891E-17±0.17	4.08±1.33^{cd}	13.50±1.93^{bc}
T_{RAN}^5*P3	0.93±1.52^c	3.663E-17±0.17	3.75±1.30^d	20.87±1.90^b
T_{RAN}^5*P4	3.36±1.52^c	2.974E-16±0.17	5.48±1.30^d	28.07±1.90^a
P Value	0.01	0.47	0.01	0.03

The means shown in lowercase letters with different superscripts among different columns differ significantly at 5 % level (P≤0.05).

The means of different parameters for significant effect were compared with Tukey's pairwise comparison at a 5.0 % level of significance.

RESULTS AND DISCUSSION

The data on the egg-laying behaviour of birds (Table 1) indicated that the egg nest type and the egg collection frequency over different periods significantly affect egg-laying behaviour of birds.

The values of floor egg percentages were 23.09±1.52, 24.57±1.52, 19.48±1.52, and 23.23±1.52 in treatments T_C^4, T_C^3, T_C^2, and T_C^1 respectively across the whole period. The percentage of floor laying was significantly higher in conventional egg nest in comparison to roll away nest. The values of floor egg percentages in roll away nest i.e. $T_{RAN}5$ were found to be 1.80±1.52, 3.77±1.54, 0.93±1.52, and 3.36±1.52 percentages in periods 1, 2, 3, and 4 respectively (Table 1). The incidence of floor-laying behaviour in conventional egg nest groups did not decrease with increase in daily egg collection frequency; however, the incidence of floor-laying in roll-away egg nest treatment groups was significantly (P < 0.01) lower than in conventional egg nest groups at all different daily egg collection frequencies. In the roll-away egg nest group, the egg laying on the floor was almost 9.44 times lower than the conventional egg nest.

Moreover, floor laying incidence also varied significantly (P < 0.01) over periods, but no specific trends were observed across the periods. Similarly, in conventional egg nest groups, the interaction with egg collection frequency over different periods varied significantly (P < 0.01) but did not show any specific trend. Although broodiness behaviour in commercial hens significantly decreased, birds still preferred discrete enclosed and dark spaces for egg-laying (Weeks and Nicol 2006; Bist *et al.*. 2023). So, multiple factors such as the presence of curtains (Struelens *et al.* 2008; Hunniford and Widowski 2018), curtain design (Stampfli *et al.* 2012), curtains colour (Brake 1993; Huber-Eicher 2004; Clausen and Riber 2012; Pillan *et al.* 2023) facilitating darkness and slope of the nest floor ensuring comfortable sitting posture during laying satisfy the behavioural needs of egg-laying hens. Moreover, the tendency to lay in the corners (Lundberg and Keeling 1999) and smaller-sized nests with dividers (Ringgenberg *et al.* 2014; Ringgenberg *et al.* 2015; Zheng *et al.* 2018) ensures seclusion during laying. Therefore, the design of the present roll-away egg nest, like its triangular shape, facilitated the fitting of the nest box in the corner of pens, partitions, black colour and floor slope angle satisfying all the required behaviour needs of laying hens, thereby attracting more birds to lay eggs in roll-away egg nests than on the floor. These findings are in accordance with Anja (2010) and Anja *et al*. (2008), who found that corner nests attract more birds in comparison to nests placed along the wall.

The values of percentage egg eating were 19.32±1.30, 22.02±1.30, 20.59±1.30, 11.44±1.30 in treatments T_{C4}, T_{C3}, TC_2, and TC1 respectively across the whole period. The percentage egg eating incidence were significantly higher in conventional egg nest in comparation to roll away nest. The values of percentage egg eating in roll away nest i.e. T_{RAN}^5 were 3.50±1.30, 4.08±1.33, 3.75±1.30, and 5.48±1.30 in periods 1,2,3 and 4, respectively (Table 1). The incidence of egg eating varied significantly across all the treatments and periods. In comparison to all conventional egg nest groups, egg eating in roll-away egg nests was significantly (P < 0.01) lower. The significantly low egg eating in the roll-away egg nest could be attributed to comparatively lower floor laying and a novel design ensuring roll down of laid eggs to the collection area in the rear end, and making eggs inaccessible for eating to the hen. Interestingly, egg-eating behaviour in the conventional egg nest groups did not decrease with increased egg collection frequency from one to four times a day, but among all conventional egg-nest groups, per cent egg eating with only once a day egg collection (T_C^1) was exceptionally low, which could be explained due to significantly lower egg production in T_C^1 group and possibly birds got sufficient longer time to completely eat up eggs without leaving any traces of broken/small pieces of eggshell on the pen floor.

Nutritional deficiency, environmental stress and specific diseases are predisposing factors for weak and broken eggshells (Cheng and Ning 2023). Although the percentage of broken eggs across all treatments and periods differed significantly without any specific trend, but overall percentage of broken eggs in both conventional as well as roll-away egg nests was too low. Contrary to our results, Ekstrand and Keeling (1994) and Wall *et al*. (2002) dealing with enriched cages found a higher number of cracked eggs inside the nest boxes than outside the nest box due to collisions among eggs inside the nest causing eggshell damage.

Eggs with more than 1/32, localized and 1/16 scattered, prominent or moderately stained surface area are considered dirty (Jacob and Mather 1997). The percentage of dirty eggs also significantly varied with the type of egg nest. Dirty eggs were significantly lower in T_C^4, T_C^3 and T_C^1 than in T_C^2 and T_{RAN}^5.

The percentages of dirty eggs were 10.59±1.89, 11.01±1.89, 21.48±1.89, and 13.81±1.89 in treatments T_C^4, T_{C3}, TC_2, and TC_1, respectively across the whole period whereas the percentages of dirty eggs in roll away nest i.e $T_{RAN}5$ were 11.50±1.90, 13.50±1.93, 20.87±1.90 and 28.07±1.90 in periods 1,2,3 and 4 respectively (Table 1). Among conventional egg nests, dirty eggs tend to decrease with increasing egg collection frequency, possibly due to lesser exposure time to birds to soil eggs in dirty environments. However, comparatively higher per cent of dirty eggs in the roll-away nests (T_{RAN}^5) than T_C^4 could be due to more soiling of the nest, as hens have the tendency to sit in a confined place and had a high incidence of egg laying in the roll-away egg nest. But this issue can be overcomed with periodic cleaning of egg nest and minor structural changes in the nest floor.

The results of egg production performance (Table 2) revealed that average egg production (HDEP and HHEP) of all treatments of laying birds across conventional as well as roll-away egg nest groups decreased significantly over the experimental period but average FCR on dozen basis of all treatments did not followed a fixed trend. However, overall egg production (THHEP and THDEP) was significantly (P < 0.01) higher in T_C^4 followed by T_{RAN}^5, T_C^2, T_C^3 and T_C^1 although the number of saleable eggs (HHEP and HDEP in T_{RAN}^5 were significantly (P < 0.01) higher than all conventional egg nest treatments (T_C^4, T_C^3, T_C^2, and T_C^1).

Similarly, FCR for total egg production was significantly (P < 0.01) lower in T_C^4 followed by T_{RAN}^5, T_C^2, T_C^3 and T_C^1 but FCR for saleable eggs was significantly (0.01) higher than all conventional egg nest treatments (T_C^4, T_C^3, T_C^2, and T_C^1). These results indicated that in conventional egg nest groups, egg production and FCR for saleable eggs significantly (P < 0.01) decreased with decreasing egg collection frequency which might be associated with lower egg loss due to egg eating, breaking and soiling in the roll-

Table 2. Egg laying behaviour of birds in relation to egg nest type and collection frequency over different periods.

Treatment (T)	THHEP	THDEP	SHDEP	SHHEP	TFCR (per dozen eggs)	FCR (per dozen eggs)	FCR (Egg weight)
T^{C4}	65.59 ± 1.81^{a}	72.89 ± 1.93^{a}	58.21 ± 1.65^{a}	52.26 ± 1.53^{b}	2.86 ± 0.15^{d}	2.36 ± 0.11^{d}	3.56 ± 0.19^{e}
T_C^3	49.41 ± 1.81^{d}	55.68 ± 1.93^{c}	42.04 ± 1.65^{c}	37.62 ± 1.53^{d}	4.02 ± 0.15^{b}	3.38 ± 0.11^{b}	5.33 ± 0.19^{b}
T_C^2	56.79 ± 1.81^{c}	63.46 ± 1.93^{b}	49.05 ± 1.65^{b}	43.69 ± 1.53^{c}	3.55 ± 0.15^{c}	2.93 ± 0.11^{c}	4.45 ± 0.19^{c}
$T_C 1$	43.45 ± 1.81^{e}	49.11 ± 1.93^{d}	42.42 ± 1.65^{c}	37.62 ± 1.53^{d}	4.54 ± 0.15^{a}	3.43 ± 0.11^{a}	5.24 ± 0.19^{a}
Average (Tc): Convention nest	53.81 ± 1.81	60.29 ± 1.93	47.93 ± 1.65^{c}	42.79 ± 1.53	3.74 ± 0.15	3.02 ± 0.11	4.65 ± 0.19
T_{RAN}^5: Novel roll-away nest	59.77 ± 0.91^{b}	61.59 ± 0.97^{b}	58.93 ± 0.83^{a}	57.18 ± 0.77^{a}	3.64 ± 0.07^{c}	2.44 ± 0.05^{d}	3.93 ± 0.09^{d}
P Value	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Period (P)							
P1	61.83 ± 1.49^{b}	61.83 ± 1.59^{c}	51.74 ± 1.36^{b}	51.74 ± 1.27^{a}	3.43 ± 0.12^{b}	2.71 ± 0.09^{b}	4.08 ± 0.15^{b}
P2	65.01 ± 1.49^{a}	67.55 ± 1.59^{b}	56.01 ± 1.36^{a}	53.94 ± 1.27^{a}	3.30 ± 0.12^{b}	2.47 ± 0.09^{c}	4.12 ± 0.15^{b}
P3	59.38 ± 1.49^{b}	71.94 ± 1.59^{a}	56.88 ± 1.36^{a}	47.26 ± 1.27^{b}	2.79 ± 0.12^{c}	2.47 ± 0.09^{c}	3.69 ± 0.15^{c}
P4	33.79 ± 1.49^{c}	40.86 ± 1.59^{d}	35.90 ± 1.36^{c}	29.76 ± 1.27^{c}	5.36 ± 0.12^{a}	3.99 ± 0.09^{a}	6.12 ± 0.15^{a}
P Value	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Interaction (Treatment*period)							
T_C^4*P1	66.19 ± 3.63^{b}	66.19 ± 3.85^{c}	53.81 ± 3.30^{b}	53.81 ± 3.07^{c}	3.25 ± 0.29^{c}	2.55 ± 0.21^{de}	3.82 ± 0.37^{d}
T_C^4*P2	79.52 ± 3.63^{a}	79.52 ± 3.85^{a}	60.00 ± 3.30^{b}	60.00 ± 3.07^{b}	2.55 ± 0.29^{d}	2.27 ± 0.21^{def}	3.39 ± 0.37^{d}
T_C^4 *P3	66.67 ± 3.63^{b}	83.33 ± 3.85^{a}	68.45 ± 3.30^{a}	54.76 ± 3.07^{bc}	2.49 ± 0.29^{d}	2.00 ± 0.21^{f}	3.13 ± 0.37^{d}
T_C^4*P4	50.00 ± 3.63^{cd}	62.50 ± 3.85^{cd}	50.59 ± 3.30^{bc}	40.48 ± 3.07^{d}	3.13 ± 0.29^{c}	2.63 ± 0.21^{de}	3.91 ± 0.37^{cd}
T_C^3*P1	54.76 ± 3.63^{c}	54.76 ± 3.85^{d}	45.71 ± 3.30^{c}	45.71 ± 3.07^{cd}	3.65 ± 0.29^{cd}	2.90 ± 0.21^{cd}	4.32 ± 0.37^{c}
T_C^3*P2	59.52 ± 3.63^{bc}	63.77 ± 3.85^{c}	51.02 ± 3.30^{bc}	47.62 ± 3.07^{cd}	3.45 ± 0.29^{c}	2.69 ± 0.21^{de}	4.91 ± 0.37^{c}
T_C^3*P3	56.19 ± 3.63^{c}	70.24 ± 3.85^{c}	42.26 ± 3.30^{cd}	33.81 ± 3.07^{de}	2.79 ± 0.29^{d}	3.15 ± 0.21^{d}	4.69 ± 0.37^{c}
T_C^3*P4	27.14 ± 3.63^{f}	33.93 ± 3.85^{e}	29.17 ± 3.30^{e}	23.33 ± 3.07^{f}	6.21 ± 0.29^{a}	4.75 ± 0.21^{a}	7.40 ± 0.37^{a}
T_C^2 *P1	71.43 ± 3.63^{b}	71.43 ± 3.85^{c}	51.90 ± 3.30^{bc}	51.91 ± 3.07^{c}	2.81 ± 0.29	2.63 ± 0.21^{de}	3.85 ± 0.37^{d}
T_C^2*P2	68.57 ± 3.63^{b}	73.47 ± 3.85^{ab}	55.61 ± 3.30^{b}	51.91 ± 3.07^{c}	2.97 ± 0.29^{d}	2.48 ± 0.21^{d}	4.08 ± 0.37^{cd}
T_C^2*P3	58.09 ± 3.63^{c}	72.62 ± 3.85^{ab}	56.55 ± 3.30^{b}	45.24 ± 3.07^{d}	2.75 ± 0.29^{d}	2.40 ± 0.21^{d}	3.58 ± 0.37^{d}
T_C^2 *P4	29.05 ± 3.63^{f}	36.31 ± 3.85^{e}	32.14 ± 3.30^{e}	25.71 ± 3.07^{f}	5.66 ± 0.29^{ab}	4.22 ± 0.21^{b}	6.29 ± 0.37^{b}
T_C^1*P1	47.62 ± 3.63^{cd}	47.62 ± 3.85^{d}	40.95 ± 3.30^{cd}	40.95 ± 3.07^{d}	4.53 ± 0.29^{c}	3.43 ± 0.21^{c}	5.37 ± 0.37^{bc}
T_C^1*P2	50.00 ± 3.63^{cd}	53.57 ± 3.85^{d}	48.98 ± 3.30^{bc}	45.71 ± 3.07^{cd}	4.05 ± 0.29^{c}	2.81 ± 0.21^{d}	4.61 ± 0.37^{c}
T_C^1*P3	51.91 ± 3.63^{c}	64.88 ± 3.85^{c}	51.19 ± 3.30^{bc}	40.95 ± 3.07^{d}	3.04 ± 0.29^{cd}	2.70 ± 0.21^{de}	3.89 ± 0.37^{cd}
T_C^1*P4	24.29 ± 3.63^{f}	30.36 ± 3.85^{ef}	28.57 ± 3.30^{e}	22.86 ± 3.07^{f}	6.55 ± 0.29^{a}	4.78 ± 0.21^{a}	7.09 ± 0.37^{a}
T_{RAN}^5*P1	69.17 ± 1.81^{b}	69.17 ± 1.93^{c}	66.31 ± 1.65^{a}	66.31 ± 1.53^{a}	2.89 ± 0.15^{d}	2.02 ± 0.11^{f}	3.01 ± 0.19^{de}
T_{RAN}^5*P2	67.41 ± 1.85^{b}	67.41 ± 1.96^{c}	64.44 ± 1.68^{a}	64.44 ± 1.56^{a}	3.48 ± 0.15^{cd}	2.07 ± 0.11^{f}	3.63 ± 0.19^{d}
T_{RAN}^5*P3	64.05 ± 1.81^{bc}	68.62 ± 1.93^{c}	65.94 ± 1.65^{a}	61.55 ± 1.53^{b}	2.94 ± 0.15^{d}	2.07 ± 0.11^{f}	3.18 ± 0.19^{d}
T_{RAN}^5*P4	38.45 ± 1.81^{e}	41.19 ± 1.93^{de}	39.03 ± 1.65^{d}	36.43 ± 1.53^{de}	5.27 ± 0.15^{b}	3.58 ± 0.11^{c}	5.91 ± 0.19^{b}
P Value	0.04	0.01	0.01	0.03	0.01	0.01	0.01

THHEP = HHEP based on total eggs collected per day, THDEP = HDEP based on total eggs collected per day, SHDEP = HDEP based on total saleable eggs per day, SHHEP = HHEP based on total saleable eggs per day, TFCR = FCR based on total eggs collected per day, and FCR = feed conversion ratio. The means shown in lowercase letters with different superscripts among different columns differ significantly at 5 % level ($P\leq0.05$)

away egg nest group. But out of these total eggs collected, few were partially eaten by birds making them unsuitable for sale purposes. So, in spite of higher egg collection frequency in the conventional nest, the total saleable eggs were highest in the roll-away nest.

At the end of the trial, the economics of different treatments were estimated for the whole period. Total average income per day was Rs. 93.07, 66.25, 76.68, 66.36 and 101.29 in treatments T_C^4, T_C^3, T_C^2, and T_C^1 and $T_{RAN}^{5,}$ respectively, across the whole period. Income varied for each treatment group across the whole period as the price of eggs fluctuated with changes in season and market demand.

The average labour charge per day across the whole period in treatments T_C^4, T_C^3, T_C^2, T_C^1, and T_{RAN}^5 were Rs. 2.45, 1.83, 1.23, 0.68 and 0.6, respectively. Minimum labour was required for egg collection in the treatment group with the rollaway nest box, whereas in the conventional nest box (T_C^1, T_C^2, T_C^3, T_C^4), more floor eggs were produced in addition to more egg collection frequency, which caused more labour use. The average production cost per day across the whole period was Rs. 79.39, 77.62, 77.02, 76.47 and 83.5 in treatments T_C^4, T_C^3, T_C^2, T_C^1 and T_{RAN}^5), respectively. The average income per day across the whole period was Rs. 93.07, 66.25, 76.68, 66.36 and 101.3 in treatments T_C^4, T_C^3, T_C^2, T_C^1, and T_{RAN}^5, respectively. Finally, the total profit per day across the whole period in percentage (%) was 14.13, -19.52, -6.87, -19.87 and 15.6 in treatments T_C^4, T_C^3, T_C^2, and T_{RAN}^5, respectively. There were losses in treatments with conventional nest boxes (T_C^1, T_C^2, and T_C^3) except T_C^4 in which loss of egg production was much less due to 4 times daily egg collection . The percentage profit per day across the whole period was highest in the rollaway nest box which indicates its suitability for rearing of layer birds in backyard or deep litter system.

The novel roll way nest provided a cosy and confined space for birds to lay eggs. Due to its novel design, eggs rolled back to the rear end, once it is laid and making it inaccessible to birds, thereby, preventing egg-eating habits, improving both the production (HDEP, HHEP, and FCR) and egg-laying behaviour parameters (percentage of floor eggs, broken eggs, egg eating, and soiled eggs) of the flock in comparison to the conventional nest.

AUTHOR CONTRIBUTIONS

Conceptualisation, methodology, and data analysis, Amit Sharma; investigation and draft writing, Anand Prakash; data validation and reviewing, Yashwant Singh, Sandeep Kaswan and Priya. All authors have read and approved the final version of the manuscript

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REFERENCES

20th Livestock Census. 2019. All India Report. People's Archive of Rural India. https://ruralindiaonline.org › library › resource › 20th-l...

Anja BR. 2010. Development with age of nest box use and gregarious nesting in laying hens. *Applied Animal Behaviour Science* **123**(1–2): 24–31

Anja K, Manja Z, Theres B and Beat HE. 2008. Nest preference of laying hens (Gallus gallus domesticus) and their motivation to exert themselves to gain nest access. *Applied Animal Behaviour Science* **112**(3–4): 321–30

Bist RB, Yang X, Subedi S and Chai L. 2023. Illuminating Solutions for Reducing Mislaid Eggs of Cage-Free Layers. Agricultural Engineering **5**: 2170–83

Brake J. 1993. Influence of nest pad color on nest preference, percentage of floor eggs, and egg production of broiler breeder hens. *Poultry Science* **72**(9): 1663–66.

Campbell DLM. 2023. Floor egg laying: can management investment prevent it? *Journal of Applied Poultry Research* **32**(4): 100371

Cheng X and Zhonghua N. 2023. Research progress on bird eggshell quality defects: a review. *Poultry Science* **102**(1): 102283

Christina B, Silke K and Lars S. 2014. Vigilance and roosting behaviour of laying hens on different perch heights. *Applied Animal Behaviour Science* **157**: 93–99

Clausen T and Riber AB. 2012. Effect of heterogeneity of nest boxes on the occurrence of gregarious nesting in laying hens. *Applied Animal Behavior Science* **142**(3–4): 168–75

Dharmaraj GY, Prasanna SB, Rudresh BH, Kamalnath M and Nagaraja R. 2023. Comparison of preference of layers for laying eggs in Mud Pots vs. nest Boxes. *Pharma Innovation* **12**(1): 811–13

Ekstrand C and Keeling L. 1994. Modified cages and get-away cages for laying hens. *A literature Review* **34**: 39

Huber-Eicher B. 2004. The effect of early colour preference and of a colour exposing procedure on the choice of nest colours in laying hens. *Applied Animal Behaviour Science* **86(**1–2): 63–76

Hunniford ME and Widowski TM. 2018. Curtained nests facilitate settled nesting behaviour of laying hens in furnished cages. *Applied Animal Behaviour Science* **202**: 39–45

Jacqueline PJ and Mather FB. 1997. Selecting Eggs for Show. Fact Sheet PS-32. 1997. Cooperative extension service. Institute of food and agricultural sciences. University of Florida.

Lentfer TL, Gebhardt-Henrich SG, Frohlich EKF and Von Borell E. 2013. Nest use is influenced by the positions of nests and drinkers in aviaries. *Poultry Science* **92** (6): 1433–42

Lundberg A and Linda J Keeling. 1999. The impact of social factors on nesting in laying hens (Gallus gallus domesticus). *Applied Animal Behaviour Science* **64** (1): 57–69

Nadine R, Ernst K F F, Alexandra H M, Hanno W and Beatrice A R. 2014. Does nest size matter to laying hens? *Applied Animal Behaviour Science* **155**: 66–73.

Onbaşılar EE, Unal N, Erdem E, Kocakaya A, and Yaranoglu B. 2015. Production performance, use of nest box, and external appearance of two strains of laying hens kept in conventional and enriched cages. *Poultry Science* **94**(4): 559–64.

Pillan G, Xiccato G, Ciarelli C, Bordignon F, Concollato A, Pascual A, Birolo M, Pirrone F, Sirri F, Averós X and Estevez I. 2023. Factors affecting space use by laying hens in a cage-free aviary system: effect of nest lighting at pullet housing and of curtain nest color during laying. *Poultry Science* **102**(4):102524.

Ringgenberg N, Fröhlich E, Harlander A, Toscano M, Würbel H and Roth B. 2015. Effects of variation in nest curtain design on pre-laying behaviour of domestic hens. Applied Animal Behaviour Science **170**: 34–43

Stampfli K, Beatrice AR, Theres B and Ernst KFF. 2011. Influence of nest-floor slope on the nest choice of laying hens. Applied Animal Behaviour Science **135**(4): 286–92

Stampfli K, Buchwalder T, Fröhlich EKF and Roth BA. 2012. Influence of front curtain design on nest choice by laying hens. *British Poultry Science* **53**(5): 553–60

Stampfli K, Buchwalder T, Fröhlich EKF and Roth BA. 2013. Design of nest access grids and perches in front of the nests: Influence on the behaviour of laying hens. *Poultry Science* **92**(4): 890–99

Struelens E, Van NA, Tuyttens F, Audoorn L, Vranken E, Zoons J, Berckmans D, Ödberg F, Van DS and Sonck B. 2008. Influence of nest seclusion and nesting material on pre-laying behaviour of laying hens. *Applied Animal Behaviour Science* **112**: 106–19

Tine LL, Sabine GGH, Ernst KFF and Eberhard VB. 2011. Influence of nest site on the behaviour of laying hens. *Applied Animal Behaviour Science* **35** (1–2): 70–77

Villanueva S, Ali ABA, Campbell DLM and Siegford JM. 2017. Nest use and patterns of egg laying and damage by 4 strains of laying hens in an aviary system. *Poultry Science* **96**(9): 3011–20

Wall H, Tauson R, and Elwinger K. 2002. Effect of nest design, passages, and hybrid on use of nest and production performance of layers in furnished cages. *Poultry Science* **81**(3): 333–339

Weeks C, and Nicol C. 2006. Behavioural needs, priorities and preferences of laying hens. *World's Poultry Science Journal* **62**: 296–307

Zheng HY, Li BM, Chen G and Wang CY. 2018. Improving the utilisation of nests and decreasing mislaid eggs with narrow width of group nests. *International Journal Agricultural and Biological Engineering* **11**(1): 83–87