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TECHNICAL AND ECONOMIC EFFICIENCY ANALYSES OF THE PRODUCTIVE PERFORMANCE AND EGG QUALITY PARAMETERS IN LAYING HENS FED BY DIETS CONTAINING RAW AND TREATED COMMON VETCH SEED AT DIFFERENT LEVELS

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ABSTRACT

The aim of the study was to determine the technical and economic optimum levels of raw and treated common vetch seed *(CVS)* on the productive performance and egg quality traits in laying hens. One hundred and sixty-eight White *(Lohmann)* layers, 30 weeks of age were randomly assigned to seven groups, each with six replicate cages of four hens. Control diet *(C)* and basal diets supplemented with 12.5 and 25% raw *CVS (%12.5 Raw Common Vetch Seed: RCVSI* and *%25 Raw Common Vetch Seed: RCVSII),* 12.5% and 25% soaking *CVS (%12.5 Soaking Common Vetch Seed: SCVSI* and *%25 Soaking Common Vetch Seed: SCVSII)* and 12.5% and 25% autoclaving *CVS (%12.5 Autoclaving Common Vetch Seed: ACVSI* and *%25 Autoclaving Common Vetch Seed: ACVSII)* were offered for 18 wks. Production elasticity *(E_p)* and the equation of marginal value of physical product *(MVPP)* and marginal resources cost *(MRC)* were used to determine technical and economic production levels, respectively. The most effective technical and economic optimum with 60.17 and 63.54 g *EW* (egg weight) in laying hens were obtained from 117.29 and 106.68 g *SCVSI* feed intakes, respectively. On the other hand, the highest technical optimum levels were obtained by 2.51 kg cm^{-2} *SS* (shell strength) and 89.56 *HU* (Haugh unit) per 90.91 g *ACVSII* and 103.97 g *RCVSII* feed intakes, respectively. The growers could reach to the highest technical and economic optimum levels in laying hens by preferring dietary *CVS* supplementation vs. *C*, and thus could provide a major benefit with the effective usage of the scarce source.

Key words: laying hens, common vetch seed, technical and economic efficiency, performance, egg quality.

INTRODUCTION

The effect of diets on the performance and egg quality of laying hens has been widely investigated in recent years; however, the relationships between the technical and economic efficiency of poultry feeds and performance traits of hens have not been investigated. Provision of balanced feed in layers has always been a major issue since there is a strong relationship between feed intake and egg quality as the performance indicators of hens. Therefore, feeding in laying hens has bears a great significance for improving egg production and quality (Celebi and Macit, 2009; Bozkurt *et al.*, 2008). The feed cost accounts for approximately 75-80% of the total production cost (Anderson, 2009; Wu *et al.*, 2008). Total cost of the energy and protein with fairly changeable source in poultry diets, further, include about 85% of the feed cost (Gunawardana *et al.*, 2008; Nanashon *et al.*, 2007).

Without decreasing egg quality and yield of laying hens, the inclusion of the most important and cheaper sources of the dietary energy and protein into the poultry diets can minimize feeding and egg production costs. In order to achieve this, the feed manufacturers should use a balanced diet composition to minimize production cost by providing a higher productivity effect on performance factors such as age, layer strain and rearing system affecting amount and quality of egg production. In other word, the commercial poultry feeds prepared with soybean-based diets not only are much more expensive but also lead to excessive use of the natural scarce sources with more alternative sources such as cereals and other legumes (vetch and alfalfa, etc.), thereby increasing production cost resulting from the technical and economic inefficiency of the scarce production factors could dramatically decrease annual net agricultural incomes of the growers.

Common Vetch Seed *(CVS) (Vicia Sativa L.)* is one of the most important and cheaper sources of dietary protein and energy, and is added to the diets of laying hens after treatment through various techniques or as a raw vetch. *CVS* is a common rain-fed forage legume best adapted to the semiarid and arid regions of the Mediterranean basin, and extensively grown to provide the seed being rich in protein and energy contents, and used as a source of concentrated feed for the farm animals among alternative farming systems in Turkey and worldwide (Yalcin *et al.*, 2003; Farran *et al.*, 2002; Kendir, 1999). It is a valuable crop in sustainable agricultural production because of its drought resistance and capability of improving soil fertility through nitrogen fixation. Although it contains relatively higher levels of protein (about 20-45%) and energy (more than 50%) yet in poultry diets. It is poorly utilized due to some allergenic and antigenic substances as well as antinutritional factors (Gul *et al.*, 2005). The presences of -cyanoalanine, vicine and convicine among the factors and substances in raw *CVS* limit its use in the diets of monogastric animals (Ressler and Takate, 2001; Darre *et al.*, 1998). As a result of individual or combined effect of these compounds; hypersensitivity, structural changes in villous and small intestine, enlargement of pancreas and toxicity may compromise the synthesis of digestive enzymes and the utilization of the nutrients (Gul *et al.*, 2005; Farran *et al.*, 2002).

Therefore, to reduce the adverse effects of raw *CVS* and to improve the utilization by increasing its nutritive value, most researches have focused on the effects of physical and chemical treatments in poultry rations, and it has been evaluated by several detoxification techniques, including soaking in water, acetic acid, sodium and potassium bicarbonate solutions and boiling as well as autoclaving (Saki *et al*., 2008; Darre *et al*., 1998), and the inclusion of treated *CVS* into the poultry diets did not create any negative effect on performance and egg quality of laying hens (Farran *et al.*, 2001).

Although poultry performance variables in response to raw and treated *CVS* are available, their optimal technical and economic efficiency levels are not yet known. Therefore, this study was designed to determine the technical and economic optimal production levels of the relationships between performances and egg quality of laying hens and six different diet levels resulting from the inclusion of *CVS* into the control diets of layers during the peak production period.

MATERIALS AND METHODS

Birds, Diet and Management: One hundred and sixty-eight, White *(Lohmann)* layers, 30 weeks of age, with uniformity of 87% (the number of hens weighing between 0.9-1.1% of the mean body weight) at the peak period of egg production, were housed according to the location of cages (50 cm width x 46 cm depth x 46 cm height). In a complete randomized block design experiment, the location of cages (cages at upper or lower level and/or by window or corridor side) was considered as a blocking factor due to a possibility of differences in airflow and light-intensity. After adaptation period of one week, the birds were randomly assigned to receive one of seven iso-caloric and iso-nitrogenous experimental diets: control diets containing 12.5 and 25% raw *RCVS*, cured for 24 h at 40 ^{0}C after soaked in water at 1:5 (wt/vol) rate and at room temperature during six days with a water change every 72 h *SCVS*, and autoclaved for 5 h at 140 ^{0}C *ACVS* for 14 weeks. Each treatment was replicated in 6 cages with 4 hens each.

It was reported that although raw *CVS* could be used safely at the inclusion rates of up to 5% in broiler diets (Saki *et al.*, 2008; Yalcin *et al.*, 2003), those of more than 20% in layer and 15% in broiler diets depresses their performances (Gul *et al.*, 2005). Furthermore, several studies supported that while the inclusions of raw *CVS* into laying hens diets at 10, 15.6 and 25% rates decreased daily feed intake and egg production and increase feed conversion (Yoruk *et al.*, 2003; Farran *et al*., 2001), those at 30, 50 and 60% resulted in mortality rates ranging from 97 to 100% a cessation of egg production in laying hens within 14 days post-feeding (Farran *et al.*, 2002; Farran *et al.*, 2001a).

The results of several experimental studies also showed that persisting toxicity symptoms after boiling at 70 ^{0}C for 24 h by soaking *CVS* in water for 24 h at room temperature or at 1:10 (wt/vol) in water at 40 ^{0}C for 72 h with a water change every 12 h (40 WV) or in 1% acetic acid at room temperature (or at 40 ^{0}C for 24 h), and autoclaving raw *CVS* directly at 140 ^{0}C for 5 h were not observed (Farran *et al.*, 2002; Farran *et al.*, 2001)

The detailed of experimental diets (Table 1) were formulated to meet the *NRC* recommendations (Jurgens, 1996). During the experimental period (90 days), feed and water were provided ad libitum and the eggs of the hens subjected to a 17:7 hours L:D cycle were collected once daily at 08:30 am.

Sample Collection and Analytical Procedure: Feed samples were collected every five days and analyzed for crude protein *(CP)*, dry matter *(DM)*, ether extract *(EE)*, crude fibre *(CF)*, acid detergent fibre *(ADF)*, neutral detergent fibre *(NDF)* and crude ash *(CA)* using by standard methods (AOAC, 1990). Metabolic energy *(ME)* and *CP* contents of the experimental diets were calculated from tabular values (Jurgens, 1996). Daily feed intake, egg weight *(EW)* and g/day *EW* gained per g/day feed intake were measured every five days. Before determination of EW, the samples of eggs from each experimental group were stored for 24 hours at room temperature, and then weighed with 0.1 mg precious balance.

Samples of 12 eggs randomly collected from each experimental group, every five-days were also collected to assess egg quality parameters (Haugh unit *(HU)* and shell strength *(SS)*) (Gunawardana *et al.*, 2009). Egg quality parameters were calculated using the following formulae and methods (Macit *et al.*, 2008): *SS* (kg/cm^2) using a machine with a spiral pressure system and $HU = 100 \times \log (AH + 7.57 - 1.7 \times EW^{0.37})$, where *AH* is albumen height (mm) and *EW* is egg weight (g).

Technical and Economic Effectiveness Analyses: The effects of the feed intake on the egg quality and performance of laying hens were analyzed by taking into consideration the following production function:

$$TPP_{in} = f(F_{in}) \quad (1)$$

Where F_{in} is the daily feed intake based on the feed types *(if ration covers feed types such as RCVSI, RCVSII, SCVSI, SCVSII, ACVSI, ACVSII and C; n presents from 1 to 7 numbers, and i refers to production levels of EW, SS and HU)*, and TPP_{in} refers *EW* and the external and internal egg quality parameters *(SS and HU)* calculated as a function of the F_{in}.

In order to measure the relationships between the feed intake and the egg quality parameters and performance of laying hens, and then to determine the optimal levels of *SS*, *HU* and *EW*, the technical production analyses including in *Marginal Physical Product (MPP), Average Physical Product (APP) and Production Elasticity (E_P)* were used (Topcu and Demir, 2005).

MPP was the extra output amount produced by using one more unit of the production factors (inputs), holding all other inputs fixed (*caeteris paribus*). *MPP* of a given experimental diet was expressed as follows:

$$MPP_{1,2in} = \frac{\Delta TPP_{1,2in}}{\Delta F_{1,2in}} \quad (2)$$

Where $\Delta F_{1,2in}$ and $\Delta TPP_{1,2in}$ were the changes in the feed amounts consumed and total physical product produced, respectively.

APP was the amount of total physical product produced per unit of feed intake as a variable input. In other word, *APP* was determined by dividing the total physical product with the amount of the variable feed, and was calculated by using the following mathematical notation:

$$APP_{in} = \frac{TPP_{in}}{F_{in}} \quad (3)$$

Where TPP_{in} and F_{in} explained the total physical product and the feed amount consumed, respectively.

The production elasticity *(E_p)* indicated approach, around how much per cent the production amount of the *TPP* changed, if the feed intake was increased by a per cent unit. In other words, it was the percentage change of *TPP* divided by the percentage change of feed intake. It was determined as follows:

$$E_p = \frac{\frac{\Delta TPP_{1,2in}}{TPP_{1in}} \cdot 100}{\frac{\Delta F_{1,2in}}{F_{1in}} \cdot 100} = \frac{\Delta TPP_{1,2in}}{TPP_{1in}} \cdot \frac{F_{1in}}{\Delta F_{1,2in}} \quad (4)$$

If the equation 4 could rearrange as follows:

$$E_p = \frac{\Delta TPP_{1,2in}}{\Delta F_{1,2in}} : \frac{TPP_{1in}}{F_{1in}} = \frac{MPP_{1,2in}}{APP_{1in}} \quad (5)$$

E_p was calculated by dividing the $MPP_{1,2in}$ *(the equation 2)* by the APP_{in} *(the equation 3)*. It was used as a major measurement tool to reach to an optimal production level technically in terms of production economics. Moreover, it must be greater than 0, but less than 1 ($0<E_p<1$) to reach to the beginning and end limits of the rational production region determined by the maximum point of the APP_{in} equalling to the $MPP_{1,2in}$ *(E_p=1)* and the minimum point equalling to the zero of the $MPP_{1,2in}$ *(E_p=0)*.

In order to be able to determine the economic optimum level, on the other hand, assessing the income and cost effects of *EW* based on the feed intakes of laying hens; *Marginal Value of Physical Product (MVPP)* and *Marginal Resource Cost (MRC)* were firstly calculated. If *MVPP* was equal to *MRC* or a little greater than $MRC\left(MVPP \geq MRC\right)$, it was assumed to have been reached to the economic optimum level (Topcu and Demir, 2005; Yaylali, 2004). *MVPP* and *MRC* were formulated by using the following equations:

$$MVPP_{1,2in} = \frac{\Delta TVPP_{1,2in}}{\Delta F_{1,2in}} = \frac{P_{pp}(\Delta TPP_{1,2in})}{\Delta F_{1,2in}} = P_{pp}\left(MPP_{1,2in}\right) \quad (6)$$

Where $\Delta TVPP_{1,2in}$ and P_{pp} indicated the change in the total value of physical product and the price of physical product ($4 giving the average of the producer prices collected per kg), respectively (FAOSTAT, 2011; TSI, 2011).

$$MRC_{1,2in} = \frac{\Delta TRC_{1,2in}}{\Delta F_{1,2in}} = \frac{P_{F_n}\left(\Delta F_{1,2in}\right)}{\Delta F_{1,2in}} = P_{F_n} \quad (7)$$

Where $\Delta TRC_{1,2in}$ and P_{F_n} presented the change in the total feed resource cost and the prices of the experimental feed considering the average of the producer prices collected per kg (*P_B = \$0.55, P_{RCVSI} = \$0.58, P_{RCVSII} = \$0.62, P_{SCVSI} = \$0.59 (calculated by being added 7% transaction costs to P_{RCVSI}), P_{SCVSII} = \$0.63 (calculated by being added 7% transaction costs to P_{RCVSII}), P_{ACVSI} = \$ 0.60 (calculated by being added 10% transaction costs to P_{RCVSI}), P_{ACVSII} = \$0.64 (calculated by being added 10% transaction costs to P_{RCVSII})*) (FAOSTAT, 2011; TSI, 2011; BFF, 2011).

RESULTS AND DISCUSSION

Tables 2 and 3 showed the technical and economic production levels of egg weight *(EW)* and shell strength *(SS)*, and Haugh unit *(HU)* in laying hens fed *RCVSI* and *RCVSII*. With 60.42 and 55.79 g *EWs* gained in response to 125.91 g *RCVSI* and 111.91 g *RCVSII* feed intakes, it was reached to the closest economic optimum levels $(MVPP = 0.79 \geq MRC = 0.58)$ and $(MVPP = 0.70 \geq MRC = 0.62)$, respectively. On the other hand, 62.88 and 62.60 g *EW* gained with 2.05 and 2.54 kg cm^{-2} *SS* and 89.15 and 89.56 *HU* recorded for 116.59 and 113.52, 119.18 and 95.04, 133.63 and 103.97 g *RCVSI* and *RCVSII* feed intakes provided the technical optimum levels (the rational production region) with E_{EW} = 0.77 and 0.80, E_{SS} = 0.73 and 0.84, E_{HU} = 0.44 and 0.89, respectively.

As compared to technical optimum production levels of *RCVSI* and *RCVSII* feed intakes, it is evident that those of *RCVSII* feed intake had a more pronounced effect than those of *RCVSI*, and thus it is better than *RCVSI* in laying hens diets.

The technical and economic production levels of *EW* and *SS* and *HU* of laying hens fed *SCVSI* and *SCVSII* were presented in Tables 4 and 5. The closest economic optimum levels for *SCVSI* $(MVPP = 1.27 \geq MRC = 0.59)$ and *SCVSII* $(MVPP = 1.06 \geq MRC = 0.63)$ were obtained with 63.54 and 60.83 g *EWs* achieved per 117.29 g *SCVSI* and 105.99 g *SCVSII* feed intake, respectively. However, 60.17 and 59.65 g *EW*, 1.77 and 1.63 kg cm^{-2} *SS* and 85.51 and 82.15 *HU* recorded with 106.68 and 101.54, 113.71 and 101.71, 104.09 and 99.50 g *SCVSI* and *SCVSII* feed intakes indicated the technical optimum levels with E_{EW} = 0.88 and 0.78, E_{SS}= 0.29 and 0.53, E_{HU} = 0.61 and 0.80, respectively.

When compared with technical optimum levels of *SCVSI* and *SCVSII* feed intakes, it was analyzed that the optimal effectiveness levels of *SS* and *HU* provided with *SCVSII* feed intake were higher than those obtained from *SCVSI* feed intake, but was not that of *EW*. Therefore, *SCVSII* could be preferred to *SCVSI* for egg quality, but *SCVSI* could be better than that of the other for the performance in laying hens diets.

Tables 6 and 7 summarized the technical and economic production levels of *EW* and its *SS* and *HU* of laying hens fed *ACVSI* and *ACVSII* feed. Both technical and economic optimum levels of *ACVSI* (E_{EW} = 0.59) and $(MVPP = 1.24 \geq MRC = 0.60)$, and *ACVSII* ($E_{EW}$ = 0.82) and $(MVPP = 1.66 \geq MRC = 0.64)$ feed intakes were realized by the 61.93 and 62.84 g *EWs* brought about per 118.68 g *ACVSI* and 124.16 g *SCVSII* feed intakes, respectively. Moreover, 2.50 and 2.51 kg cm^{-2} *SS*, and 82.21 and 92.02 *HU* calculated for 118.68 and 90.91, and 127.80 and 112.57 g *ACVSI* and *ACVSII* feed intakes gave the technical optimum levels with E_{SS} = 0.31 and 0.96, and E_{HU} = 0.53 and 0.56, respectively.

When compared with the technical optimum levels of *ACVSI* and *ACVSII*, it was observed that the optimal effectiveness levels of *EW, SS* and *HU* for *ACVSII* feed intake were higher than those for *ACVSI*. Therefore, *ACVSII* was better than *ACVSI* in laying hens diets.

Table 8 presented the technical and economic production levels of *EW* and its *SS* and *HU* of laying hens fed by *C*. Economic optimum level for *C* $(MVPP = 1.22 \geq MRC = 0.55)$ was determined by 62.66 g *EW* gained per 118.79 g *C* feed intake. 65.97 g *EW*, 2.15 kg cm^{-2} *SS* and 80.41 *HU* calculated for 125.96, 118.79 and 135.79 g *C* feed intakes, furthermore, supported by the technical optimum levels with E_{EW} = 0.58, E_{SS} = 0.94 and E_{HU} = 0.25 and 0.56, respectively.

As a result of the economic optimum levels taking into consideration relationship between *EW* and alternative *CVS* feed intakes, the highest (63.54 g) and lowest (55.79 g) *EWs* were obtained by 117.29 g *SCVSI* and 111.91 g *RCVSII* feed intake, and thus their *Eps* determined for the best economic efficiency levels were 0.59 and 0.35, respectively (Table 3, 4 and 9). These results were supported by a number of the studies taking into consideration *Eps* with the range 0.22 and 0.98 at the economic efficiency levels of the relationships between the poultry diets enriched by supplementary ingredient and the poultry egg production (Topcu and Arslan, 2013; Begum *et al.*, 2011; Mohaddes, 2011; Oladeebo and Ambe-Lamidi, 2007; Ojo, 2003). The production at the economic efficiency levels of laying hens for *SCVSI* and *RCVSII* intake mean that took place at the stage II of total physical product *(TPP)* curve (the efficient region of the egg production), and that occurred a lower increase than one percent increase in their *EW* gains in response to one percent increase in *SCVSI* and *RCVSII* intake. When being carried out such a production for these feeds, it was utilized from the advantages of the scale economics, and the factor cost may cause the production cost per scale to decrease dramatically due to the efficiency of the scarce production sources. Therefore, it could be economically achieved up to the targeted *EWs* by providing the needed feed types and quantity of feed.

The results of the present study also indicated that 60.17 and 65.97 g *EWs* gained in response to 106.68 g *SCVSI* and 125.96 g *C* intake were achieved at the highest and lowest technical optimum levels (E_{EW} = 0.88 and 0.58). On the other hand, 2.51 and 1.77 kg cm^{-2} *SS* per 90.91 g *ACVSII* and 113.71 g *SCVSI* intake, and 89.56 and 80.41 *HU* per 103.97 g *RCVSII* and 135.96 g *C* intake were also provided at the highest and lowest technical optimum levels (E_{SS} = 0.96 and 0.29, E_{SS} = 0.89 and 0.25) (Table 9). The results of the present study are similar to those of the previous research conducted on the technical efficiency levels restricted by *Ep*s varying between 0.10 and 0.99, and considering the relationships between hens' performances and their feed intake (Topcu and Arslan, 2013; Ashagidigbi *et al.*, 2011; Begum *et al.*, 2011; Heidari *et al.*, 2011; Mohaddes, 2011; Binuomote *et al.*, 2008; Change and Villano, 2008; Alabi and Uruna, 2006; Ojo, 2003). Therefore, the farmers could technically obtain the targeted *EW, SS* and *HU* by providing the needed feed types and quantity of feed.

Table 1. Ingredients and chemical composition of the experimental diets (%)

	Experimental Diets[1]						
	C	***RCVSI***	***RCVSII***	***SCVSI***	***SCVCII***	***ACVSI***	***ACVSII***
Ingredients (%)							
Control diet	100	74.48	49.66	74.48	49.66	74.48	49.66
Common vetch seed	0	12.58	24.83	12.58	24.83	12.58	24.83
Barley	0	12.58	24.83	12.58	24.83	12.58	24.83
Lysine	0.016	0.008	0.016	0.008	0.016	0.008	0.016
Methionine	0.016	0.008	0.016	0.008	0.016	0.008	0.016
Choline chloride	0.016	0.008	0.016	0.008	0.016	0.008	0.016
Sulfur	0.003	0.002	0.003	0.002	0.003	0.002	0.003
Chemical composition (%)							
CP	15.91	19.13	16.44	17.56	17.63	17.95	15.91
DM	91.97	89.94	90.41	91.01	90.94	90.87	90.30
EE	3.89	3.31	2.44	3.28	2.82	3.07	3.77
ADF	7.04	7.85	7.90	6.96	9.63	7.51	8.16
NDF	25.18	34.02	23.79	25.31	35.38	29.23	25.89
CF	6.18	4.52	4.95	3.55	5.83	6.49	5.27
CA	13.31	10.14	9.26	10.25	9.50	10.76	7.76
ME[2] *Kcal/kg*	2650	2637	2634	2637	2634	2637	2634
CP[2]	16.00	16.00	16.00	16.00	16.00	16.00	16.00

[1]Diets: *C* = control diet containing commercial second period meal of laying hens; *RCVSI* = control diet containing raw common vetch seed (12.5%); *RCVSII* = control diet containing raw common vetch seed (25%); *SCVSI* = control diet containing cured common vetch seed after soaking (12.5%); SCVSII = control diet containing cured common vetch seed after soaking (25%); *ACVSI* = control diet containing autoclaved common vetch seed (12.5%); *ACVSII* = control diet containing autoclaved common vetch seed (25%).
[2] It is calculated from tabular values of feedstuffs for chickens (Jurgens, 1996).

Table 2. Technical and economic production levels of *EW, SS* and *HU* based on *RCVSI* feed of laying hens

RCVSI	***EW***	***MPP***	***APP***	E_{EW}	***MVPP***	***MRC***	***SS***	***MPP***	***APP***	E_{SS}	***HU***	***MPP***	***APP***	E_{HU}
112.39	57.74	-	0.51	-	-	-	1.97	-	0.018	-	88.06	-	0.78	-
125.91	**60.42**	**0.20**	**0.48**	**0.41**	**0.79**	**0.58**	0.97	-0.074	0.008	-9.60	87.37	-0.05	0.69	-0.07
116.10	54.30	0.62	0.47	1.33	2.50	0.58	1.17	-0.020	0.010	-2.02	94.88	-0.76	0.82	-0.94
125.29	60.93	0.72	0.49	1.48	2.89	0.58	1.23	0.007	0.010	0.67	93.41	-0.16	0.75	-0.21
115.21	54.01	0.69	0.47	1.46	2.75	0.58	2.00	-0.076	0.017	-4.40	84.71	0.86	0.74	1.17
119.18	***64.02***	***2.52***	***0.54***	***4.69***	***10.09***	***0.58***	***2.05***	***0.013***	***0.017***	***0.73***	***87.96***	***0.82***	***0.74***	***1.11***
118.23	60.60	3.63	0.51	7.08	14.50	0.58	1.35	0.742	0.011	65.02	72.74	16.14	0.62	26.24
122.82	67.97	1.61	0.55	2.90	6.43	0.58	1.33	-0.004	0.011	-0.40	85.20	2.71	0.69	3.91
123.21	65.94	-5.18	0.54	-9.68	-20.72	0.58	1.82	1.247	0.015	84.44	79.53	-14.42	0.65	-22.33
122.64	65.40	0.95	0.53	1.78	3.79	0.58	1.65	0.297	0.013	22.11	87.89	-14.62	0.72	-20.41
116.59	***62.88***	***0.42***	***0.54***	***0.77***	1.66	0.58	1.66	-0.002	0.014	-0.12	93.36	-0.90	0.80	-1.13
117.82	65.82	2.39	0.56	4.28	9.57	0.58	1.60	-0.049	0.014	-3.59	78.65	-11.93	0.67	-17.87
125.30	60.63	-0.69	0.48	-1.44	-2.78	0.58	1.67	0.009	0.013	0.70	94.43	2.11	0.75	2.80
128.66	62.67	0.61	0.49	1.25	2.44	0.58	1.55	-0.036	0.012	-2.97	87.68	-2.01	0.68	-2.95
133.63	55.84	-1.38	0.42	-3.30	-5.51	0.58	1.52	-0.006	0.011	-0.53	***89.15***	***0.30***	***0.67***	***0.44***
107.38	65.96	-0.39	0.61	-0.63	-1.54	0.58	0.45	0.041	0.004	9.73	87.57	0.06	0.82	0.07
115.21	65.21	-0.10	0.57	-0.17	-0.38	0.58	1.47	0.130	0.013	10.20	97.38	1.25	0.85	1.48
113.76	57.60	5.24	0.51	10.35	20.96	0.58	1.69	-0.151	0.015	-10.20	87.52	6.79	0.77	8.82

*Bold and italic bold numbers refer the economic optimum and technical optimum levels, respectively.

Table 3. Technical and economic production levels of *EW, SS* and *HU* based on *RCVSII* feed of laying hens

RCVSII	***EW***	***MPP***	***APP***	E_{EW}	***MVPP***	***MRC***	***SS***	***MPP***	***APP***	E_{SS}	***HU***	***MPP***	***APP***	E_{HU}
110.01	64.39	-	0.59	-	-	-	2.55	-	0.023	-	86.70	-	0.79	-
103.17	65.30	-0.13	0.63	-0.21	-0.53	0.62	2.71	-0.023	0.026	-0.89	85.98	0.11	0.83	0.13
100.01	53.70	3.67	0.54	6.83	14.66	0.62	2.38	0.104	0.024	4.38	84.93	0.33	0.85	0.39
111.91	**55.79**	**0.18**	**0.50**	**0.35**	**0.70**	**0.62**	0.65	-0.145	0.006	-25.02	95.19	0.86	0.85	1.01
95.83	58.41	-0.16	0.61	-0.27	-0.65	0.62	2.05	-0.087	0.021	-4.07	83.33	0.74	0.87	0.85
103.97	58.40	0.00	0.56	0.00	-0.01	0.62	1.28	-0.095	0.012	-7.68	***89.56***	***0.76***	***0.86***	***0.89***
113.52	***62.60***	***0.44***	***0.55***	***0.80***	1.76	0.62	1.56	0.029	0.014	2.13	88.51	-0.11	0.78	-0.14

123.64	56.76	-0.58	0.46	-1.26	-2.31	0.62	2.00	0.043	0.016	2.69	90.06	0.15	0.73	0.21
97.07	62.73	-0.22	0.65	-0.35	-0.90	0.62	2.66	-0.025	0.027	-0.91	87.26	0.11	0.90	0.12
116.92	64.51	0.09	0.55	0.16	0.36	0.62	1.90	-0.038	0.016	-2.36	97.99	0.54	0.84	0.64
87.89	59.28	0.18	0.67	0.27	0.72	0.62	2.38	-0.017	0.027	-0.61	89.11	0.31	1.01	0.30
95.04	57.66	-0.23	0.61	-0.37	-0.90	0.62	***2.54***	***0.022***	***0.027***	***0.84***	87.96	-0.16	0.93	-0.17
109.64	63.77	0.42	0.58	0.72	1.67	0.62	1.22	-0.090	0.011	-8.12	91.91	0.27	0.84	0.32
128.40	63.43	-0.02	0.49	-0.04	-0.07	0.62	2.03	0.043	0.016	2.73	88.23	-0.20	0.69	-0.29
103.48	53.23	0.41	0.51	0.80	1.64	0.62	0.82	0.049	0.008	6.13	89.44	-0.05	0.86	-0.06
111.93	61.27	0.95	0.55	1.74	3.81	0.62	2.66	0.218	0.024	9.17	92.92	0.41	0.83	0.50
104.26	60.20	0.14	0.58	0.24	0.56	0.62	2.69	-0.004	0.026	-0.15	88.97	0.52	0.85	0.60
93.04	63.98	-0.34	0.69	-0.49	-1.35	0.62	0.48	0.197	0.005	38.16	87.22	0.16	0.94	0.17

*Bold and italic bold numbers refer the economic optimum and technical optimum levels, respectively.

Table 4. Technical and economic production levels of *EW, SS* and *HU* based on *SCVSI* feed of laying hens

SCVSI	***EW***	***MPP***	***APP***	E_{EW}	***MVPP***	***MRC***	***SS***	***MPP***	***APP***	E_{SS}	***HU***	***MPP***	***APP***	E_{HU}
116.50	67.84	-	0.58	-	-	-	1.73	-	0.015	-	86.02	-	0.74	-
115.81	61.99	8.48	0.54	15.85	33.92	0.59	1.68	0.073	0.015	5.00	86.23	-0.31	0.74	-0.41
117.65	55.83	-3.36	0.47	-7.08	-13.43	0.59	2.53	0.463	0.022	21.53	76.64	-5.22	0.65	-8.02
102.51	64.01	-0.54	0.62	-0.87	-2.16	0.59	2.00	0.035	0.020	1.79	91.80	-1.00	0.90	-1.12
122.87	62.09	-0.09	0.51	-0.19	-0.38	0.59	1.57	-0.021	0.013	-1.65	87.44	-0.21	0.71	-0.30
115.66	61.47	0.09	0.53	0.16	0.35	0.59	0.86	0.098	0.007	13.24	93.34	-0.82	0.81	-1.01
118.82	65.38	1.24	0.55	2.25	4.95	0.59	2.66	0.569	0.022	25.41	86.61	-2.13	0.73	-2.92
127.00	61.29	-0.50	0.48	-1.04	-2.00	0.59	1.83	-0.101	0.014	-7.04	87.25	0.08	0.69	0.11
113.71	63.65	-0.18	0.56	-0.32	-0.71	0.59	***1.77***	***0.005***	***0.016***	***0.29***	72.15	1.14	0.63	1.79
106.68	***60.17***	***0.49***	***0.56***	***0.88***	1.98	0.59	1.79	-0.003	0.017	-0.17	92.52	-2.90	0.87	-3.34
117.29	**63.54**	**0.32**	**0.54**	**0.59**	**1.27**	**0.59**	1.47	-0.030	0.013	-2.41	80.01	-1.18	0.68	-1.73
117.52	65.12	6.84	0.55	12.34	27.35	0.59	2.45	4.222	0.021	202.49	87.09	30.50	0.74	41.16
118.46	64.60	-0.55	0.55	-1.02	-2.21	0.59	1.51	-0.993	0.013	-77.92	86.23	-0.91	0.73	-1.25
110.21	60.61	0.48	0.55	0.87	1.94	0.59	1.67	-0.019	0.015	-1.28	87.32	-0.13	0.79	-0.17
111.04	60.56	-0.06	0.55	-0.10	-0.22	0.59	1.77	0.122	0.016	7.64	88.99	2.03	0.80	2.53
104.09	67.72	-1.03	0.65	-1.58	-4.12	0.59	1.50	0.039	0.014	2.70	***85.51***	***0.50***	***0.82***	***0.61***
123.73	66.65	-0.05	0.54	-0.10	-0.22	0.59	2.00	0.025	0.016	1.57	78.60	-0.35	0.64	-0.55
121.14	62.86	1.47	0.52	2.83	5.87	0.59	0.49	0.583	0.004	144.18	87.87	-3.58	0.73	-4.93

*Bold and italic bold numbers refer the economic optimum and technical optimum levels, respectively.

Table 5. Technical and economic production levels of *EW, SS* and *HU* based on *SCVSII* feed of laying hens

SCVSII	***EW***	***MPP***	***APP***	E_{EW}	***MVPP***	***MRC***	***SS***	***MPP***	***APP***	E_{SS}	***HU***	***MPP***	***APP***	E_{HU}
96.79	57.48	-	0.59	-	-	-	1.84	-	0.019	-	83.75	-	0.87	-
101.54	***59.65***	***0.46***	***0.59***	***0.78***	1.83	0.63	2.27	0.090	0.022	4.05	82.63	-0.24	0.81	-0.29
105.99	**60.83**	**0.27**	**0.57**	**0.46**	**1.06**	**0.63**	3.22	0.214	0.030	7.03	81.61	-0.23	0.77	-0.30
107.68	59.05	-1.06	0.55	-1.92	-4.22	0.63	1.18	-1.208	0.011	-110.19	87.52	3.50	0.81	4.31
85.16	62.00	-0.13	0.73	-0.18	-0.52	0.63	1.49	-0.014	0.017	-0.79	80.77	0.30	0.95	0.32
101.71	52.81	-0.55	0.52	-1.07	-2.22	0.63	***1.63***	***0.008***	***0.016***	***0.53***	85.08	0.26	0.84	0.31
97.34	61.68	-2.03	0.63	-3.20	-8.12	0.63	1.90	-0.062	0.020	-3.17	79.78	1.21	0.82	1.48
98.55	63.07	1.14	0.64	1.79	4.57	0.63	1.47	-0.355	0.015	-23.79	87.70	6.53	0.89	7.34
109.04	56.71	-0.61	0.52	-1.17	-2.43	0.63	1.82	0.033	0.017	2.00	89.63	0.18	0.82	0.23
117.59	56.95	0.03	0.48	0.06	0.11	0.63	1.56	-0.030	0.013	-2.29	81.32	-0.97	0.69	-1.40
100.86	54.99	0.12	0.55	0.21	0.47	0.63	2.00	-0.026	0.020	-1.33	89.67	-0.50	0.89	-0.56
103.59	53.58	-0.51	0.52	-1.00	-2.06	0.63	1.98	-0.007	0.019	-0.38	84.84	-1.77	0.82	-2.16
105.83	67.43	6.17	0.64	9.68	24.68	0.63	1.77	-0.094	0.017	-5.60	85.40	0.25	0.81	0.31
98.38	60.55	0.92	0.62	1.50	3.69	0.63	1.90	-0.017	0.019	-0.90	88.03	-0.35	0.89	-0.39
104.59	62.93	0.38	0.60	0.64	1.53	0.63	1.68	-0.035	0.016	-2.20	86.44	-0.25	0.83	-0.31
118.84	57.33	-0.39	0.48	-0.81	-1.57	0.63	2.58	0.063	0.022	2.91	94.92	0.59	0.80	0.74
99.50	59.71	-0.12	0.60	-0.20	-0.49	0.63	2.66	-0.004	0.027	-0.15	***82.15***	***0.66***	***0.83***	***0.80***
98.64	55.76	4.60	0.57	8.14	18.41	0.63	1.00	1.937	0.010	191.04	93.32	-13.02	0.95	-13.76

*Bold and italic bold numbers refer the economic optimum and technical optimum levels, respectively.

Table 6. Technical and economic production levels of *EW, SS* and *HU* based on *ACVSI* feed of laying hens

ACVSI	*EW*	*MPP*	*APP*	E_{EW}	*MVPP*	*MRC*	*SS*	*MPP*	*APP*	E_{SS}	*HU*	*MPP*	*APP*	E_{HU}
120.73	66.54	-	0.55	-	-	-	1.13	-	0.009	-	86.12	-	0.71	-
132.00	65.72	-0.07	0.50	-0.15	-0.29	0.60	0.96	-0.015	0.007	-2.07	73.65	-1.11	0.56	-1.98
134.85	69.60	1.36	0.52	2.64	5.44	0.60	2.21	0.438	0.016	26.73	77.45	1.33	0.57	2.32
124.95	60.86	0.88	0.49	1.81	3.53	0.60	3.08	-0.088	0.025	-3.57	92.97	-1.57	0.74	-2.11
123.21	62.29	-0.82	0.51	-1.62	-3.27	0.60	2.74	0.195	0.022	8.79	92.47	0.29	0.75	0.38
123.43	60.53	-8.08	0.49	-16.48	-32.33	0.60	2.63	-0.505	0.021	·23.70	89.05	-15.71	0.72	-21.77
119.66	69.37	-2.35	0.58	-4.05	-9.39	0.60	1.50	0.300	0.013	23.92	77.23	3.14	0.65	4.86
119.79	66.24	-25.00	0.55	-45.21	-100.00	0.60	1.49	-0.080	0.012	-6.43	88.86	93.04	0.74	125.42
124.89	61.99	-0.83	0.50	-1.68	-3.33	0.60	1.70	0.041	0.014	3.02	80.50	-1.64	0.64	-2.54
127.80	64.76	0.95	0.51	1.88	3.80	0.60	2.56	0.295	0.020	14.75	81.06	0.19	0.63	0.30
118.68	**61.93**	**0.31**	**0.52**	**0.59**	**1.24**	**0.60**	***2.50***	***0.007***	***0.021***	***0.31***	91.88	-1.19	0.77	-1.53
117.70	62.36	-0.43	0.53	-0.82	-1.73	0.60	1.66	0.855	0.014	60.64	81.79	10.27	0.69	14.78
125.77	68.77	0.79	0.55	1.45	3.18	0.60	1.27	-0.048	0.010	-4.78	84.42	0.33	0.67	0.49
120.80	65.51	0.66	0.54	1.21	2.63	0.60	2.23	-0.193	0.018	·10.48	79.80	0.93	0.66	1.41
127.80	62.30	-0.46	0.49	-0.94	-1.84	0.60	1.75	-0.069	0.014	-5.01	***82.21***	***0.34***	***0.64***	***0.53***
119.89	58.14	0.53	0.48	1.08	2.10	0.60	0.77	0.124	0.006	19.29	88.52	-0.80	0.74	-1.08
121.41	60.50	1.56	0.50	3.13	6.24	0.60	0.87	0.066	0.007	9.19	98.82	6.79	0.81	8.34
112.48	61.48	-0.11	0.55	-0.20	-0.44	0.60	0.61	0.029	0.005	5.37	96.79	0.23	0.86	0.27

*Bold numbers refer both economic and technical optimum levels for *EW*, and italic numbers refer the technical optimum levels.

Table 7. Technical and economic production levels of *EW, SS* and *HU* based on *ACVSII* feed of laying hens

ACVSII	*EW*	*MPP*	*APP*	E_{EW}	*MVPP*	*MRC*	*SS*	*MPP*	*APP*	E_{SS}	*HU*	*MPP*	*APP*	E_{HU}
112.53	59.86	-	0.53	-	-	-	3.08	-	0.027	-	93.37	-	0.83	-
90.91	68.95	-0.42	0.76	-0.55	-1.68	0.64	***2.51***	***0.026***	***0.028***	***0.96***	91.27	0.10	1.00	0.10
108.23	59.73	-0.53	0.55	-0.96	-2.13	0.64	1.97	-0.031	0.018	-1.71	82.74	-0.49	0.76	-0.64
112.14	62.99	0.84	0.56	1.49	3.35	0.64	3.17	0.307	0.028	10.87	86.31	0.92	0.77	1.19
109.54	68.14	-1.98	0.62	-3.18	-7.92	0.64	1.83	0.515	0.017	30.85	91.30	-1.92	0.83	-2.30
117.64	67.48	-0.08	0.57	-0.14	-0.33	0.64	2.31	0.059	0.020	3.02	80.23	-1.37	0.68	-2.00
112.95	59.77	1.64	0.53	3.10	6.57	0.64	2.25	0.013	0.020	0.64	92.42	-2.60	0.82	-3.17
101.11	65.92	-0.52	0.65	-0.80	-2.08	0.64	1.80	0.038	0.018	2.13	87.11	0.45	0.86	0.52
117.25	59.97	-0.37	0.51	-0.72	-1.47	0.64	2.69	0.055	0.023	2.40	81.94	-0.32	0.70	-0.46
124.16	**62.84**	**0.42**	**0.51**	**0.82**	**1.66**	**0.64**	1.90	-0.114	0.015	-7.48	97.33	2.23	0.78	2.84
112.57	68.43	-0.48	0.61	-0.79	-1.93	0.64	2.34	-0.038	0.021	-1.83	***92.02***	***0.46***	***0.82***	***0.56***
122.36	62.28	-0.63	0.51	-1.24	-2.51	0.64	1.91	-0.044	0.016	-2.82	91.69	-0.03	0.75	-0.04
91.63	64.05	-0.06	0.70	-0.08	-0.23	0.64	0.90	0.033	0.010	3.35	92.57	-0.03	1.01	-0.03
114.07	60.72	-0.15	0.53	-0.28	-0.59	0.64	1.61	0.032	0.014	2.24	98.82	0.28	0.87	0.32
125.12	57.53	-0.29	0.46	-0.63	-1.16	0.64	0.50	-0.100	0.004	-25.14	99.46	0.06	0.79	0.07
117.19	62.85	-0.67	0.54	-1.25	-2.69	0.64	2.91	-0.304	0.025	-12.24	92.70	0.85	0.79	1.08
98.88	63.25	-0.02	0.64	-0.03	-0.09	0.64	0.50	0.132	0.005	26.02	88.05	0.25	0.89	0.29
120.81	66.01	0.13	0.55	0.23	0.50	0.64	2.00	0.068	0.017	4.13	92.01	0.18	0.76	0.24

*Bold numbers refer both economic and technical optimum levels for *EW*, and italic numbers refer the technical optimum levels.

Table 8. Technical and economic production levels of *EW, SS* and *HU* based on *C* feed of laying hens

C	*EW*	*MPP*	*APP*	E_{EW}	*MVPP*	*MRC*	*SS*	*MPP*	*APP*	E_{SS}	*HU*	*MPP*	*APP*	E_{HU}
118.43	62.1	-	0.52	-	-	-	2.1	-	0.018	-	79.80	-	0.67	-
115.01	59.2	0.86	0.51	1.66	3.42	0.55	2.0	0.026	0.018	1.50	93.30	-3.95	0.81	-4.87
127.53	71.5	0.98	0.56	1.75	3.93	0.55	3.1	0.087	0.024	3.57	85.80	-0.60	0.67	-0.89
127.84	60.2	·37.10	0.47	-78.73	-148.39	0.55	2.3	-2.569	0.018	-140.97	76.20	-31.71	0.60	-53.22
131.05	64.6	1.37	0.49	2.77	5.47	0.55	1.5	-0.246	0.012	-20.89	87.30	3.47	0.67	5.21
125.96	64.2	0.08	0.51	0.16	0.33	0.55	2.7	-0.224	0.021	-10.53	91.80	-0.88	0.73	-1.20
126.14	63.99	-1.28	0.51	-2.52	-5.11	0.55	1.33	-7.560	0.011	-717.02	81.16	-59.60	0.64	-92.63
121.88	64.73	-0.17	0.53	-0.33	-0.69	0.55	2.27	-0.220	0.019	-11.83	92.82	-2.73	0.76	-3.59
115.96	***65.97***	***0.30***	***0.52***	***0.58***	1.22	0.55	2.17	-0.024	0.017	-1.42	78.96	-3.39	0.63	-5.41
135.91	66.46	0.05	0.49	0.10	0.19	0.55	1.68	-0.049	0.012	-3.99	***80.41***	***0.15***	***0.59***	***0.25***
133.79	62.76	1.74	0.47	3.71	6.96	0.55	2.00	-0.151	0.015	-10.07	88.52	-3.82	0.66	-5.77
128.61	69.96	-1.39	0.54	-2.56	-5.56	0.55	1.98	0.004	0.015	0.25	80.31	1.59	0.62	2.54
137.43	61.86	-0.92	0.45	-2.04	-3.67	0.55	2.20	0.025	0.016	1.56	79.86	-0.05	0.58	-0.09

126.36	64.24	-0.21	0.51	-0.42	-0.86	0.55	2.04	0.014	0.016	0.90	71.17	0.78	0.56	1.39
139.29	65.52	0.10	0.47	0.21	0.40	0.55	1.81	-0.018	0.013	-1.37	62.44	-0.68	0.45	-1.51
137.89	60.26	3.78	0.44	8.64	15.11	0.55	1.90	-0.065	0.014	-4.69	81.32	-13.56	0.59	-22.99
142.80	67.66	1.51	0.47	3.18	6.03	0.55	2.56	0.134	0.018	7.50	79.69	-0.33	0.56	-0.59
118.79	**62.66**	**0.21**	**0.53**	**0.40**	**0.83**	**0.55**	***2.15***	***0.017***	***0.018***	***0.94***	79.53	0.01	0.67	0.01

*Bold and italic bold numbers refer the economic optimum and technical optimum levels, respectively.

Table 9. Summary of the technical and economic optimal levels and group means of *EW, SS* and *HU* based on seven feed types of laying hens

	RCVSI		***RCVSII***		***SCVSI***		***SCVSII***		***ACVSI***		***ACVSII***		***C***	
	level	*mean*	level	*mean*	level	*mean*	Level	*mean*	level	*mean*	level	*mean*	level	*mean*
							Economic optimum							
F_{EW}	125.91	*119.96*	***111.91***	*106.10*	**117.29**	*115.59*	105.99	*102.87*	118.68	*123.10*	124.16	*111.61*	118.79	*128.93*
EW	60.42	*61.55*	***55.79***	*60.30*	**63.54**	*63.08*	60.83	*59.03*	61.93	*63.83*	62.84	*63.38*	62.66	*64.33*
MVPP	0.79	-	***0.70***	-	**1.27**	-	1.06	-	1.24	-	1.66	-	0.83	-
MRC	0.58	-	***0.62***	-	**0.59**	-	0.63	-	0.60	-	0.64	-	0.55	-
							Technical optimum							
F_{EW}	116.59	*119.96*	113.52	*106.10*	**106.68**	*115.59*	101.54	*102.87*	118.68	*123.10*	124.16	*111.61*	***125.96***	*128.93*
EW	62.88	*61.55*	62.60	*60.30*	**60.17**	*63.08*	59.65	*59.03*	61.93	*63.83*	62.84	*63.38*	***65.97***	*64.33*
E_{EW}	0.77	-	0.80	-	**0.88**	-	0.78	-	0.59	-	0.82	-	***0.58***	-
F_{SS}	119.18	*119.96*	95.04	*106.10*	***113.71***	*115.59*	101.71	*102.87*	118.68	*123.10*	**90.91**	*111.61*	118.79	*128.93*
SS	2.05	*1.51*	2.54	*1.92*	***1.77***	*1.74*	1.63	*1.89*	2.50	*1.76*	**2.51**	*2.01*	2.15	*2.10*
E_{SS}	0.73	-	0.84	-	***0.29***	-	0.53	-	0.31	-	**0.96**	-	0.94	-
F_{HU}	133.63	*119.96*	**103.97**	*106.10*	104.09	*115.59*	99.50	*102.87*	127.80	*123.10*	112.57	*111.61*	***135.96***	*128.93*
HU	89.15	*87.64*	**89.56**	*89.18*	85.51	*85.64*	82.15	*85.81*	82.21	*85.76*	92.02	*90.63*	***80.41***	*81.68*
E_{HU}	0.44	-	**0.89**	-	0.61	-	0.80	-	0.53	-	0.56	-	***0.25***	-

* Bold and italic bold numbers indicate the highest and lowest technical and economic optimum levels, respectively.

Conclusions: The results of the present study showed that 117.29 g *SCVSI* producing 63.54 g *EW* in laying hens not only at the economic optimum production level taking into account farmers financial power but also 106.68 g *SCVSI* producing 60.17 g *EW* at the technical optimum production level without considering their financial power had the major effect on marginal productivity of feed intake on laying performance. On the other hand, 90.91 g *ACVSII* and 103.97 g *RCVSII* producing 2.51 kg cm^{-2} *SS* and 89.56 *HU* at the technical optimum production levels also significantly affected egg quality. Therefore, for improvement in laying performance and egg quality *(EW, SS and HU)*, *SCVSI* should be preferred than other feeds for improving *SS* and *HU* at the technical and economic optimum levels, along with use of *ACVSII and RCVSII* than other feeds for improving *SS* and *HU* at the technical optimum levels. Consequently, the farmers could provide a major benefit in terms of the effective usage of the scarce source by producing at the technical and economic optimum levels.

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