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Impact of selenium supplementation on productive performance and egg selenium status in native Aseel chicken

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ABSTRACT
A study to examine the impact of selenium forms on productive traits and egg selenium deposition in Aseel was conducted. A total of 96 selenium-treated 21-week-aged Aseel birds were used, 84 females (1726.25 ± 121.65 g) and 12 males (1973.17 ± 182.84 g) from Lakha, Mushki, Peshaweri and Mianwali varieties. Birds were distributed into four experimental groups (21 females and 3 males/variety), further subdivided into three treatment groups A, B and C with 8 birds each, 7 females and 1 male (4 varieties ×3 Se treatments ×8 birds/treatment). Group A and B were the experimental while, C was a control group. Ration for the birds of group A included 0.3 ppm Se-enriched yeast, group B with 0.3 ppm sodium selenite, while, group C received a basal ration containing no selenium. Experimental birds were maintained separately in battery cages from 22 to 42 weeks. The pullets received Se-enriched yeast (organic source of selenium) supplemented ration gained the sexual maturity earlier (168.61 ± 0.64 d) and represented increased ($p \leq .05$) body weight (1973.56 ± 3.43 g); egg production (38.17 ± 1.27%); egg mass (112.52 ± 2.63 g); FCR/dozen eggs (3.26 ± 0.06); FCR/kg egg mass (6.77 ± 0.23) and the selenium contents in the whole egg (11.70 ± 0.01 µg), in egg yolk (8.31 ± 0.01 µg) and in egg albumen (3.33 ± 0.01 µg). It is concluded that Se-enriched yeast is more potent than sodium selenite and is a key supplement used to improve production performance and egg-selenium status of Aseel.

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Aseel chicken; egg production; enriched egg; selenium sources; sexual maturity

Introduction

Trace elements having an exceptional contribution in biological functions such as production, reproduction and antioxidant defence (Surai 2000; Waseem et al. 2016a,b,c,d). Selenium is one of the vital trace elements required for the normal functioning of the body, and thus has a significant role in the maintenance of optimal health. It is well known that indispensable trace elements increase the performance of poultry and its deficiency becomes the source of a variety of serious disorders. The symptoms of selenium deficiency in poultry have been related to its role in antioxidant protection through the enzyme glutathione peroxidase (GPx). It is an important constituent of GPx involved in cellular antioxidant defence (Madkour et al. 2015). Selenium is linked with body weight, egg production, fertility, hatchability and immune response in poultry birds (Yoon et al. 2007; Attia et al. 2010; Waseem et al. 2016). Selenium is involved in improving the productive and reproductive performance of both male and female birds (Attia et al. 2010). Researchers assessed the effects of different forms of selenium (inorganic and organic); the inorganic source of selenium includes sodium selenite and calcium selenide (Hess et al. 2000), while the organic form includes selenomethionine, Se-enriched yeast and the Se-enriched alga (Payne & Southern 2005). It has described that organic selenium supplementation in commercial poultry feeds has positive impact (El-Sheikh & Ahmed-Nagwa 2006; Baylan et al. 2010). The use of Se-enriched yeast in laying hen diets increases selenium content of egg (Utterback et al. 2005; Gajcevic et al. 2009; Attia et al. 2010). It is further reported that selenium sources help increasing egg production traits as well as fertility and hatchability (Attia et al. 2010; Canoğullari et al. 2010; Waseem et al. 2016). In particular, expansions and commercialisation of organic sources of selenium have originated a new era in the availability of Se-enriched products (Fisinin et al. 2009). It has been advised that eggs from hens fed with Se-enriched probiotics can serve as a nutraceutical food with high selenium and low

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cholesterol contents for both healthy people and patients with cardiovascular disorder (Pan et al. 2011). The increase in selenium content in eggs is expressed in a stronger antioxidant protection of yolk, prolonged stability and nutritional value of eggs (Hess et al. 2003). There is the indication that for adult human a greater dietary Se intakes (100–300 μg/d) more than recommended dietary allowance (55 μg/d) may have possible health benefits (Fisinin et al. 2009; Schrauzer 2009). Se-enriched eggs have remained to be a virtuous source of Se for humans (Surai et al. 2007). Bennett and Cheng (2010) demonstrated that Se supplementation is a practical way of producing Se-enriched eggs for the consumers. According to NRC (1994), selenium requirement for laying hens ranges from 0.05 to 0.08 ppm, however, AAFCO (2003) recommended 0.3 ppm maximum allowable level.

Currently, Pakistan is facing a severe issue of very low per capita protein availability. With the rapid increase in the global human population, the people of the developing countries are facing the hazards of undernourishment in terms of protein foods, especially from animal origin and unluckily Pakistan is included among the sufferers (Jatoi 2012). Under present situation, concerted efforts are needed to produce animal protein in a considerable quantity to fulfil requirements of the masses. Moreover, increasing demand for quality animal proteins is offering a good opportunity for the native poultry breeds to be introduced into the current poultry production system (Blackburn 2006). Poultry is ranked amongst the essential animal protein sources available globally (Kocaman et al. 2006). Among different indigenous poultry breeds of Pakistan, Aseel chickens, the ancestors of White Cornish and Plymouth Rock (Dohner 2001) have revealed an appreciable degree of resistance to diseases as compared to exotic breeds. Meat and eggs from native breeds are most demanded products for the consumers. Additionally, in some communities, village chickens are important in breaking the ferocious cycle of poverty, malnutrition and disease (Robert 1992). Despite having excellent attributes, the volume of research to understand and utilise the overall potential of Aseel is still very small. Keeping in view the importance of Aseel chicken, especially in our rural economy, this study was undertaken with the objective to determine the possible ways to enhance the productive performance of different varieties of Aseel through supplementation of selenium, also to assess the impact of selenium forms on the potential of this breed concerning the production of functional foods in the form of Se-enriched eggs.

Materials and methods

Animal welfare

All the experimental manipulations were undertaken in compliance with the Institutional Guidelines for the Care and use of Experimental Animals.

Experimental animal and design

A total number of 400 day-old Aseel birds from four well recognised Aseel varieties, namely Lakha, Mushki, Peshaweri and Mianwali, were used in the experiment. The birds were procured from Avian Research and Training (ART) Center, University of Veterinary and Animal Sciences (UVAS), Lahore. After a pre-experimental period of three weeks, a total number of 240 birds, 60 from each variety (30 male and 30 female) from this base population of 400 birds were selected and divided according to a randomised complete block design into three experimental groups. These birds were reared up to the age of 21 weeks on three experimental diets. The first group was exposed to the diet supplemented with 0.3 ppm of organic selenium (Se-enriched yeast). The second group was given the diet supplemented with 0.3 ppm of inorganic Se (sodium selenite). The third group was offered the basal diet without Se supplement. The birds were reared at the Indigenous Chicken Genetic Resource Center, UVAS, Lahore. From these treated birds aged 21 weeks, a total number of 96 birds, 84 females and 12 males, were picked up and divided according to a randomised complete block design into four equal experimental groups (LA, MK, PS and MN) of 24 birds from each variety (21 females and 3 males from each variety). The selected Se-treated birds from all four varieties had undergone the respective treatment groups and varieties (blocks) for the study started from 22 weeks of age. The birds of each group were further sub-divided into three treatment groups A, B and C; each comprising 8 bird (7 females and 1 male). The groups A and B were experimental while group C was considered as a control. Each treatment group was replicated 8 times with one bird in each replicate (4 varieties $\times$3 dietary treatments $\times$8 birds/treatment). The birds were initially weighed and individually tagged for identification.

Experimental rations and husbandry

The experimental birds were fed three basal rations, formulated according to NRC (1994) standards (Table 1). Ration-I (Pre-breeder feed) was fed from 22 to 24 weeks of age and consisted of 11.22 MJ/kg

Table 1. Ingredients and chemical composition of basal feeds.

	Ration-I (Pre-breeder)	Ration-II (Layer breeder)	Ration-III (Male breeder)
Ingredients, %			
Maize	42.61	63.13	39.40
Rice tips	19.00	–	31.00
Wheat bran	13.00	–	15.80
Soybean meal 48%	15.62	27.11	10.45
Corn gluten 65%	1.00	–	–
Dicalcium phosphate	1.20	1.50	0.70
Sodium chloride	–	0.30	–
Limestone	7.42	7.60	2.65
Vitamin mineral premix[a]	–	0.30	–
DL-Methionine	0.15	0.06	–
Total	100	100	100
Analysed chemical composition			
Crude Protein, %	15.22	17.54	13.29
ME by calculation[b], MJ/kg	11.22	11.43	11.94
Calcium, %	2.71	3.19	1.12
Phosphorus, %	0.36	0.42	0.22
Lysine, %	0.84	0.87	0.74
Methionine, %	0.44	0.46	0.39
Analysed selenium, ppm	0.06	0.10	0.04

[a]Premix per kg compound feed: Vitamin A 12,000 U; Vitamin D_3 2200 ICU; Vitamin E 10 mg; Vitamin K 32 mg; Vitamin B_1 1 mg; Vitamin B_2 4 mg; Vitamin B_6 1.5 mg; Vitamin B_{12} 10 µg; Nicotinic acid 20 mg; Folic acid 1 mg; Pantothenic acid 10 mg; Biotin 50 µg; Choline chloride 500 mg; Copper 10 mg; Iron 30 mg; Manganese 55 mg; Zinc 50 mg.
[b]Metabolizable energy was estimated according to NRC (1994).

ME and 15.22% CP, Ration-II (Layer breeder feed) was fed from 25 to 42 weeks of age and was 11.43 MJ/kg ME and 17.54% CP, and Ration-III (Male breeder feed) was formulated to contain the energy value of 11.94 MJ/kg and 13.29% CP and was fed from 22 to 42 weeks of age. All three diets were supplemented with 0.3 ppm of Se-enriched yeast (Organic selenium, Selemax® 2000 ppm, Lencois Paulista, Brazil) for group A, with 0.3 ppm of sodium selenite (Sodium selenite 99%min, Armenia, Suzhou Haijin Chemical Co., Ltd. Jiangsu, China (Mainland)) for group B and group C was a control group with no Se. The experimental birds were maintained individually in three-tiered laying wired battery cages (each measuring 3 × 2 feet). These cages were fitted with slopping wire floors and dropping trays to enable egg collection and elimination of droppings. The cages were placed in a well-ventilated open-sided poultry house under similar management conditions throughout the experimental period. The experiment was consisted of four phases of production (pre-peak, peak, post-peak and terminal). The stud mating system was practised by providing access to each of seven females to respective male once a week (for 22 h on separate days of the week, i.e. one hen/cock/22 h) to obtain fertile eggs. Fresh and clean drinking water was ensured through automatic nipple drinkers. Limit-fed feeding system was practised through removable trough feeders. The lighting schedule was 16 h light: 8 h dark. Routine immunisation and veterinary care were ensured to protect bird's health status.

Aseel growth and production parameters

The feed intake was recorded daily and the body weights were taken at the end of each production phase with the help of weighing balance with 1 g accuracy; age at sexual maturity or the age at first lay was recorded when the female started laying eggs. Egg production, egg mass, FCR/dozen eggs and FCR/kg egg mass were recorded according to the methods adopted by Ahmad (2013).

Egg selenium estimation

Three eggs from each replicate during the peak phase of production were randomly selected to estimate egg selenium contents. Egg selenium concentration was analysed by Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES), model (Perkin Elmer 2100-DV, USA). The analysis was carried out by wet digestion method (Analytical grade Nitric acid and Per Chloric acid) at the Nuclear Institute for Agriculture & Biology (NIAB), Faisalabad, Pakistan. The feed samples were analysed for chemical composition with the help of AOAC (1995).

Statistical analysis

The data were subjected to Analysis of Variance (ANOVA) technique (Steel et al. 1997) in Randomised Complete Block Design (RCBD) using Statistical Analysis System (SAS, 9.1, SAS Institute 1996). Comparison among treatment means was made through Duncan's Multiple Range (DMR) test (Duncan 1955). Differences were considered significant at ($p \leq .05$). The results were expressed as means with their standard errors.

Results and discussion

Selenium analysis in experimental rations

Table 2 shows that the analysed selenium concentration in ration fed to the birds of group C was 0.06, 0.10 and 0.04 ppm in the pre-layer breeder, layer breeder and male breeder rations, respectively. After the supplementation of selenium from different sources. total concentration of selenium in experimental Ration-1 was 0.33 ppm Se-enriched yeast (Se-Y), 0.32 ppm sodium selenite (Sod-Sel); in Ration-II, 0.34 ppm Se-Y and 0.33 ppm Sod-Sel, whereas in

Table 2. Composition of supplemental and analysed selenium[a] (ppm).

Experimental Rations	Ration-I (pre-breeder)			Ration-II (layer breeder)			Ration-III (male breeder)		
Treatment units	A	B	C	A	B	C	A	B	C
Supplemental level of Se-Y	0.30	0.00	0.00	0.30	0.00	0.00	0.30	0.00	0.00
Supplemental level of Sod-Sel	0.00	0.30	0.00	0.00	0.30	0.00	0.00	0.30	0.00
Analysed Se in basal diets	0.00	0.00	0.06	0.00	0.00	0.10	0.00	0.00	0.04
Analysed level of Se-Y	0.33	0.00	0.00	0.34	0.00	0.00	0.32	0.00	0.00
Analysed level of Sod-Sel	0.00	0.32	0.00	0.00	0.33	0.00	0.00	0.31	0.00

[a]Analyzed selenium level in diets = Analysed selenium in basal diet + Analysed selenium in supplemented diet; Se: selenium; Se-Y: selenium yeast (organic Se source); Sod-Sel: sodium selenite (inorganic Se source); A: treatment group, fed with Se-Y supplemented ration; B: treatment group, fed with Sod-Sel supplemented ration; C: control group, fed with basal ration without Se supplement.

Table 3. Impact of different selenium sources and Aseel varieties on growth and production parameters in the pullets of indigenous Aseel.

Variables	DFI g ± SEM	BW g ± SEM	AAM d ± SEM	EP % ± SEM	EM g ± SEM	FCR/dozen eggs ± SEM	FCR/kg egg mass ± SEM
Se sources (*n* = 28)							
Se-Y	88.30 ± 0.11[a]	1973.56 ± 3.43[a]	168.61 ± 0.64[c]	38.17 ± 1.27[a]	112.52 ± 2.63[a]	3.26 ± 0.06[c]	6.77 ± 0.23[c]
Sod-Sel	85.96 ± 0.07[b]	1954.61 ± 3.22[b]	184.03 ± 1.49[b]	28.07 ± 0.59[b]	82.06 ± 1.59[b]	4.21 ± 0.07[b]	8.33 ± 0.18[b]
C	85.78 ± 0.08[b]	1960.06 ± 3.47[b]	205.67 ± 1.71[a]	22.44 ± 0.63[c]	63.84 ± 1.28[c]	4.81 ± 0.06[a]	10.12 ± 0.24[a]
Varieties of indigenous Aseel (*n* = 21)							
LA	86.80 ± 0.25[ab]	1958.70 ± 4.74[b]	186.33 ± 3.42[a]	28.80 ± 1.56[bc]	86.77 ± 3.23[ab]	4.08 ± 0.16[b]	8.16 ± 0.46[b]
MK	86.55 ± 0.26[b]	1955.04 ± 3.91[b]	186.85 ± 3.74[a]	27.31 ± 1.67[c]	78.29 ± 3.60[d]	4.29 ± 0.19[a]	9.01 ± 0.43[a]
PS	86.54 ± 0.28[b]	1967.60 ± 4.05[a]	185.38 ± 3.78[a]	30.51 ± 2.34[ab]	88.25 ± 6.34[a]	3.93 ± 0.23[b]	8.01 ± 0.55[b]
MN	86.82 ± 0.29[a]	1969.64 ± 3.55[a]	185.85 ± 4.09[a]	31.62 ± 2.82[a]	81.80 ± 4.82[bc]	4.07 ± 0.20[b]	8.16 ± 0.41[b]

Different alphabets on means show significant ($p \leq .05$) difference; SEM: standard error of means; DFI: daily feed intake; BW: body weight; AAM: age at maturity; EP: egg production; EM: egg mass; Se-Y: Se-enriched yeast; Sod-Sel: sodium selenite; C: control (without Se supplement); LA: Lakha; MK: Mushki; PS: Peshaweri; MN: Mianwali; *n*: number of observations.

Ration-III, 0.32 ppm Se-Y and 0.31 ppm Sod-Sel in treatment groups A and B, respectively.

Production performance results

Production performance of indigenous Aseel pullets was improved when fed with the organic source of selenium (Se-enriched yeast: Se-Y) supplemented ration compared with the birds exposed to no selenium or the ration supplemented with an inorganic source of selenium (sodium selenite: Sod-Sel). Tables 3 and 4 show the impact of different sources of selenium, varieties of indigenous Aseel pullets and their interaction on different production parameters. Average daily feed intake was increased in Se-Y fed pullets as compared to those in the no selenium supplemented or Sod-Sel treated groups. Among four varieties, feed intake was increased in the pullets of Mianwali variety than rest of the varieties. It has been reported that feed intake in poultry birds varies in different varieties (Bell & Weaver 2005) due to their genetic differences. In the interaction of different varieties and selenium sources (V × Se source), the pullets of Mianwali presented enhanced daily feed intake on Se-Y supplemented feed. Selenium, which is considered an essential dietary micro-mineral for poultry, is reported to have negative or positive impacts on production performance. Like a study on dual purpose breeding hens (Attia et al. 2010) as well as on quail breeders (Cruz and Fernandez 2011) revealed the increase in feed intake due to the addition of Se-Y. The results of the present study are in line with some other researchers who demonstrated the higher daily feed intake in the birds fed organic selenium supplemented diets compared to inorganic and control (Papazyan et al. 2006). Chinrasri et al. (2009) detected that different selenium sources had no effect on feed intake, however, feed intake was increased in hens fed diets supplemented with selenomethionine compared with the basal diet. On the contrary, most of the researchers have different point of view and reported no significant influences of organic Se on feed intake (Payne et al. 2005; Utterback et al. 2005; Richter et al. 2006; Hanafy et al. 2009). Similarly, it has been observed that feed intake remained same in broiler chickens (Spears et al. 2003; Niu et al. 2009) or laying hens (Pavlovic et al. 2009) where selenium could not establish its effect on average daily feed intake (Invernizzi et al. 2013).

Improved ($p \leq .05$) body weight in Se-Y fed group was observed in contrast to other two dietary treatments. Among varieties, the pullets of Mianwali exhibited enhanced body weight and in interaction, the pullets of same variety displayed the increased body weight than rest of the interactions. The standard body weight of Aseel differs from 3 to 5 kg of cocks and 2 to 4 kg for hens (Sharma & Chatterjee 2006). This difference in the body weight between

Table 4. Impact of interaction of Aseel varieties and selenium sources on production performance in the pullets of indigenous Aseel.

Variables	DFI g ± SEM	BW g ± SEM	AAM d ± SEM	EP % ± SEM	EM g ± SEM	FCR/dozen eggs ± SEM	FCR/kg egg mass ± SEM
Varieties of indigenous Aseel × Se sources ($n = 7$)							
LA							
Se-Y	88.25 ± 0.33^{a}	1948.64 ± 9.33^{bc}	170.57 ± 1.29^{c}	34.15 ± 1.68^{b}	93.35 ± 1.28^{b}	3.42 ± 0.10^{d}	6.76 ± 0.22^{de}
Sod-Sel	86.29 ± 0.15^{b}	1955.19 ± 6.17^{abc}	185.57 ± 2.87^{b}	28.80 ± 1.68^{c}	86.64 ± 2.67^{c}	4.14 ± 0.10^{c}	8.27 ± 0.49^{c}
C	85.97 ± 0.16^{bcd}	1972.27 ± 7.08^{a}	202.86 ± 3.85^{a}	23.45 ± 1.47^{de}	68.78 ± 1.66^{e}	4.70 ± 0.13^{ab}	9.89 ± 0.78^{a}
MK							
Se-Y	88.12 ± 0.16^{a}	1949.71 ± 5.54^{bc}	170.71 ± 1.08^{c}	33.93 ± 1.58^{b}	94.75 ± 3.01^{b}	3.48 ± 0.09^{d}	7.71 ± 0.39^{cd}
Sod-Sel	85.89 ± 0.13^{bcd}	1946.60 ± 4.73^{c}	182.28 ± 2.98^{b}	26.56 ± 0.98^{cd}	80.43 ± 2.26^{c}	4.40 ± 0.12^{bc}	8.54 ± 0.46^{bc}
C	85.58 ± 0.13^{cd}	1968.80 ± 7.21^{ab}	207.57 ± 3.32^{a}	21.43 ± 1.09^{e}	59.69 ± 1.28^{a}	5.02 ± 0.05^{a}	10.77 ± 0.16^{a}
PS							
Se-Y	88.29 ± 0.10^{a}	1956.40 ± 5.35^{abc}	167.14 ± 1.06^{c}	40.85 ± 0.98^{a}	125.70 ± 2.99^{a}	2.96 ± 0.08^{e}	5.85 ± 0.15^{e}
Sod-Sel	85.86 ± 0.13^{bcd}	1970.17 ± 6.87^{ab}	184.14 ± 3.28^{b}	27.45 ± 1.22^{c}	83.80 ± 3.99^{c}	4.14 ± 0.21^{c}	8.16 ± 0.29^{c}
C	85.48 ± 0.05^{d}	1976.23 ± 7.35^{a}	204.85 ± 3.45^{a}	23.22 ± 1.31^{de}	64.86 ± 3.51^{e}	4.70 ± 0.13^{ab}	10.03 ± 0.58^{a}
MN							
Se-Y	88.56 ± 0.20^{a}	1976.95 ± 6.92^{a}	166.00 ± 0.75^{c}	43.75 ± 1.41^{a}	126.50 ± 4.16^{a}	3.20 ± 0.08^{de}	6.76 ± 0.46^{de}
Sod-Sel	85.81 ± 0.13^{bcd}	1963.68 ± 4.05^{abc}	184.14 ± 3.28^{b}	29.46 ± 0.36^{c}	77.35 ± 2.51^{d}	4.19 ± 0.07^{c}	8.33 ± 0.37^{c}
C	86.09 ± 0.16^{bc}	1968.29 ± 6.83^{ab}	207.42 ± 3.54^{a}	21.65 ± 1.31^{e}	61.79 ± 1.68^{ef}	4.83 ± 0.09^{a}	9.73 ± 0.36^{ab}

Different alphabets on means show significant ($p \leq .05$) difference; SE: standard error of means; DFI: daily feed intake; BW: body weight; AAM: age at maturity; EP: egg production; EM: egg mass; Se-Y: Se-enriched yeast; Sod-Sel: sodium selenite; C: control (without Se supplement); LA: Lakha; MK: Mushki; PS: Peshaweri; MN: Mianwali; n: number of observations.

varieties may be due to genetic variations (Babar et al. 2012), leading to variances in their production potential (Ahmad et al. 2014). The findings of our study are in agreement with those of Kanchana and Jeyanthi (2010), who claimed that increase in body weight is linked to the inclusion of organic selenium in the diet of broilers (Upton et al. 2008). Variations in the body weight of layers, breeders and broilers have also been reported by the supplementation of different selenium sources in the diets. Several researchers reported a positive correlation between organic selenium and body weight in broilers (Salman et al. 2007) and layers (Kanchana & Jeyanthi 2010). Selenium-added diets, likewise, improved the body weight of laying hens (Skrivan et al. 2006; Arpasova et al. 2009; Hanafy et al. 2009), broilers (Sevcikova et al. 2006) and quails breeders (Sahin et al. 2008). On the other hand, it has been reported that no significant ($p > .05$) effect of selenium on final body weight in layers (Scheideler et al. 2010; Aljamal 2011) as well as in broilers (Vara Prasad Reddy et al. 2007; Yoon et al. 2007) were observed. In natural process of aerobic respiration, small amounts of partially reduced oxygen are generated and these radicals are termed as free radicals which can inactivate certain enzyme system, which has been shown to be damaging to a wide variety of biological molecules including proteins, deoxyribonucleic acid and lipids (Suari 2006). Selenium is an integral constituent of an antioxidant enzyme glutathione peroxidase (GPx) which is responsible for preventing the formation of damaging free radicals. It has been demonstrated that there is a highly significant, positive correlation between selenium concentration and GPx activity in most tissues. The provision of suitable levels of Se-Y which is more bioavailable than Se-Sel to the birds resulted in the proper functioning of GPx, which ultimately showed subsequent effects by enhancing the growth performance (Suari 2000).

The birds exposed to the Se-Y supplemented ration were noticed with improved ($p \leq .05$) results regarding production parameters and was proved to be a superior supplement than Sod-Sel. The SY-fed pullets exhibited earlier sexual maturity compared to those in the no Se or Sod-Sel supplemented groups, while non-significant difference ($p > .05$) was observed among varieties. In interaction, Mianwali gained sexual maturity significantly ($p \leq .05$) earlier compared to rest of the interactions. This result is in line with the findings of Surai (2006) and Attia et al. (2010). Egg production was recorded during pre-peak, peak, post peak and terminal phases of production from 27 to 42 weeks of age. The egg production was improved in the SY-fed group than those of Sod-Sel or control groups. The Mianwali variety showed enhanced egg production among four varieties of Aseel. The maximum egg production was detected in the pullets of Mianwali in interaction with the organic source of selenium i.e. Se-Y supplemented ration. The better egg production was reported in layers due to the supplementation of Se-Y against inorganic selenium (Sara et al. 2008; Hanafy et al. 2009) and also in quail breeders (Cruz & Fernandez 2011). Payne et al. (2005) did not notice differences on percentage hen-day production of hens fed by sources or the level of selenium. Similarly, Chinrasri et al. (2009) described that different selenium sources in addition to the level of 0.3 mg/kg had no effects on egg production of hens. Differences in egg production in Aseel varieties have already been claimed (Iqbal et al. 2012) and may be attributed to their variations in genetic potential (Akhtar et al. 2007). It is believed that Se-yeast is more effective than inorganic selenium due to the greater bioavailability and existence of huge amounts of selenomethionine (Wu et al. 2011). The findings of this study presented higher ($p \leq .05$) egg mass on Se-Y supplemented ration compared to rest of the dietary treatments. The birds of Peshaweri showed an increased egg mass than other varieties. In interaction, significantly ($p \leq .05$) improved egg mass was observed in SY-fed Mianwali variety. Gjorgovska et al. (2012) reported that Se-Y supplementation significantly improved the egg mass in laying hens. FCR/dozen eggs was improved in the pullets received Se-Y compared to Sod-Sel FCR/dozen eggs or the group fed with no selenium supplemental ration FCR/dozen eggs. Among the varieties, Peshawari exhibited improved FCR/dozen eggs than remaining three varieties. Interaction results showed significantly ($p \leq .05$) improved FCR/dozen eggs in the pullets of Peshaweri variety when fed with Se-Y included feed. Arpasova et al. (2012) reported the in-line results that Se-Y supplementation improves FCR/dozen egg. Improved FCR/dozen by the supplementation of organic selenium in the diet may be due to its more bioavailability (Cruz & Fernandez 2011), which might have ameliorated digestion and metabolism resulting in efficient utilisation of ration into better FCR/dozen than Sod-Sel or without selenium. The better FCR/kg egg mass was improved in the pullets fed SY compared to Sod-Sel FCR/kg egg mass and no Se supplemental group FCR/kg egg mass. The Peshaweri variety, among four varieties, represented improved FCR/kg egg mass. Overall interactions also yielded the significant variations regarding the FCR with the best result in Peshawari variety FCR/kg egg mass fed Se-Y supplemented ration The addition of Se-Y in the diets of laying hens significantly improves the FCR/kg egg mass (Ganpule & Manjunatha 2003; Arpasova et al. 2009). Different studies have also revealed that organic selenium, which is more bio-available (Cruz & Fernandez 2011), is actively absorbed in the intestine than passive absorption of inorganic selenium (Surai 2002) and further increases productive (Leeson et al. 2008) and reproductive performance of poultry (Sluis 2007; Hanafy et al. 2009; Attia et al. 2010). Advantages of organic selenium for commercial laying hens are connected to better shell quality and maintenance of egg freshness during storage (Papazyan et al. 2006).

Table 5. Impact of selenium sources and Aseel varieties on egg selenium concentration in the pullets of indigenous Aseel.

Variables	Se content in egg yolk µg ± SEM	Se content in egg albumen µg ± SEM	Se content in whole egg µg ± SEM
Se sources ($n = 12$)			
Se-Y	8.31 ± 0.01^{a}	3.33 ± 0.01^{a}	11.70 ± 0.01^{a}
Sod-Sel	6.50 ± 0.01^{b}	2.60 ± 0.01^{b}	9.13 ± 0.01^{b}
C	5.52 ± 0.01^{c}	2.22 ± 0.01^{c}	7.77 ± 0.01^{c}
Varieties of indigenous Aseel ($n = 9$)			
LA	6.78 ± 0.40^{ab}	2.72 ± 0.16^{a}	9.53 ± 0.57^{a}
MK	6.76 ± 0.40^{b}	2.71 ± 0.16^{a}	9.51 ± 0.57^{a}
PS	6.80 ± 0.41^{a}	2.72 ± 0.16^{a}	9.55 ± 0.57^{a}
MN	6.78 ± 0.41^{ab}	2.71 ± 0.16^{a}	9.53 ± 0.57^{a}

Different alphabets on means show significant ($p \leq .05$) difference; SE: standard error of means; Se: selenium; Se-Y: Se-enriched yeast; Sod-Sel: sodium selenite; C: control (without Se supplement); LA: Lakha; MK: Mushki; PS: Peshaweri; MN: Mianwali; n: number of observations.

Table 6. Impact of interaction of Aseel varieties and selenium sources on egg selenium concentration in the pullets of indigenous Aseel.

Variables	Se content in egg yolk µg ± SEM	Se content in egg albumen µg ± SEM	Se content in whole egg µg ± SEM
Varieties of indigenous Aseel × Se sources ($n = 3$)			
LA			
Se-Y	8.31 ± 0.01^{a}	3.33 ± 0.01^{a}	11.70 ± 0.01^{a}
Sod-Sel	6.50 ± 0.02^{b}	2.61 ± 0.01^{b}	9.14 ± 0.02^{b}
C	5.52 ± 0.02^{c}	2.21 ± 0.01^{c}	7.77 ± 0.03^{c}
MK			
Se-Y	8.29 ± 0.01^{a}	3.32 ± 0.01^{a}	11.67 ± 0.01^{a}
Sod-Sel	6.47 ± 0.02^{b}	2.59 ± 0.01^{b}	9.10 ± 0.03^{b}
C	5.52 ± 0.03^{c}	2.21 ± 0.01^{c}	7.76 ± 0.03^{c}
PS			
Se-Y	8.34 ± 0.01^{a}	3.34 ± 0.01^{a}	11.73 ± 0.03^{a}
Sod-Sel	6.51 ± 0.01^{b}	2.60 ± 0.01^{b}	9.14 ± 0.01^{b}
C	5.53 ± 0.01^{c}	2.22 ± 0.01^{c}	7.79 ± 0.02^{c}
MN			
Se-Y	8.33 ± 0.01^{a}	3.32 ± 0.01^{a}	11.70 ± 0.02^{a}
Sod-Sel	6.49 ± 0.01^{b}	2.60 ± 0.01^{b}	9.13 ± 0.02^{b}
C	5.51 ± 0.01^{c}	2.21 ± 0.01^{c}	7.75 ± 0.01^{c}

Different alphabets on means show significant ($p \leq .05$) difference; SE: standard error of means; Se: selenium; Se-Y: Se-enriched yeast; Sod-Sel: sodium selenite; C: control (without Se supplement); LA: Lakha; MK: Mushki; PS: Peshaweri; MN: Mianwali; n: number of observations.

Determination of selenium in eggs

Egg selenium concentration was improved in the eggs of the pullets of indigenous Aseel by both the organic (Se-Y) and the inorganic (Sod-Sel) selenium sources, with the Se-Y treatment superior to Sod-Sel. Tables 5 and 6 show the impact of selenium sources, four varieties of Aseel and their interaction on egg selenium concentration in indigenous Aseel pullets. Improved ($p \leq .05$) selenium contents in egg albumen in egg yolk and in the whole egg were recorded in the Se-Y fed pullets compared to the pullets exposed to Sod-Sel supplemented ration or the ration without selenium addition. Among the varieties, non-significant ($p > .05$) differences were observed except the pullets of Peshaweri, those presented higher yolk selenium content. Significantly ($p \leq .05$) increased selenium content in the whole egg in egg yolk and in egg albumen were recorded in the pullets of Peshaweri variety in the Se-Y fed group in interaction. The results showed that organic selenium source was more potent than the inorganic source. The dietary inclusion of Se-Y in hen ration elevates selenium concentration in egg, egg albumen and egg yolk. Sara et al. (2008), Fisinin et al. (2008) and Hanafy et al. (2009) reported that the addition of hen's diet with organic selenium not only improves health and productive potential, but also be a better way to produce eggs enriched with selenium. These results appear to be highly consistent with previous studies by Gajcevic et al. (2009), who indicated that that selenium content in albumen was increased as a result of Se-yeast supplementation. It was further reported that yolk-Se concentration significantly increased due to organic and inorganic selenium supplementation and the greatest increase was observed by the group fed diet supplemented with organic selenium (Payne & Southern 2005; Leeson et al. 2008; Attia et al. 2010). Moreover, Briens et al. (2013) stated that the different absorption manner between organic and inorganic selenium sources led to the different digestibility rates, with the inorganic source having a poorer digestibility than the organic form. Moreover, some other researchers stated that the addition of hens' diet with organic selenium not only improves their health status and productivity but can also be a natural way to yield functional food, respectively the production of eggs enriched with selenium (Fisinin et al. 2008; Sara et al. 2008; Hanafy et al. 2009). Adequate and natural supply of essential nutrients in a suitable and available form can be attained by consumption of functional organic foods. This mainly means food of animal origin (eggs, meat and milk) when the animals are raised on a specially adapted feed enriched with substances whose levels in standard food are insufficient. Paton et al. (2002) concluded that the possible reason for the enhanced levels of selenium in albumen, yolk and egg content after inclusion of dietary Se-Y can be due to the fact that hens have additional metabolic pathway by which selenium is transferred into the egg. For example, increased level of selenium in egg albumen of hens exposed to Se-yeast may be due to the incorporation of greater amounts of selenium as selenomethionine during albumen synthesis that could replace methionine, thereby providing additional selenium.

Conclusions

Based on the findings of this study, it may be stated that it is possible for Aseel pullets to gain sexual maturity significantly earlier and that the egg production, egg mass, FCR/dozen eggs, FCR/kg egg mass and egg Se content can be enhanced in the pullets of Aseel through feeding Se-Y supplemented ration @ 0.3 ppm. It is therefore concluded that organic selenium source (Se-enriched yeast) is the superior supplement that can improve the production traits of Aseel pullets as well as may assists to produce a quality functional food in the shape of Se-enriched eggs. However, further work is needed to extend these findings.

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The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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