*Pakistan J. Zool., vol. 50(3), pp 995-1003, 2018.* **DOI**: http://dx.doi.org/10.17582/journal.pjz/2018.50.3.995.1003

# Effect of Organic Selenium Supplementation in Diet on Gastrointestinal Tract Performance and Meat Quality of Goat

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**Article Information**
**Received 13 December 2017**
**Revised 02 January 2018**
**Accepted 10 January 2018**
**Available online 19 April 2018**

**Authors' Contribution**
**MM conceived and designed the study. SPS executed the study and wrote the manuscript. JG and ABK supervised the study and helped in data analysis. YL and SAS provided the technical assistance in writing the manuscript.**

**Key words**
**Selenium yeast, Gastrointestinal tract, Digestibility, Carcass, Goat.**

## ABSTRACT

Ten cross-bred goats of about 4 months of age and 10.5 kg body weight were randomly selected for the study and divided into two groups (n=5/each). Basal diet given to the animals consist of roughage and concentrate at the ratio of 65:35. Group A was kept without any supplementation whereas group B was supplemented with selenium yeast (SY) at the dose rate of 0.3 mg/kg.diet for 8 weeks. The results showed that the weights (% of empty body weight) of rumen (4.18 ± 0.30 vs 3.49 ± 0.10); duodenum (0.32 ± 0.01 vs 0.27 ± 0.01); colon (1.14 ± 0.03 vs 1.06 ± 0.01), caecum (0.62 ± 0.03 vs 0.57 ± 0.01) and the whole large intestine (2.44 ± 0.04 vs 2.32 ± 0.03) significantly increased ($P < 0.05$) in B compared to A. The weights of liver, heart, kidney and spleen were not significantly different ($P > 0.05$) between the groups, however, the lung weight increased in B (1.15 ± 0.04 vs 0.99 ± 0.04, $P < 0.05$) compared to A. Digestibility trails revealed that utilization of dry matter (DM), crude protein (CP) and crude fiber (CF) increased ($P < 0.05$) by 13.71, 12.02 and 4.78% at week 3 and by 11.11, 11.8 and 3.46 % at week 6 in B compared to A. Among carcass characteristics the carcass dressing % (52.99 ± 0.77 vs 49.41 ± 0.6 ) and leg weight (kg) (1.28 ± 0.06 vs 1.05 ± 0.04) increased ($P < 0.05$) in B compared to A. The physico-chemical properties of meat were not significantly different between the groups except fat content (2.75 ± 0.25 vs 2.00 ± 0.05%, $P < 0.096$) which tended to increase in B compared to A. These data demonstrated that dietary SY supplementation increased gastrointestinal tract weight and nutrient digestibilities, and improved some carcass characteristics in goats.

## INTRODUCTION

Selenium (Se) is an important micro-nutrient which is necessarily required in smaller concentration in the animal feed for a wide range of physiological activities. In most of the areas of Pakistan, the soil Se level is too low, yielding Se-deficient plants, which ultimately leads to depletion of Se in animals (Khan *et al*., 2006; Ahmad *et al*., 2009). Depending upon the physiological status of animals, the Se deficiency is manifested by nutritional degenerative myopathy (white muscle disease) and early death in lambs and calves (Underwood, 2012), poor growth rate and delayed puberty in young animals and reproductive (dystocia, retained placenta, infertility) and productive (reduced milk and meat production) disorders in adults (Ramirez-Bribiesca *et al*., 2005; Enjalbert *et al*., 2006; Ahmad *et al*., 2009). Thus, Se supplementation in animal's ration is extremely important to avoid Se-deficiency related problems. It is supplemented in either organic or inorganic forms to livestock, however, organic Se is extensively used as supplement in the diet of ruminants because of its increased bioavailability in the tissues and superior physiological role over inorganic Se (Arthur, 2000; Tapiero *et al*., 2003; Maiorino *et al*., 1999; McKenzie *et al*., 1998; Beck *et al*., 2005). Selenium yeast (SY) is an excellent source of synthetic organic Se frequently used as supplement in the ruminant's diet (Kelly and Powers, 1995; Wang *et al*., 2009).

An animal's growth and production performance requires efficient digestion and absorption of nutrients throughout the GIT and the efficient peripheral flow of absorbed nutrient for suitable utilization. Growth of digestive organs is an important indicator of body growth because it represents the amount of nutrient utilization and

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0030-9923/2018/0003-0995 $ 9.00/0

therefore makes it available to the periphery (Johnson *et al*., 1990).

Supplementation of trace minerals including Se in diet influences the growth and nutrient digestibility rates in GIT. Inorganic Se supplemented in diet at the dose rate 0.2 – 0.6 mg/kg.DM either in selenate or selenite forms increased total tract digestibility in sheep fed high concentrate diet (Del Razo-Rodriguez *et al*., 2013) whereas no effect was observed in sheep fed low concentrate diet (Del Razo-Rodriguez *et al*., 2013; Alimohamady *et al*., 2013; Serra *et al*., 1994). Total tract digestibility of nutrients was higher in multiparous dairy cattle fed organic selenium at 0.15 and 0.3 g/kg DM compared to control but no difference in the digestibility was found at 0.45 g/kg DM (Wang *et al*., 2009).

Oxidation reactions adversely affects the nutritive value and flavors of meat products and can be prevented by the antioxidant ability of glutathione peroxidase (GSH-Px) (DeVore *et al*., 1983; Morrissey *et al*., 1998; Gatellier *et al*., 2004). Reduction in the oxidation maintain the meat quality, which requires the availability of an antioxidant in the meat (Faustman and Cassens, 1989; Sanchez-Escalante *et al*., 2001).

There is scarcity of information concerning the effects of Se on nutrient utilization and GIT growth of ruminants thus the recent study aimed to evaluate the effects of SY on nutrient digestibility, GIT growth and meat quality of goat.

## MATERIALS AND METHODS

*Selection and management of animals*

Ten cross-bred goats of around 4 months of age, weighing 10.5 kg body weight were used in this study. After four weeks of acclimatization to the environment, the animals were housed in distinct pens of 2.5 × 4 ft area per pen and randomly divided into two groups; *i.e.* A and B (n=5/group). Animals in group A received basal diet consisting of roughage and concentrate (65:35) and that in group B along with basal diet supplemented with organic selenium (selenium yeast, SY) at the dose of 0.3 mg/kg diet. Feed and water were provided *ad libitum*. On the basis of percent dry matter, the basal diet contained 20.89% crude protein, 3.64% crude fat, 6.67% crude fiber and 7.73% ash. The metabolizable energy (ME) in basal diet was 10.85 MJ/kg DM and the Se concentration was 0.03 mg/kg diet. The experiment lasted for eight weeks.

*Sample collection, slaughter and measurements*

Throughout experimental period feed samples were collected once in a week and composited for chemical analysis. Fecal samples were collected on 3$^{rd}$ and 6$^{th}$ week of trial. The wet fecal samples were instantly dried in forced air oven at 65°C for 48 h, grinded and then stored at -20°C for chemical analysis. Feed and fecal samples were analyzed for dry matter (DM), crude protein (CP), ether extract (EE) and ash according to the methods of AOAC (2000) and Viram *et al*. (2017). Immediately after slaughter, the abdominal cavity of the animal was opened and the entire gastrointestinal tract as well as other visceral organs were removed and collected in a clean tub. Whole stomach and its various parts (Rumen, reticulum, omasum and abomasum) were isolated from the rest of the viscera, emptied and washed with cold phosphate buffer solution (PBS) and then weighed. The parts of small intestine such as duodenum, jejunum, and ileum, and the parts of large intestine such as caecum, rectum and colon were identified and isolated as described by Neville *et al*. (2008). After identification and careful separation, each part was emptied, washed in PBS and weighed. Visceral organs (heart, liver, lungs, kidneys and spleen) were collected and weighed.

*Determination of carcass and meat characteristics*

The carcass characteristics including carcass weight, dressing percentage and leg length were measured as described by Lawler *et al*. (2004). The meat samples were isolated from longissimus dorsi (LD) muscle to evaluate the physico-chemical characteristics. The LD muscle was exercised from the carcasses from left side, between the 8$^{th}$ and 11$^{th}$ thoracic vertebrae, according to descriptions by Honikel (1998) and all visible fat was trimmed from the muscles before any physical and chemical analyses were carried out. A piece of meat (10 g) was homogenized in distilled water (90 ml) and the pH was determined by pH meter (Ockreman, 1985). The water holding capacity (WHC) was analyzed by following the protocol given by Wardlaw *et al*. (1973). Meat sample (8 g) was mixed in 12 ml of 0.6 M NaCl solution in the test tube and then centrifuged at (4°C) at 10,000 rpm for 15 min. The supernatant was poured and WHC was measured and expressed in percentage. Cooking loss was measured according to the method as given by Kondaiah *et al*. (1985). Meat sample (20g) was placed in a polyethylene bag and heated for 1 h in a water bath at core temperature of 72°C. Cooked out was drained, cooled and then weighed to determine the cooking loss. According to the method described by Sen *et al*. (2004) drip loss was measured. Meat sample (50g) was placed in polyethylene bag with sealad cover and refrigerated (4°C) for 24 h, then wiped and dried with filter paper and weighed. The difference among definite weight of sample and after refrigeration was expected as drip loss. Chemical characteristics of meat were determined by the method of Association of Official Analytical Chemists (AOAC, 2000). Lipids were extracted and purified from the homogenized sample with

a chloroform: methanol mixture (1:1 v/v) according to the method of Hanson and Olley (1963). The total lipids were gravimetrically determined.

**Table I.- Effects of dietary selenium yeast supplementation fed for 8 weeks on weights of gastrointestinal tract and other visceral organs of goat.**

| Weights (% EBW) | Basal diet (n=5) | Basal diet ± Se yeast (n=5) | P-Value |
|---|---|---|---|
| Rumen | 3.49 ± 0.10 | 4.18 ± 0.30 | 0.047 |
| Omasum | 0.58 ± 0.05 | 0.53 ± 0.04 | 0.74 |
| Abomasum | 0.66 ± 0.05 | 0.64 ± 0.04 | 0.481 |
| Whole stomach | 4.73 ± 0.07 | 5.34 ± 0.33 | 0.158 |
| Duodenum | 0.27 ± 0.01 | 0.32 ± 0.01 | 0.03 |
| Jejunum | 0.59 ± 0.01 | 0.63 ± 0.02 | 0.87 |
| Ileum | 1.46 ± 0.01 | 1.49 ± 0.03 | 0.73 |
| Small intestine | 2.31 ± 0.01 | 2.34 ± 0.02 | 0.65 |
| Colon | 1.06 ± 0.01 | 1.14 ± 0.03 | 0.045 |
| Caecum | 0.57 ± 0.01 | 0.62 ± 0.03 | 0.09 |
| Rectum | 0.69 ± 0.03 | 0.68 ± 0.05 | 0.933 |
| Large intestine | 2.32 ± 0.03 | 2.44 ± 0.04 | 0.047 |
| Kidneys | 0.40 ± 0.02 | 0.43 ± 0.02 | 0.691 |
| Lungs | 0.99 ± 0.04 | 1.15 ± 0.04 | 0.041 |
| Liver | 2.07 ± 0.11 | 2.03 ± 0.12 | 0.974 |
| Heart | 0.51 ± 0.02 | 0.57 ± 0.04 | 0.471 |
| Spleen | 0.31 ± 0.02 | 0.27 ± 0.06 | 0.732 |

EBW, empty body weight. Values (mean ± SE) differ significantly at $P < 0.05$.

## RESULTS

Table I shows the effects of dietary SY supplementation on weights (percent empty body weight, % EBW) of visceral organ of goats. The weight of rumen increased in B (4.18 ± 0.30 vs 3.49 ± 0.10, $P < 0.05$) compared to A, however, the weights of whole stomach, omasum and abomasum were not significantly different ($P > 0.05$) between the groups. The weights of small intestine as a whole, and ileum and jejunum were not different ($P > 0.05$) between the groups however duodenal weight increased in B (0.32 ± 0.01 vs 0.27 ± 0.01, $P < 0.05$) compared to A. The weight of rectum was not significantly different between the groups, however, the weights of colon (1.14 ± 0.03 vs 1.06 ± 0.01) and caecum (0.62 ± 0.03 vs 0.57 ± 0.01) increased ($P < 0.05$) in A compared to B, which resulted in the increase of whole large intestine weight (2.44 ± 0.04 vs 2.32 ± 0.03, $P < 0.05$) in B compared to A. No significant difference ($P > 0.05$) was observed between the two dietary groups on the weights of liver, heart, kidney and spleen, however, the lung weight increased in B (1.15 ± 0.04 vs 0.99 ± 0.04, $P < 0.05$) compared to A.

**Table II.- Effects of dietary selenium yeast supplementation for 8 weeks on nutrient digestibility in goats.**

| Items | Basal diet (n=5) | Basal diet ± Se yeast (n=5) | P-Value |
|---|---|---|---|
| **Week 3** | | | |
| Dry matter | 66.43 ± 1.33 | 75.54 ± 0.95 | 0.003 |
| Crude protein | 65.82 ± 0.86 | 73.73 ± 1.34 | 0.028 |
| Ether extract | 71.32 ± 2.41 | 72.46 ± 1.05 | 0.104 |
| Crude fiber | 79.04 ± 1.15 | 82.89 ± 0.53 | 0.041 |
| **Week 6** | | | |
| Dry matter | 70.61 ± 1.82 | 78.46 ± 0.55 | 0.003 |
| Crude protein | 68.47 ± 2.48 | 76.55 ± 0.34 | 0.016 |
| Ether extract | 73.94 ± 2.33 | 76.5 ± 1.06 | 0.002 |
| Crude fiber | 80.55 ± 0.55 | 83.75 ± 0.57 | 0.05 |

Values (mean ± SE) differ significantly at $P < 0.05$.

**Table III.- Effects of dietary selenium yeast supplementation for 8 weeks on carcass characteristics of goats.**

| Items | Basal diet (n=5) | Basal diet ± Se yeast (n=5) | P-value |
|---|---|---|---|
| Carcass weight (kg) | 6.45 ± 0.59 | 7.58 ± 0.66 | 0.049 |
| Carcass length (cm) | 52.25 ± 3.22 | 55.75 ± 3.71 | 0.736 |
| Dressing (%) | 49.41 ± 0.6 | 52.99 ± 0.77 | 0.048 |
| Leg length (cm) | 29.50 ± 1.26 | 31.0 ± 1.22 | 0.587 |
| Leg weight (kg) | 1.05 ± 0.04 | 1.28 ± 0.06 | 0.040 |
| Rib cage weight (kg) | 1.28 ± 0.06 | 1.5 ± 0.15 | 0.307 |

Values (mean ± SE) differ significantly at $P < 0.05$.

The effects of dietary SY supplementation on digestibility in goats at weeks 3 and 6 are shown in Table II. At week 3, the digestibilities of dry matter (DM) (75.54 ± 0.95 vs 66.43 ± 1.33), crude protein (CP) (73.73 ± 1.34 vs 65.82 ± 0.86) and crude fiber (CF) (82.89 ± 0.53 vs 79.04 ± 1.15) increased ($P < 0.05$) in B compared to A, however, the digestibility of ether extract (EE) was not different ($P > 0.05$) between two A and B. Similarly, at week 6, the digestibilities of DM (78.46 ± 0.55 vs 70.61 ± 1.82), CP (76.55 ± 0.34 vs 68.47 ± 2.48), CF (83.75 ± 0.57 vs 80.55 ± 0.55) and EE (76.5 ± 1.06 vs 73.94 ± 2.33) significantly increased ($P < 0.05$) in B compared to A.

Table III shows the effects of dietary SY supplementation on carcass characteristics of goats. The result showed that the carcass dressing % and leg weight (kg) increased ($P < 0.05$) in B (52.99 ± 0.77 and 1.28 ± 0.06) compared to A (49.41 ± 0.6 and 1.05 ± 0.04). However, the other carcass traits such as rig cage weight, carcass length, leg length, rib cage girth, lion weight, and back weight were not different ($P > 0.05$) between the groups.

The physic-chemical properties of goat meat are depicted in Table IV. The physical properties of meat including pH, WHC, cooking loss and drip loss were not different between A and B. However, the pH was reduced by 0.15 units, and the cooking and drip losses were reduced by approximately 11 and 13.5 % in B compared to A. Amongst the chemical properties of meat the moisture, protein and ash contents were not different ($P > 0.05$) between the groups, however, the fat content (2.75 ± 0.25 vs 2.00 ± 0.05%, $P < 0.096$) tended to increase in B compared to A.

**Table IV.- Effects of dietary selenium yeast supplementation for 8 weeks on physico-chemical properties of meat of goats.**

| Items | Basal diet (n=5) | Basal diet ± Se yeast (n=5) | P-value |
|---|---|---|---|
| pH | 5.59 ± 0.15 | 5.44 ± 0.20 | 0.78 |
| WHC (%) | 76 ± 4.10 | 79.5 ± 2.87 | 0.72 |
| Cooking loss (%) | 40.41 ± 1.51 | 36.34 ± 1.91 | 0.38 |
| Drip loss (%) | 2.51 ± 0.25 | 2.21 ± 0.11 | 0.46 |
| Moisture (%) | 56.88 ± 3.59 | 51.75 ± 1.01 | 0.64 |
| CP (%) | 22.91 ± 0.67 | 21.77 ± 0.37 | 0.39 |
| Fat (%) | 2.0 ± 0.5 | 2.75 ± 0.25 | 0.09 |
| Ash (%) | 0.85 ± 0.12 | 0.83 ± 0.12 | 0.99 |

Values (mean ± SE) differ significantly at $P < 0.05$.

## DISCUSSION

The GIT of ruminants is characterized by the presence of complex stomachs (especially rumen) followed by the small and large intestines. The rumen and large intestine (particularly colon and caecum) produce as well as absorb short chain fatty acids (SCFA) and fulfills ~ 90% energy requirement of the ruminant's body needed for maintenance, growth and production (Malhi *et al*., 2013). In the current study, the dietary selenium yeast (SY) supplementation resulted in the increase of weights of rumen, colon, caecum and the intact large intestine of goats. Previous studies have shown that addition of organic selenium in the diet improved fermentation by elevating the concentrations of propionate and total SCFA and by increasing microbial counts in rumen, caecum and colon of animals (Kim *et al*., 1997; Liu *et al*., 2007; Wang *et al*., 2009; Faixová *et al*., 2016). The SCFA have trophic effect on GIT epithelium which may stimulate epithelial growth and thereby increase the organ weight (Malhi *et al*, 2013; Moolchand *et al*., 2013). Thus, in the present study, the increase in ruminal and large intestine weights in goats fed SY diet might be due to its positive effects on fermentation. In addition to rumen and large intestine, the present study showed an increase in the weight of duodenum and jejunum of SY-fed goats. In agreement with our results, earlier studies have shown an increase in duodenal and jejunal weight of goats and steers fed organic Se compared to their control (Soto-Navarro *et al*., 2004; Ahmed *et al*., 2016). The improved growth in these segments of intestine is due to proliferative action of Se (Neville *et al*., 2008).

In the existing study, weights of liver, heart and spleen did not differ significantly between the groups; however, lung weight increased in SY-fed goats compared to control. Previous studies reported no differences in weights of liver, spleen and kidney in steers and finishing cattle fed organic selenium at the dose rate of approximately 0.3 g/kg of dry matter (Lawler *et al*., 2004; Sretenović *et al*., 2012). However, in relation with our results, Reed *et al*. (2007) reported an increase in lung weight of ewes fed SY supplemented diet. Apart from kidney, significant amount of organic Se is expelled in the form of its metabolite, dimethyl selenide ($Se(CH_3)_2$) through lungs (Behne and Kyriakopoulos, 2001). Explaining the reason of higher lung weight, Reed *et al*. (2007) suggested that the removal of excess Se caused increased respiration and thus lung capacity which was reflected in its weight.

In the current study, digestibility of dry matter (DM), crude protein (CP) and crude fiber (CF) increased by 13.71, 12.02 and 4.78% at week 3 and by 11.11, 11.8 and 3.46% at week 6, in goats fed diet supplemented with SY compared to control. Consistent with our findings, previous studies have reported an increase in nutrients digestibility in pigs and cattle (Wang *et al*., 2009; Adkins and Evans, 1984). Moreover, the increase in digestibility at week 3 and 6 were of equal magnitude, which suggests that numerical increase in digestibility of nutrients is independent of treatment period. Consistently, Adkins and Evans (1984) did not observe temporal effects of SY on nutrient digestibility analyzed at week 2 and 4 in young pigs. However, SY supplementation produced dose-dependent effects on nutrient utilization. Animals fed diet supplemented with SY at various doses between 0.1 to 0.3 mg/kg. DM of diet showed linear increase in nutrient digestibility in dose-dependent manner while the SY supplementation at the dose rate of 0.45 mg/kg DM of diet reduced nutrient digestibility (Wang *et al*., 2009; Adkins and Evan, 1984). These data show that SY at higher doses (≥ 0.45 mg/kg of dietary DM) may cause adverse effects on nutrient digestibility.

In the present study, the dressing percentage, carcass weight and leg weight increased by 7.2%, 17.5% and 21.9% respectively, in goats fed SY supplemented diet compared with control. Consistent with the present results, Hernandez-Calva *et al*. (2013) reported that Se increased leg weight and dressing percentage in lambs

and they suggested that the increase in carcass weight and dressing percentage may be due to increase in leg weight. The increase in the meat cuts weight suggests improved muscle growth which might be due to antioxidant and hypertrophic effects of Se in muscles. Dietary Se has been shown to elevate glutathione peroxidase (GSH-Px) activity in muscle (Chung *et al*., 2007) and induce hypertrophy in type-I skeletal muscle fibers (Rannem *et al*., 1995). In the present study, the physical properties of meat including pH, WHC; cooking loss and drip loss were not different between the two groups. In accordance with our results previous studies have shown no significant effect of SY supplementation on pH, WHC, cooking loss and drip loss in meat of lambs and calves (Marounek *et al*., 2006; Esterhuyse, 2012; Hernandez-Calva *et al*., 2013). Amongst the chemical properties, the moisture, protein and ash contents (%) of meat showed no any difference between the groups, however, the fat content of meat increased by 37.5 % in B compared to A. Consistent with our results, Marounek *et al*. (2006) observed no significant effects of Se supplemented diet on moisture, protein and ash contents, however, they observed non-significant increase in fat content of meat by 11.76 % in calves fed Se supplemented diet compared to those fed diet without Se supplementation. The elevated fat synthesis in muscles of SY fed goats may be attributed to insulin-like effects of Se because insulin has been shown to haveS anabolic effects on fat (McNeill *et al*., 1991; Berg *et al*., 1995).

## CONCLUSION

The results of present study showed that dietary SY supplementation increased weight of some parts of gastrointestinal tract, enhanced nutrient digestibility and improved some carcass characteristics in goats.

*Statement of conflict of interest*

Authors have declared no conflict of interest.

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