**Selenium sources in the diet of dairy cows and their effects on milk production and quality, on udder health and on physiological indicators of heat stress**

Carlos E. Oltramari,1 Maria da G. Pinheiro,2 Mariana S. de Miranda,3 Juliana R.P. Arcaro,1 Lívia Castelani,1 Luciandra M. Toledo,1 Luiz A. Ambrósio,1 Paulo R. Leme,3 Marcelo Q. Manella,4 Irineu Arcaro Júnior1

1Instituto de Zootecnia, Agência Paulista de Tecnologia dos Agronegócios, São Paulo, Brazil
2Pólo Regional de Desenvolvimento Tecnológico dos Agronegócios do Centro Leste, Agência Paulista de Tecnologia dos Agronegócios, São Paulo, Brazil
3Faculdade de Zootecnia e Engenharia de Alimentos, Universidade de São Paulo, Brazil
4Alltech do Brasil, Paraná, Brazil

**Abstract**

Twenty-four dairy cows, with daily average milk production of 18.1 kg, were fed diets containing different selenium (Se) sources. The purpose of this paper is to evaluate the effects of such diets on milk production and quality, on the occurrence of mastitis, and on physiological variables. During the experimental period (124 days), all the cows received the same diet: a total mixed feed with 0.278 mg/kg DM of selenium. In the inorganic Se treatment, the selenium source was sodium selenite and in the organic Se treatment the source was selenium yeast (Saccharomyces cerevisiae CNCM I-3060). There were no significant differences in milk yield or in Se concentration in the milk. No significant differences between the treatments were observed in protein, lactose, solids-not-fat and percentage of total solids. The animals subjected to the organic Se treatment presented higher (P=0.013) percentage of milk fat and lower (P=0.014) somatic cell count (SCC) than those subjected to the inorganic Se treatment. There was no significant difference in subclinical mastitis between the treatments. However, both Se sources reduced the incidence of mastitis (subclinical positive mastitis and strongly positive mastitis) between the pre-experimental and experimental phases. There was no significant difference in rectal temperature (RT) between the treatments. Respiratory frequency (RF) was lower (P=0.027) in the inorganic treatment than in the organic one, whereas haircoat temperature (HT) was lower (P=0.007) in the organic treatment than in the inorganic one.

**Introduction**

Selenium (Se) is an essential element in the nutrition of ruminants. It is essential to the antioxidant function of the glutathione peroxidase (GSH-Px) enzyme and is related to complex enzymatic and metabolic functions. The GSH-Px enzyme is essential to cell and tissue protection from damage caused by oxygen resulting from leukocytes during the phagocytosis. Also, selenium can act on neutrophils and consequently reduces the incidence of inflammatory processes such as mastitis.

The proportion of Se in grains or in forage depends on the presence of this element in the soil. There may be variations in different areas (Stevens, 1985). In the United States, in areas considered seleniferous (where there is high concentration of Se in the soil), Se can reach 0.14 mg/kg DM in pastures and 0.66 mg/kg DM in cereals (Combs, 2001). In Brazil, corn samples presented Se concentration that varied from 0.01 to 0.05 mg/kg DM, whereas levels of Se in forage varied from 0.01 to 0.12 mg/kg DM (Gierus, 2007). The Se concentration in the soil varies greatly even over relatively small areas. Because of this, Se supplement is recommended to maintain the minimum consumption level and to ensure effective immune response. According to the National Research Council (NRC, 2001), the Se recommendations for dairy cattle vary from 0.1 to 0.3 mg/kg DM, regardless of the age and the physiological state of the animal, but there is no reference to the form in which Se supplement should be used, i.e. organic or inorganic. However, according to Slavik et al. (2008), selenium-enriched yeast and GSH-Px were much more effective than sodium selenite for increasing the concentration of Se in blood, colostrum and milk. The most used organic Se supplement is a compound of organic molecules, selenomethionine and selenocysteine, similar to the amino acids methionine and cysteine, but with a Se molecule instead of a sulfur molecule (Weiss, 2003). The most used inorganic forms are sodium selenite and sodium selenate. In feeds in general, and in yeasts, Se is found in the organic form.

According to Ceballos et al. (2009), after 75 days, dairy cattle supplemented with 6.0 mg per day of organic selenium had greater Se concentration in the milk when compared to inorganic supplementation. It was also associated with reductions in the incidence of mastitis and in its severity, and had an impact on somatic cell count (SCC), mortality of calves, and the incidence of placenta retention (Weiss, 2003). It is also believed that Se helps reduce free radicals originating from the reaction of the organism when it is faced with oxidative stress caused by high temperatures, which are frequent in tropical climates like Brazil.

Despite the importance of this issue, there are no publications about organic sources of Se for dairy cows in Brazil. The purpose of this paper is to evaluate the effects of organic and inorganic sources of Se in the diet of dairy cows on milk production and quality, on mammary gland health, and on physiological indicators of heat stress.
Materials and methods

The study was developed in the Instituto de Zootecnia, Nova Odessa, State of São Paulo, Brazil, located at 22°46'39"S and 47°17'45"W, at 570 masl. According to the Köppen classification, the climate is a Cwa: tropical with a dry winter and a hot rainy summer. Yearly precipitation is 1307 mm, mean temperature 26°C, and the mean relative humidity 75%.

Twenty-four lactating dairy cows (Holstein Friesian and Brown Swiss) were used, with an average weight of 600 kg and daily average milk production of 18.1 kg. The cows were housed in a free stall barn, 36 m long and 12 m wide, with 3.80 m high open sides and a concrete floor, without fans and sprinklers. The feed bunk was the same length as the barn, with six water tanks and 28 resting places. The cows were divided into two groups in a randomised block design, according to breed, lactation number, and lactation period. Before the beginning of the experiment, a California Mastitis Test (CMT) test was performed and the statistical analysis showed no difference in udder health between the two groups of cows. The diet was based on the National Research Council (NRC, 2001) recommendations. It consisted basically of corn, soybean meal, whole cotton seed and corn silage. All the cows were group fed the same total mixed feed with 0.278 mg.kg⁻¹ of selenium added from two distinct sources: seleni-Alltech, 0.1% Se) and sodium selenite (0.617 mg/kg; Conagin). The average DM intake of the diet was determined through daily weighing of the feed offered and orts in the next day. The amount of feed offered was adjusted weekly so that there were approximately 10% orts. Before the experiment, feed samples were collected for the determination of dry matter (DM), crude protein (CP), ether extract (EE) and mineral matter (MM), according to the Association of Official Analytical Chemists (AOAC, 1990). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analysed with the methodology described by Goering and Van Soest (1970). Table 1 shows the ingredients and the chemical composition of the experimental diets.

During the experimental period (124 days), the cows were milked twice a day. Milk samples from each cow were collected weekly for the determination of fat, protein, lactose, solids-not-fat, percentage of total solids and SCC. In order to determine Se concentration, three milk samples from each animal (Days 1, 62 and 124 of the experimental period) were collected. The total Se concentration in the milk was established by the atomic absorption spectrophotometry with graphite oven (Csuros and Csuros, 2002). To evaluate clinical and subclinical mastitis, 10 animals per treatment were considered. Four days before the experiment and in the last experimental week, the Tamis test and the udder analysis were performed to detect clinical mastitis, according to the methodology proposed by Radostitis (1994). The CMT was used as an indicator of leukocyte count. CMT reactions were coded as negative (trace, 1, 2 and 3) according to the methodology described by Daniel et al. (1966). The purpose of the tests was to detect the clinical and subclinical mastitis, respectively.

The physiological variables were measured once a week on the same days as milk sampling. The respiratory frequency (RF) was obtained with the counting of movements of the right flank of the animals. The rectal temperature (RT) was measured with a digital clinical thermometer. The haircoat temperature (HT) in the head, in the back, in the lower leg and in the udder was measured with an infrared digital thermometer. The HT was calculated as a weighted mean. The weight attributed was: 10% for the head, 70% for the back, 12% for the lower leg, and 8% for the udder, as described by Pinheiro et al. (2005).

The comparison between the mean effects of the treatments on the milk production was analyzed with the F test of the variance analysis. The milk composition (Se, fat, protein, lactose, solids-not-fat, total solids and SCC) and the physiological variables (RF, RT and HT) were analysed with the non-parametric Wilcoxon test for paired data, as described by Conagin et al. (2009). The χ² test was used with 5% significance level to evaluate the occurrence of clinical and subclinical mastitis.

Results and discussion

Milk production and selenium concentration

The average dry matter intake of the diet was 18 kg and the daily consumption of Se for both treatments was 6.44 mg; both Se sources contributed with 5.00 mg per cow.

The animals supplied with organic Se and inorganic Se showed no differences in total milk production and in fat-corrected milk (P=0.95) (Table 2). Similar results were verified in studies by Juniper et al. (2006) and by Viero et al. (2010) using doses of sodium selenite and selenium yeast similar to those used in our study. Other studies (Gierus et al., 2002; Heard et al., 2007) that included Se in the diet of lactating cows did not show improvements in the milk production. Se concentration in the milk was not affected by the experimental diets (P=0.39) (Table 2). These results are in agreement with those found by Viero et al. (2010).

Table 1. Ingredients and chemical composition of the experimental diets.

| Ingredient                  | Diet                        |
|-----------------------------|-----------------------------|
| Ingredients, %              |                             |
| Corn silage                 | 53.6                        |
| Triturated corn             | 18.4                        |
| Soybean meal                | 6.0                         |
| Whole cotton seed           | 10.8                        |
| Protein-mineral premix °    | 11.2                        |
| Nutrients                   |                             |
| Crude protein, %DM          | 17.55                       |
| Ether extract, %DM          | 4.70                        |
| Mineral matter, %DM         | 7.78                        |
| Neutral detergent fibre, %DM| 38.87                       |
| Acid detergent fibre, %DM   | 24.94                       |
| Metabolisable energy, Mcal/gDM| 2.82                     |

°Product composition: dry matter, 92%; crude protein, 40%; metabolisable energy, 2.52 Mcal/kg; ether extract, 1.8%; calcium, 45 g/kg; phosphorus, 14 g/kg; magnesium, 10 g/kg; potassium, 10 g/kg; sodium, 16 g/kg; sulfur, 2 g/kg; zinc, 520 mg/kg; copper, 180 mg/kg; manganese, 145 mg/kg; iodine, 16 mg/kg; selenium, 2.5 mg/kg; cobalt, 10 mg/kg; iron, 360 mg/kg; vitamin A, 30,000 UI/kg; vitamin D, 1500 UI/kg; vitamin E, 500 UI/kg.

Table 2. Total milk yield and 4% fat-corrected milk of cows receiving sodium selenite (inorganic selenium) and selenium yeast (organic selenium) during the 124 experimental days.

| Variable           | Treatment      | N  | Mean  | Median | Standard deviation | Standard error | P     |
|--------------------|----------------|----|-------|--------|--------------------|----------------|-------|
| Total milk yield   | Inorganic Se   | 9  | 2247.3| 2147.8 | 295.4              | 98.4           | 0.95  |
|                    | Organic Se     | 9  | 2251.9| 2299.1 | 286.0              | 95.3           |       |
| Milk corrected yield (4% fat) | Inorganic Se | 9  | 2233.8| 2134.9 | 293.6              | 97.8           | 0.39  |
|                    | Organic Se     | 9  | 2302.6| 2350.8 | 292.4              | 97.4           |       |

Se, selenium.
However, they differ from other studies (Givens et al., 2004; Juniper et al., 2006) that showed that sources of organic Se provided an increase in the concentration of this mineral in the milk. Juniper et al. (2006) attributed that increase to the greater bioavailability of Se in organic form, resulting from larger intestinal absorption. According to the meta-analysis by Ceballos et al. (2009), animals supplied with 6 mg a day of organic Se presented larger Se concentration in the milk 75 days after the beginning of the supplement intake than animals supplied with inorganic Se.

**Milk constituents and somatic cell count**

In this study, the experimental diets had no effect on protein, on lactose, on solids-not-fat or on the percentage of total solids in the milk (P=0.05). Accordingly, Juniper et al. (2006), Heard et al. (2007), Paschoal (2007), and Wang et al. (2009) observed no effect of the organic Se supplement (with the same product, Saccharomyces cerevisiae CNCM I-3060) on percentages of protein and lactose. In all the literature consulted, we did not find any effects of Se sources on solids-not-fat or on the percentage of total solids. The percentage of milk fat of the animals supplied with organic Se was higher than the animals that received inorganic Se (4.15 and 3.96%, respectively; P=0.013) (Table 3). This increase can be connected with the decrease in SCC and with the cases of clinical mastitis that occurred in this treatment. According to Duncan et al. (1991), animals with low incidence of mastitis presented larger concentrations of milk fat, due to the lower enzymatic action of lipases of leukocytes origin, which increases in conditions of immune stress. Organic Se also resulted in a decrease in the SCC (log₂) when compared to the inorganic Se treatment (6.54 and 7.54, respectively; P=0.014) (Table 3). This result is extremely important for milk production, as SCC is used as a parameter to evaluate the health of the mammary gland. It is also positively correlated with the occurrence of mastitis and consequently with milk quality. The decrease in SCC can be explained by the better response of neutrophils to infectious agents that cause mastitis in the cows supplied with organic Se (Ibeagha et al., 2009). According to Ortman and Peharson (1999), there is greater Se absorption in the organic form, such as selenomethionine and selenocysteine, compared with inorganic sources, such as sodium selenite and selenate (91 and 81%, respectively).

Sánchez et al. (2007) verified a decrease in SCC of the milk of goats (supplied with barium selenite: 1 mg Se per kg body weight with sub-

### Table 3. Number of observations, mean, standard deviation, median, median difference and probability of the variables of milk quality of animals receiving sodium selenite (inorganic selenium) and selenium yeast (organic selenium).

| Treatment          | N  | Mean | Standard Deviation | Median | Median Difference | P    |
|--------------------|----|------|--------------------|--------|-------------------|------|
| Fat, %             |    |      |                    |        |                   |      |
| Inorganic Se       | 171| 4.07 | 0.66               | 3.96   | -0.19*            | 0.01 |
| Organic Se         | 171| 4.17 | 0.82               | 4.15   |                   |      |
| Protein, %         |    |      |                    |        |                   |      |
| Inorganic Se       | 169| 3.09 | 0.25               | 3.11   | 0.11              | 0.80 |
| Organic Se         | 169| 3.09 | 0.35               | 3.00   |                   |      |
| Lactose, %         |    |      |                    |        |                   |      |
| Inorganic Se       | 170| 4.52 | 0.26               | 4.60   | 0.07              | 0.49 |
| Organic Se         | 170| 4.51 | 0.19               | 4.53   |                   |      |
| Total solids, %    |    |      |                    |        |                   |      |
| Inorganic Se       | 171| 12.62| 0.89               | 12.56  | -0.25             | 0.16 |
| Organic Se         | 171| 12.72| 0.97               | 12.81  |                   |      |
| DME, %             |    |      |                    |        |                   |      |
| Inorganic Se       | 170| 8.55 | 0.38               | 8.55   | -0.05             | 0.74 |
| Organic Se         | 170| 8.55 | 0.42               | 8.60   |                   |      |
| Somatic cells, log₂/mL |    |      |                    |        |                   |      |
| Inorganic Se       | 171| 7.32 | 1.66               | 7.54   | 1.00*             | 0.01 |
| Organic Se         | 171| 6.93 | 2.65               | 6.54   |                   |      |

N: number of observations; Se: selenium; DME: non-fat dry extract. *Significance for difference of medians by Wilcoxon’s test at 5% probability.

### Table 4. Number of observations, mean, standard deviation, median, median difference and probability of the respiratory frequency, rectal temperature and haircoat temperature of animals receiving sodium selenite (inorganic selenium) and selenium yeast (organic selenium).

| Treatment       | N  | Mean      | Standard Deviation | Median | Median Difference | P    |
|-----------------|----|-----------|--------------------|--------|-------------------|------|
| RF, breaths/min | 153| 58.04     | 17.26              | 57.00  | -3.00*            | 0.027|
| RT, °C          | 153| 59.90     | 14.77              | 60.00  |                   |      |
| Inorganic Se    | 153| 38.98     | 0.59               | 39.00  | -0.05             | 0.435|
| Organic Se      | 152| 39.08     | 0.55               | 39.05  |                   |      |
| HD, °C          | 153| 35.88     | 1.33               | 36.22  | 0.14*             | 0.007|
| Inorganic Se    | 153| 35.65     | 1.48               | 36.08  |                   |      |
| Organic Se      | 153| 35.65     | 1.48               | 36.08  |                   |      |

N: number of observations; RF: respiratory frequency; RT: rectal temperature; HT: haircoat temperature. *Significance for difference of medians by Wilcoxon test at 5% probability.

Figure 1. Number of mammary quarters by level of subclinical mastitis (CMT) in the inorganic and organic selenium treatments.
cutaneous injection) raised in Se-deficient soils. However, no significant differences in SCC were reported by Juniper et al. (2006), Heard et al. (2007), Paschoal (2007) or Viero et al. (2010) when comparing sources and doses of Se, and these results were possibly due to the low SCC observed during the experiments.

Clinical mastitis
In the pre-experimental phase, 10% of the animals subjected to both treatments (2.5% of the mammary quarters) presented clinical mastitis. This percentage was higher than the internationally accepted indices of 3% in the herd. However, in the last experimental week there was less incidence of clinical mastitis. The inorganic Se treatment had 2 animals and 2 mammary quarters with clinical mastitis. There were no cases in the animals supplied with organic Se, and this may be explained by the preventive function of neutrophils and the antioxidant action of Se. According to Sordillo and Aitken (2009), when there is evidence of infection, neutrophils and macrophages migrate from the bloodstream to the mammary gland tissue in order to fight infection. The phagocytosis of the infectious agents for the defence cells causes an accentuated increase in the production of cellular oxygen, which is highly toxic. When there are appropriate amounts of Se circulating, these toxic metabolites are neutralised by antioxidant enzymes, mainly GSH-Px, elevating the phagocytic capacity of the organism. On the other hand, Se deficiency results in oxygen accumulation that can cause lesions or even cell lysis.

Similar results were found by Weiss et al. (1999) who supplied dairy cows with increasing levels of sodium selenite. They verified significantly higher Se concentration in the blood and lower incidence of clinical mastitis. Dairy goats that received barium selenate by subcutaneous injection presented lower incidence of clinical mastitis than the group that was not supplied with Se (Sánchez et al., 2007). The same authors concluded that Se supplement is indispensable for the prevention of mastitis in goats, mainly in areas with Se-deficient soil. On the other hand, Costa et al. (1997) did not observe any significant difference between the treatment with Se (1.8 mg sodium selenite per animal, daily) and the control group (without supplement) regarding incidence of clinical mastitis (diagnosed by TAMIS test), of subclinical mastitis (diagnosed by CMT test), and of intramammary infections. These results can be explained by the relatively low Se daily supplement. According to Paschoal et al. (2003), the daily supplement with 5 mg sodium selenite, initiated 30 days before calving, decreases the incidence of clinical mastitis in the 12 weeks of lactation by 38%.

Subclinical mastitis
In the pre-experimental phase of this study, both groups of cows (i.e. those supplied with organic and those with inorganic Se) were in similar conditions of health. In the experimental phase, there was a reduction in the number of cases of subclinical mastitis in both treatments when compared to the pre-experimental phase (P=0.05).

Figure 1 shows the number of mammary quarters of 20 cows with subclinical mastitis (1, 2, 3) or without mastitis (negative) in the inorganic Se and organic Se treatments in the pre-experimental and experimental phases. Milk samples were collected daily before the animals were fed with Se. In the experimental phase, Se was added for a period of 18 weeks. Samples were collected daily in the 18th week. The analysis was carried out in the pre-experimental phase (daily, before the Se treatments) and in the last experimental week (18th week) with the CMT.

The inorganic Se group had a 20% increase in cases of negative CMT between the pre-experimental and experimental phases, changing from 15 to 18 mammary quarters free of subclinical mastitis. The organic Se treatment changed from 12 negative cases in the pre-experimental phase to 5 cases after the supplement intake (58.3%). With regards to the slightly positive (+) subclinical mastitis, the inorganic Se group presented a 38.6% increase and the organic Se group presented a 28.4% increase between the two research phases. In the inorganic Se treatment, there was a decrease from 50 mammary quarters infected with positive (+) subclinical mastitis to 20 cases between the pre-experimental and the experimental phases; a 60% decrease. Considering the same mastitis level and period, the organic Se treatment decreased from 20 to 10 cases, totalling a 50% decrease. With regards to strongly positive (+++) subclinical mastitis, there was a decrease from 20 to 10 mammary quarters between the pre-experimental and experimental phases for the inorganic Se treatment, totalling a 50% decrease. The organic Se treatment reduced strongly positive subclinical mastitis by 81.8% (from 11 to 2 infected mammary quarters).

Zanetti et al. (1998) concluded that the daily oral supplement with 5 mg sodium selenite, in the last month of gestation, significantly increased the serum level of this mineral in dairy cows, which reduced the incidence of subclinical mastitis (diagnosed by CMT test). Furthermore, the calves of cows that received Se supplement presented serum levels that were 66% higher than the progeny of cows that had no supplement. In a recent study, Ibeagha et al. (2009) affirmed that the Se supplement, mainly in the organic form, increases the action of neutrophils and consequently improves the immune response of animals by intracellular phagocytosis. This explains the decrease in the incidence of positive and strongly positive subclinical mastitis.

Physiological variables
The RF of the animals supplied with inorganic Se was lower (P=0.027) than that of those supplied with organic Se. The animals subjected to both treatments presented RF levels that were above those considered normal for adult cows, i.e. approximately 24 movements per minute in thermal comfort (18°C), according to Randall et al. (1997). This suggests the need for using respiratory thermolysis in order to maintain homeothermy. There was a reduction in the HT of the animals subjected to the organic Se treatment when compared to those subjected to the inorganic Se treatment (P=0.007). Greater RF presented by the animals subjected to the organic Se treatment suggests that there was larger heat dissipation, which may result in lower HT. These results indicate that organic Se had no effect on RF or HT. There was no difference in RT between the inorganic Se and organic Se treatments (P=0.435) (Table 4). Both treatments were effective in maintaining RT within the normal range for lactating cows, i.e. between 38.8 and 39.5°C (Table 4).

Conclusions
Although the supplement of organic Se in the diet did not increase milk production, it had a positive effect on the percentage of milk fat. It also reduced CCS and improved mammary gland health.

References
AOAC, 1990. Official methods of analysis, 15th ed. Association of Official Analytical Chemists, Washington, DC, USA.
Ceballos, A., Sanches, J., Stryhn, H., Montgomery, J.B., Barkema, H.W., Wichtel, J.J., 2009. Meta-analysis of the effect of oral selenium supplementation on milk selenium concentration in cattle. J. Dairy Sci. 92:324-342.
Combs, G.F. Jr., 2001. Selenium in global food

[Ital J Anim Sci vol.13:2014]
systems. Brit. J. Nutr. 85:517-547.
Conagin, A., Nagai, V., Ambrósio, L.A., 2009. Princípios de técnica experimental e análise estatística de experimentos. Fundação de Apoio à Pesquisa Agrícola and Agência Paulista de Tecnologia dos Agronegócios Publ., Campinas, SP, Brazil.
Costa, E.O., Lucci, C.S., Abe, S.Y., White, C.R., Ribeiro, A.R., Watanabe, E.T., Gabaldi, A.S., Sá Filho, R., 1997. Influência da suplementação de selênio na incidência de mastite. Rev. Bras. Med. Vet. 19:169-172.
Csuros, M., Csuros, C., 2002. Environmental sampling and analysis for metals. Lewis Publ., Boca Raton, FL, USA.
Daniel, R.C.W., Barnum, D.A., Rennie, J.C., 1966. Variation in Modified California Mastitis test scores in dairy cattle. J. Dairy Sci. 49:1226-1229.
Duncan, S.E., Christen, G.L., Penfield, M.P., 1991. Rancid flavor at milk: relationship of acid degree value, free fatty acids and sensory perception. J. Food Protect. 56:394-397.
Gierus, M., 2007. Organic and inorganic sources of selenium in the nutrition of dairy cows: digestion, absorption, metabolism and requirements. Cienc. Rural 37:1212-1220.
Gierus, M., Schwarz, E.L., Kirchgessner, M., 2002. Selenium supplementation and selenium status of dairy cows fed diets based on grass, grass silage or maize silage. J. Anim. Physiol. An. N.86:74-82.
Givens, D.I., Allison, R., Cottrill, B., Blake, J.S., 2004. Enhancing the selenium content of bovine milk through alteration of the rumen fermentation, lactation performance and feed digestibilities in lactating dairy cows. J. Dairy Sci. 87:46:1556-1547.
Goering, H.K., Van Soest, P.J., 1970. Forage fiber analysis. Agriculture handbook no. 379. Agriculture Research Service, United States Department of Agriculture Publ., Washington, DC, USA.
Heard, J.W., Stockdale, C.R., Walker, G.P., Leddin, C.M., Dunshea, F.R., McStosh, G.H., Shields, P.M., McKenna, A., Young, G.P., Doyle, P.T., 2007. Increasing selenium concentration in milk: effects of amount of selenium from yeast and cereal grain supplements. J. Dairy Sci. 90:4117-4127.
Ibeagha, A.E., Ibeagha-Awemu, E.M., Mehrzad, J., Baurhoo, B., Kwatalala, P., Zhao, X., 2009. The effect of selenium sources and supplementation on neutrophil functions in dairy cows. Animal 7:1037-1043.
Juniper, D.T., Phipps, R.H., Jones, A.K., Bertin, G., 2006. Selenium supplementation of lactating dairy cows: effect on selenium concentration in blood, milk, urine, and feces. J. Dairy Sci. 89:3544-3551.
National Research Council, 2001. Nutrient requirements of dairy cattle, 7th rev. ed. National Academy Press, Washington, DC, USA.
Ortman, K., Peharson, B., 1999. Effect of selenium as a feed supplement to dairy cows in comparison to selenite and selenium yeast. J. Anim. Sci. 77:3365-3370.
Paschoal, J.J., Zanetti, M.A., Cunha, J.A., 2003. Supplementation of selenium and vitamin E on milk somatic cell count of Holstein dairy cows. Rev. Bras. Zootec. 32:2032-2039.
Pinheiro, M.G., Nogueira, J.R., Lima, M.L.P., Leme, P.R., Macari, M., Naas, I.A., Lalloni, L.A., Tiito, E.A.L., Pereira, A.F., 2005. Holding pen environment effects on skin temperature, rectal temperature and milk production in Jersey cows. Rev. Port. Zootec. 12:37-43.
Radostitis, O.M., Leslie, K.E., Pettrow, J., 1994. Herd health: food animal production medicie, 2nd ed. W.B. Saunders Co. Publ., Philadelphia, PA, USA.
Randall, D., Burgeon, W., French, K., 1997. Animal physiology mechanisms and adaptations, 4th ed. H.W. Freeman and Co. Publ., New York, NY, USA.
Sánchez, J., Montes, P., Jimenez, A., Andrés, S., 2007. Prevention of clinical mastitis with barium selenate in dairy goats from a selenium-deficient area. J. Dairy Sci. 90:2350-2354.
Slavik, P., Illek, J., Brix, M., Hlavicova, J., Rajmon, R., Jilek, F., 2008. Influence of organic versus inorganic dietary selenium supplementation on the concentration of selenium in colostrum, milk and blood of beef cows. Acta Vet. Scand. 50:1-6.
Sordillo, L.M., Aitken, S.L., 2009. Impact of oxidative stress on the health and immune function of dairy cattle. Vet. Immunol. Immunop. 128:104-109.
Stevens, J.B., 1985. Serum selenium concentrations and glutathione peroxidase activities in cattle grazing forages of various selenium concentrations. Am. J. Vet. Res. 46:1556-1561.
Viero, V., Fischer, V., Machado, S.C., Zanella, M.B., Ribeiro, M.E.R., Barbosa, R.S., Stumpf, J.R.W., Cobucci, J.A., 2010. Efeito da suplementação com diferentes níveis de selênio orgânico e inorgânico na produção e na composição do leite e no sangue de vacas em lactação. Arq. Bras. Med. Vet. Zoo. 62:382-390.
Wang, C., Liu, Q., Yang, W.Z., Dong, Q., Yang, X.M., 2009. Effects of selenium yeast on rumen fermentation, lactation performance and feed digestibilities in lactating dairy cows. Livest. Sci. 126:239-244.
Weiss, W.P., 2003. Selenium nutrition of dairy cows: comparing responses to organic and inorganic selenium forms. pp 333-343 in Proc. 19th Alltech’s Nat. Annual Symp., Madison, WI, USA.
Weiss, W.P., Todhunter, D.A., Hogan, J.S., Smith, K.L., 1990. Effect of duration of supplementation of selenium and vitamin E on periparturient dairy cows. J. Dairy Sci. 73:3187-3194.
Zanetti, M.A., Neunhaus, L.E.D., Schalch, E., Martins, J.H., 1998. Effect of selenium and vitamin E supplementation in dairy cows. Rev. Bras. Zootec. 27:405-408.