# Effect of supplementary zinc and manganese methionine chelates on productive and reproductive performance of dairy Friesian cows

**Ghada S. El-Esawy[1]; W.A. Riad[1]; A.M.A. Mohy El-Dein[1]; M.F.E. Ali[2] and H.M.A. Gaafar[1]**

*[1]Animal Production Research Institute, Agriculture Research Center, Dokki, Giza, Egypt;*
*[2] Animal Production Department, Faculty of Agriculture, Kafrelsheikh University, Egypt*

SUMMARY

Twenty lactating Friesian cows with average live body weight of 500 kg and at 2-4 season of lactation were used after calving and divided into four similar groups (5 each) assigned randomly to four treatments. Cows were fed the basal ration consisted of 40% concentrate feed mixture (CFM), 40% fresh berseem (FB) and 20% rice straw(RS), on dry matter (DM) basis. The 1st group was unsupplemented and served as control (T1), while 2nd, 3rd and 4th groups were supplemented with zinc methionine (ZINPRO) and manganese methionine (MANPRO)at 100 mg Zn/head/day (T2), 100mgMn/head/day (T3) and 50 mg Zn + 50mg Mn/head/day (T4), respectively. Results indicated that the digestibility of all nutrients as well as nutritive values increased significantly ($P<0.05$) with zinc and manganese methionine supplemented treatments than control. Average daily intake was higher markedly ($P<0.05$) in T2 compared to T1. Total volatile fatty acids (TVFA's) concentration increased significantly ($P<0.05$), however, ammonia nitrogen ($NH_3$-N) decreased significantly ($P<0.05$) with chelated zinc and manganese supplements. Plasma total protein and globulin concentrations increased significantly ($P<0.05$), however, AST and ALT enzymes activity decreased significantly ($P<0.05$) with chelated zinc and manganese supplements. Also, actual milk and 4% fat corrected milk (FCM) yield and the contents of fat, protein, lactose, solids not fat and total solids in milk were increased significantly ($P<0.05$), however, somatic cell count decreased significantly ($P<0.05$) with chelated zinc and manganese supplements. Chelated zinc and manganese supplements improved feed conversion ratio. Average daily feed cost of cows in T2 was significantly higher ($P<0.05$) than that of T1. Whereas, feed cost per 1 kg 4% FCM decreased significantly ($P<0.05$), however, the output of daily 4% FCM and net revenue increased significantly ($P<0.05$) with chelated zinc and manganese supplements. Chelated zinc and manganese supplements improved decreased days to first estrus and service, service period, days open, calving interval and number of service per conception and increased conception rate (P<0.05). In conclusion, chelated zinc and manganese supplements for dairy Friesian cows improved digestibility, feed intake, rumen fermentation activity, some blood plasma parameters, milk yield and composition, feed conversion ratio and economic efficiency as well as postpartum reproductive traits.

Keywords: Chelated zinc and manganese, lactating Friesian cows, digestibility, milk yield and composition, feed and economic efficiency, reproductive traits.

## INTRODUCTION

The nutritional support of high yielding cows depends not only on precisely balanced basic nutrients but also on minerals, which contents in feeds vary in particular years and depend on soil type and harvest time (Brzóska, et al., 2003a and b). The important factor, that affects both the absorption and utilization of trace elements in the metabolic pathways, is their chemical form. Minerals and vitamins deficiencies may result in delayed onset of estrus, repeat breeding and/ or infertility (Underwood and Suttle, 1999).

To avoid deficiency of trace minerals, mineral supplementation has been recommended as an important nutritional strategy to maintain production, reproduction, and health of dairy cows (Spears, 1996), since these are important in vital functions such as blood synthesis, structure of hormones, vitamins synthesis, reproductive function, formation of enzymes, and immune system integrity (NRC, 2001). Trace minerals are those that although essential for normal body functions, are required in a very small amount in feeding. This group includes cobalt, copper, iodine, iron, manganese, molybdenum, selenium, zinc, and chromium (NRC, 2001).

As animal productivity increased in the last years, there was an increase in the requirements and interest for more effective animal feeding strategies. This has led to the development of a specific area of study focused on the effects of the structure of minerals on their retention and relationship with health and performance of dairy cows (Nocek et al., 2006; Siciliano-Jones et al., 2008).

Trace minerals have been supplemented in the form of inorganic compounds such as sulfates. Sulfates are associated in normal conditions and dissociated when solubilized in water. Minerals dissociated in the reticulum-rumen, omasum and abomasum can interact with digestion compounds, becoming insoluble and indigestible, and excreted in feces (McDonald et al., 1996; Spears, 2003). Polyphenols and some specific carbohydrates can alter the mineral absorption process. In addition, some minerals have a mutual antagonism, such as iron, manganese, and cobalt (NRC, 2001).

In a meta-analytic study, demonstrated increase in fat and protein, and milk yield and improved reproductive rates with organic source of trace minerals depending on the supplementation period, mineral source used, environmental conditions, and requirement of animals (Rabiee et al., 2010). Research has demonstrated that specific amino acid complexes of trace minerals are more bioavailable (Paripatananont and Lovell, 1995) and have better retention (Nockels et al., 1993) than inorganic sources. In studies conducted by Strusinska et al. (2004), Ziemiński et al. (2002) and Kinal et al. (2005) found that the use of chelates and amino acid complexes with Cu, Zn and Mn in dairy cow nutrition led to a decrease in milk somatic cell count after organic form application was noted.

The objective of this study was to investigate the effect of adding chelated zinc or/and manganese methionine on feed intake, digestibility coefficients, rumen fermentation activity, some blood plasma biochemical, milk yield and composition, feed conversion ratio, economic efficiency and postpartum reproductive traits.

## MATERIAL AND METHODS

The current work was carried out at Sakha Animal Production Research Institute, Animal Production Research Institute (APRI), Agricultural Research Center, Ministry of Agriculture in Co-operation with Department of Animal Production, Faculty of Agriculture, Kafrelsheikh University, Egypt.

### *Experimental animals and treatments*

Twenty lactating Friesian cows with average live body weight of 500 kg and at 2-4 season of lactation were used after calving and divided into four similar groups (5 each) assigned randomly to four treatments. Cows were fed the basal ration consisted of 40% concentrate feed mixture (CFM), 40% fresh berseem (FB) and 20% rice straw(RS), on DM basis. The 1$^{st}$ group was unsupplemented and served as control (T1), while 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ groups were supplemented with zinc methionine (ZINPRO) and manganese methionine (MANPRO) at 100 mg Zn/head/day (T2), 100mgMn/head/day (T3) and 50mg Zn+ 50mg Mn/head/day (T4), respectively. ZINPRO® (zinc methionine complex) and MANPRO® (manganese methionine complex) are built on a unique, patented molecule that consists of one metal ion bound to one amino acid ion – called a metal specific amino acid complex and are a nutritional feed ingredient for animals that contains organic zinc and manganese produced by Zinpro

Corporation, Minnesota, USA. The chemical composition of feedstuffs and basal ration are shown in Table 1.

Table 1: Chemical composition of feedstuffs and basal ration

| Item | DM % | Composition of DM % | | | | | |
|---|---|---|---|---|---|---|---|
| | | OM | CP | CF | EE | NFE | Ash |
| Concentrate feed mixture | 91.30 | 95.72 | 16.80 | 12.38 | 2.77 | 63.77 | 4.28 |
| Fresh berseem | 17.27 | 87.41 | 15.92 | 27.65 | 2.59 | 41.25 | 12.59 |
| Rice straw | 90.14 | 82.78 | 3.20 | 35.91 | 2.24 | 41.63 | 17.02 |
| Basal ration | 61.46 | 89.81 | 13.73 | 23.19 | 2.59 | 50.30 | 10.19 |

*Management procedure*

Cows were fed to cover their recommend requirements according to NRC (2001) allowances for dairy cows and adjusted every week based on the average body weight of animals and milk production. Concentrate feed mixture were offered twice daily at 8 a.m. and 4 p.m., fresh berseem was offered daily at 10 a.m., while rice straw was offered at 1p.m. Fresh water was available for cows in build basin all the day round.

*Digestibility trails*

Digestibility trails were conducted during the feeding period using 3 cows from each group to determine the digestibility coefficients and nutritive values of the experimental ration. Each digestibility trial consisted of 15 days as preliminary period followed by 7 days as collection period. Acid insoluble ash was used as a natural marker (Van Keulen and Young, 1997). Feces samples were taken from the rectum of each cow twice daily with 12 hours interval during the collection period and composited for each cow. Samples of feedstuffs were taken at the beginning, middle and end of the collection period. Representative samples of feedstuffs and feces were dried in air oven at 60 $^{0}$C for 48 hours, ground and chemically analyzed according to the methods of AOAC (1990). Nutrients digestibility coefficients were calculated from the equation stated by Schneider and Flat, (1975) as follows:

$$\text{DM digestibility \%} = 100 - \left(100 \times \frac{\text{AIA \% in feed}}{\text{AIA \% in feces}}\right)$$

$$\text{Nutrient digestibility \%} = 100 - \left(100 \times \frac{\text{AIA \% in feed}}{\text{AIA \% in feces}} \times \frac{\text{Nutrient \% in feces}}{\text{Nutrient \% in feed}}\right)$$

where AIA is acid insoluble ash.

*Milk yield and samples*

Cows were mechanically milked and daily milk yield was recorded individually and corrected for 4% fat content (FCM) using the formula of Gaines (1928) as follows: 4% FCM = 0.4 x milk yield (kg) +15 x fat yield (kg).

Milk samples from the consecutive evening and morning milkings were taken every week during the experimental period and mixed in proportion to milk yield. Composite milk samples were analyzed for fat, protein, lactose, solids not fat (SNF) and total solids (TS), by Milko-Scan, Model 133 B. Ash was determined by difference.

*Rumen liquor samples*

Rumen liquor samples were taken once time from cows at 3 hours after the morning feeding using stomach tube with draw pulse power of the automatic milking machine. Every sample was strained through double layers of cheesecloth and pH value was determined immediately using Orian 680 digital pH meter. Ammonia nitrogen ($NH_3$-N) was determined using saturated solution of magnesium oxide distillation according to the method of AOAC (1990). The total volatile fatty acids (TVFA's) was determined by the steam distillation method described by (Warner, 1964).

*Blood samples*

Blood samples were taken from the jugular vein of cows at 3 hours post-feeding in centrifuge tubes containing anticoagulant (EDTA). Then centrifuged for 15 minutes at 4000 r.p.m. to obtain plasma and kept in deep freezer until analysis. Blood plasma total protein, albumin, globulin (by difference), urea nitrogen, AST and ALT were determined calorimetrically using commercial diagnostic kits (test- combination-Pasteur Lap.).

*Feed conversion ratio*

Feed conversion ratio was expressed as the amounts of DM, TDN and DCP required for producing 1kg 4%FCM.

*Economic evaluation*

Economic evaluation parameters were average daily feed cost, feed cost per kg 4% FCM, output of average 4% FCM yield, net revenue and net revenue improvements.

*Statistical analysis*

The data were statistically analyzed using general linear model procedure adopted by IBMSPSS Statistics 22 for Windows (2014) for one-way ANOVA. Statistical significant effects were further analyzed and means were compared using Duncan's multiple range test. Statistical significant was determined at P≤0.05.

## RESULTS AND DISCUSSION

### *Digestibility coefficients and nutritive values*

The effect of zinc and manganese methionine supplements on nutrients digestibility coefficients and nutritive values in different treatments are presented Table 2. Based on control ration, digestibility of OM, CP, CF, EE and NDF as well as nutritive values in terms of TDN and DCP increased significantly (P<0.05) with both zinc and manganese methionine supplements in T2, T3 and T4 with the best results in T2 (zinc methionine).

The improvement in digestibility coefficients could be attributed that zinc and manganese methionine can play indirect role to stimulate anaerobic fermentation of organic matter that improve the utilization efficiency of nutrients and direct role to improve digestion in abomasums. These results are in a good agreement with those obtained by Garg et al.(2008)who found that digestibility of DM, OM, CP, EE, NDF, ADF, hemicellulose and cellulose, DCP and TDN increased significantly (P<0.05) with zinc methionine supplement for lambs. Gaafar et al. (2011) stated that nutrients digestibility coefficients and nutritive values increased significantly (P<0.05) with zinc methionine supplement for lactating cows. El Ashry et al. (2012) reported that digestibility coefficients and nutritive value increased significantly (P<0.05) with combination of zinc, manganese and copper methionine chelates supplements for early lactation dairy cows.

Table 2: Nutrients digestibility coefficients and nutritive values for different treatments

| Item | Treatments | | | | SEM |
|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | |
| Digestibility coefficients % | | | | | |
| OM | $67.39^{b}$ | $69.68^{a}$ | $69.41^{a}$ | $69.50^{a}$ | 0.22 |
| CP | $69.22^{b}$ | $71.99^{a}$ | $71.62^{a}$ | $71.65^{a}$ | 0.33 |
| CF | $66.29^{b}$ | $68.69^{a}$ | $68.38^{a}$ | $68.66^{a}$ | 0.83 |
| EE | $70.05^{b}$ | $72.23^{a}$ | $71.44^{ab}$ | $71.30^{ab}$ | 0.87 |
| NFE | $68.08^{b}$ | $70.74^{a}$ | $69.64^{ab}$ | $70.41^{a}$ | 0.47 |
| Nutritive values % | | | | | |
| TDN | $63.20^{b}$ | $65.60^{a}$ | $64.88^{a}$ | $65.33^{a}$ | 0.28 |
| DCP | $9.50^{b}$ | $9.88^{a}$ | $9.83^{a}$ | $9.84^{a}$ | 0.05 |

a, b: Values in the same row with different superscripts differ significantly (P<0.05).

*Daily feed intake*

Average daily feed intake by lactating cows as affected by zinc and manganese methionine supplements are presented in Table 3. Average daily feed intake in terms of DM, TDN, CP and DCPby lactating cows were higher markedly (P<0.05) with zinc methionine supplement in T2 compared to T1 (control), whereas in T3 (manganese methionine) and T4 (zinc and manganese methionine combination) were intermediate with insignificant differences. In this study, DM, TDN, CP and DCP intake are cover the recommended requirements of lactating cows producing 15-17 kg milk/ day according to NRC (2001). These results are in accordance with those obtained by El Ashry et al. (2012) who reported that supplementation of organic metal had a significant increase in DM intake by lactating cows. Gaafar et al. (2011) found that the intake of TDN and DCP by lactating cows increased significantly with zinc methionine supplement.

Table 3: Average daily feed intake by lactating cows in different treatments

| Item | Treatments | | | | SEM |
|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | |
| As fed basis (kg/day/head): | | | | | |
| Concentrate feed mixture | 6.80 | 7.11 | 6.96 | 6.87 | |
| Fresh berseem | 35.92 | 37.57 | 36.78 | 36.29 | |
| Rice straw | 3.44 | 3.60 | 3.52 | 3.48 | |
| Total | 46.16 | 48.28 | 47.26 | 46.64 | |
| On DM basis (kg/day/head): | | | | | |
| Total DM | $15.51^{b}$ | $16.22^{a}$ | $15.88^{ab}$ | $15.67^{ab}$ | 0.14 |
| TDN | $9.80^{b}$ | $10.64^{a}$ | $10.30^{ab}$ | $10.24^{ab}$ | 0.11 |
| CP | $2.13^{b}$ | $2.23^{a}$ | $2.18^{ab}$ | $2.15^{ab}$ | 0.04 |
| DCP | $1.47^{b}$ | $1.60^{a}$ | $1.56^{ab}$ | $1.54^{ab}$ | 0.02 |

a, b: Values in the same row with different superscripts differ significantly (P<0.05).

*Rumen liquor parameters*

Data related to rumen liquor measurements as pH, ammonia-N and TVFA's concentrations are presented in Table 4. The pH values seemed to be within in very narrow range being 6.69- 6.74 without any significant differences among tested rations T1 even T4. There a slight decrease in pH value detected with increase the concentration of TVFA's, whereas, TVFA's concentration increased significantly (P<0.05) with zinc and manganese methionine supplements with the highest value in T2 (20.71 mEq/100 ml). However, the concentration of $NH_3$-N decreased significantly (P<0.05) with zinc and manganese methionine supplements with the lowest value in T2 (15.51 mg/100 ml).

These results suggest that the anaerobic fermentation of protected amino acids was more efficient and faster yielding more TVFA's than that in control. The decreased ruminal $NH_3$-N concentration in supplemented treatments may be due to improve the rumen microbes activity utilizing $NH_3$-N to produce microbial protein. The pH values are within the normal range obtained by Van Soest (1982) who stated that the optimum pH value for growth of cellulytic microorganisms was 6.7±0.5 pH degree. Gaafar et al. (2011) found that pH value of rumen liquor was not significantly affected (P>0.05), while, the concentrations of TVFA's increased significantly (P<0.05) and $NH_3$-N decreased significantly (P<0.05) with zinc methionine supplementation. El Ashry et al. (2012) indicated that rumen liquor pH values of sheep did not significantly differ among treatments.

The $NH_3$-N were significantly (P<0.05) higher in inorganic metals than organic metals. Sheep in organic metals treatment had higher (P<0.05) total VFA concentrations than those in the inorganic metals. Jung et al. (2013) reported that ruminal fermentation patterns in lactating Holstein cows including pH, ammonia-N and VFA post-feeding were significantly altered when animals were supplemented with chelated minerals relative to the control (P<0.05).

Table 4: Rumen fermentation activity and some blood plasma constituents for different treatments

| Item` | Treatments | | | | SEM |
|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | |
| Rumen fermentation activity: | | | | | |
| pH value | 6.74 | 6.69 | 6.72 | 6.71 | 0.03 |
| TVFA's (mEq/100 ml) | 18.80$^{b}$ | 20.71$^{a}$ | 20.65$^{a}$ | 20.55$^{a}$ | 0.22 |
| $NH_3$-N (mg/100 ml) | 17.98$^{a}$ | 15.51$^{b}$ | 15.62$^{b}$ | 15.59$^{b}$ | 0.26 |
| Blood plasma constituents: | | | | | |
| Total protein (g/dl) | 7.26$^{b}$ | 8.30$^{a}$ | 8.19$^{a}$ | 8.10$^{a}$ | 0.13 |
| Albumin (g/dl) | 3.95 | 4.20 | 4.12 | 4.10 | 0.09 |
| Globulin (g/dl) | 3.31$^{b}$ | 4.10$^{a}$ | 4.07$^{a}$ | 4.00$^{a}$ | 0.10 |
| Creatinine (g/d) | 1.63 | 1.55 | 1.58 | 1.56 | 0.04 |
| AST (U/L) | 65.74$^{a}$ | 60.51$^{b}$ | 59.81$^{b}$ | 59.71$^{b}$ | 0.59 |
| ALT (U/L) | 30.80$^{a}$ | 25.79$^{b}$ | 26.31$^{b}$ | 26.12$^{b}$ | 0.49 |

a, b: Values in the same row with different superscripts differ significantly (P<0.05).

*Blood plasma biochemical parameters*

Results concerning the effect of chelated zinc and manganese supplements for lactating cows on some blood plasma parameters are shown in Table 4. In the present study, total protein and globulin concentrations in plasma were nearly similar for treatments supplemented with chelated zinc and manganese methionine (T2, T3 and T4) without significant differences (P>0.05), but were increased significantly (P<0.05) compared with control (T1) and were within the normal range being 6-8.3 g/dl (Kancko, 1989).

While, plasma albumin and creatinine concentrations were insignificantly (P>0.05) differ among the different treatments. However, AST and ALT enzymes activity decreased significantly (P<0.05) treatments supplemented with chelated zinc and manganese methionine (T2, T3 and T4) compared to T1. These results agreed with those obtained by Gaafar et al. (2011)who found that cows supplemented with zinc methionine showed the highest plasma total protein, albumin and globulin concentrations (P<0.05). Also, zinc methionine supplementation led to significant decrease (P<0.05) in the activity of AST and ALT.

*Milk yield and composition*

Data concerning milk yield and its composition are presented in Table 5. Actual milk yield and 4% fat corrected milk (FCM) were increased significantly (P<0.05) in Zn and Mn methionine supplemented treatments (T2, T3 and T4) compared with control treatment (T1). Actual milk yield increased by 13.32, 12.12 and 12.19% in T2, T3and T4 compared toT1, respectively. The corresponding values for 4% FCM were 15.99, 13.83 and 14.13%, respectively. Moreover, the contents of fat, protein, lactose, solids not fat and total solids in milk were increased significantly (P<0.05) in T2, T3 and T4 compared with T1. However, somatic cell count decreased significantly (P<0.05) in chelated zinc and manganese treatments compared the control one.

The increase in milk yield with zinc methionine supplementation might be due to one or more of the following reasons: 1) higher nutrients digestibility (Table 2), feed intake (Table 3) and TVFA's concentration and lower ammonia nitrogen concentration in the rumen (Table 4) of animals given chelated zinc and manganese; 2) apparent increase in the efficiency of nitrogen utilization as well as an increased conversion and availability of nutrients for milk synthesis (Iwanska et al., 1999) or 3) Methionine seems to be the most limiting for milk synthesis because it is heavily utilized by the mammary gland and are present in relatively low concentrations in plasma (Schwab et al., 1992). Noeek (2006) reported an increased milk production in animals receiving diets containing organically complexed minerals and a mixture of inorganic and organically complexed minerals. Gaafar et al. (2011) observed significant increase (P<0.05) in the yield of actual milk and 4% and milk composition of cows supplemented with zinc methionine.

The increase of milk fat with zinc and manganese methionine supplementation might be due to that methionine in particular might facilitate the transfer of blood lipids to milk by furnishing methyl group for synthesis of choline and phosphatidylcholine, which represent an important link between methionine and lipid metabolism in ruminants (Seymour et al., 1990). Sobhinard (2010) and Gaafar et al. (2011) reported that somatic cell count was reduced by addition of Zn methionine complex to the diet, this refer to that Zn methionine plays integral role in immune function by activating T-lymphocyte responsiveness, thus impacting the effectiveness of somatic cells within the mammary gland.

Table 5: Average daily milk yield, milk composition and somatic cell count (SCC) for different treatments

| Item | Treatments | | | | Mean |
|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | |
| Average daily milk yield (kg/day): | | | | | |
| Actual milk | 14.19$^{b}$ | 16.08$^{a}$ | 15.91$^{a}$ | 15.92$^{a}$ | 0.24 |
| Increase% | 100.00$^{b}$ | 113.32$^{a}$ | 112.12$^{a}$ | 112.19$^{a}$ | 0.74 |
| 4% FCM | 13.45$^{b}$ | 15.60$^{a}$ | 15.31$^{a}$ | 15.35$^{a}$ | 0.23 |
| Increase% | 100.00$^{b}$ | 115.99$^{a}$ | 113.83$^{a}$ | 114.13$^{a}$ | 0.76 |
| Milk composition %: | | | | | |
| Fat | 3.65$^{b}$ | 3.80$^{a}$ | 3.75$^{a}$ | 3.76$^{a}$ | 0.05 |
| Protein | 2.72$^{b}$ | 2.89$^{a}$ | 2.84$^{a}$ | 2.85$^{a}$ | 0.04 |
| Lactose | 4.32$^{b}$ | 4.46$^{a}$ | 4.42$^{a}$ | 4.43$^{a}$ | 0.03 |
| Solids not fat | 7.74$^{b}$ | 8.05$^{a}$ | 7.96$^{a}$ | 7.98$^{a}$ | 0.05 |
| Total solids | 11.39$^{b}$ | 11.85$^{a}$ | 11.71$^{a}$ | 11.74$^{a}$ | 0.07 |
| SCC (× $10^3$ cell/ml) | 169.7$^{a}$ | 141.6$^{b}$ | 144.7$^{b}$ | 142.3$^{b}$ | 2.76 |

a, b, c: Values in the same row with different superscripts differ significantly (P<0.05).

*Feed conversion ratio*

Feed conversion ratio expressed as the amounts of DM, TDN, CP and DCP per 1 kg 4% FCM as affected by chelated ZN and Mn supplement are shown in Table 6. The amounts of DM, TDN, CP and DCP per 1 kg 4% FCM were significantly decreased (P<0.05) in chelated Zn and Mn treatments (T2-T4) compared to control (T1).The amounts of DM, TDN, CP and DCP per 1 kg 4% FCM in chelated Zn and Mn treatments (T2-T4) decreased by 9.57-11.30, 6.85-8.22, 9.49-11.39 and 5.50-8.26% compared to T1, respectively. These results are in accordance with those obtained by Shakweer et al. (2010) who reported that zinc methionine supplements improved feed efficiency. Gaafar et al. (2011) showed that supplementation of zinc methionine improved feed conversion improved feed conversion, leding to reduce the quantities of DM, TDN and DCP required to produce one kg of 4% FCM (P<0.05).

*Economic efficiency*

The effect of chelated Zn and Mn supplements on economic efficiency is shown in Table 6. Average daily feed cost of cows in T2 was significantly higher (P<0.05) than that of T1, while in T3 and T4 was intermediate without significant differences reflecting the same trend with feed intake. However, feed cost per 1 kg 4% FCM decreased significantly (P<0.05) in chelated Zn and Mn treatments (T2-T4) compared to T1. The output of daily 4% FCM and net revenue increased significantly (P<0.05) in chelated Zn and Mn treatments (T2-T4) compared to T1. These results agreed with those obtained by Shakweer *et al*. (2010) who reported that feed cost per kg milk produced decreased, while economic cash return was more pronounced with ration contained zinc methionine than control. Also, economic efficiency was improved with added zinc methionine compared to control group. Gaafar *et al.* (2011) found that average daily feed cost per kg of 4% FCM decreased and average income from milk production increased with zinc methionine supplementation (P<0.05).

Table 6: Feed conversion ratio and economic efficiency for different groups

| Item | Treatments | | | | SEM |
|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | |
| Feed conversion ratio: | | | | | |
| DM kg/ kg 4%FCM | 1.15$^{a}$ | 1.04$^{b}$ | 1.04$^{b}$ | 1.02$^{b}$ | 0.09 |
| TDN kg/ kg 4%FCM | 0.73$^{a}$ | 0.68$^{b}$ | 0.67$^{b}$ | 0.67$^{b}$ | 0.05 |
| CP kg/ kg 4%FCM | 0.158$^{a}$ | 0.143$^{b}$ | 0.142$^{b}$ | 0.140$^{b}$ | 0.018 |
| DCP kg/ kg 4%FCM | 0.109$^{a}$ | 0.103$^{b}$ | 0.102$^{b}$ | 0.100$^{b}$ | 0.011 |
| Economic efficiency: | | | | | |
| Feed cost (LE/day)* | 46.34$^{b}$ | 48.47$^{a}$ | 47.45$^{ab}$ | 46.83$^{ab}$ | 0.23 |
| Feed cost (LE)/ kg 4% FCM | 3.45$^{a}$ | 3.11$^{b}$ | 3.10$^{b}$ | 3.05$^{b}$ | 0.05 |
| Output of 4% FCM (LE/day)* | 60.53$^{b}$ | 70.20$^{a}$ | 68.90$^{a}$ | 69.08$^{a}$ | 0.27 |
| Net revenue (LE/day) | 14.19$^{b}$ | 21.73$^{a}$ | 21.45$^{a}$ | 22.25$^{a}$ | 0.17 |
| Net revenue improvement % | 100.00$^{b}$ | 153.14$^{a}$ | 151.16$^{a}$ | 156.80$^{a}$ | 0.35 |

a, b: Values in the same row with different superscripts differ significantly (P<0.05).
* The prices of 1 kg were 5.00 LE for concentrate feed mixture, 0.31 LE for fresh berseem, 0.35 LE for rice straw, 160 LE for chelated zinc and manganese methionine and 4.50 LE for 4% FCM.

*Reproductive performance*

Results in Table 7 showed significant differences (P<0.05) in postpartum reproductive performance among cows in different treatments. Days to first estrus and service, service period, days open, calving interval and number of service per conception decreased significantly (P<0.05) in chelated Zn and Mn treatments (T2-T4) compared to T1. However, conception rate revealed the opposite trend, which increased significantly (P<0.05) in chelated Zn and Mn treatments (T2-T4) compared to T1. These results are in agreement with those obtained by Hardcastle (1995) who found that days to first estrus were significantly lower (P<0.05) in the treatment group. Bosseboeuf et al. (2006) reported that mean services per conception was less in the amino acid chelates (AAC) group compared with the inorganic metal salts (IM) group (1.50 vs. 1.90). In the IM group, 87% of the cows ultimately became pregnant compared with 96% in the AAC group ($P < 0.05$).

Table 7: Postpartum reproductive performance of cows in different treatments

| Item | Treatments | | | | SEM |
|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | |
| First estrus (day) | 38.8$^{a}$ | 30.3$^{b}$ | 32.1$^{b}$ | 30.9$^{b}$ | 1.05 |
| First service (day) | 64.5$^{a}$ | 47.8$^{b}$ | 53.9$^{b}$ | 52.1$^{b}$ | 2.001 |
| Service period (day) | 57.8$^{a}$ | 45.8$^{b}$ | 51.2$^{ab}$ | 48.6$^{ab}$ | 1.87 |
| Days open (day) | 122.3$^{a}$ | 93.6$^{c}$ | 105.1$^{b}$ | 100.7$^{bc}$ | 5.12 |
| Calving interval (day) | 407.4$^{a}$ | 380.2$^{b}$ | 388.9$^{b}$ | 386.7$^{b}$ | 6.09 |
| No of service per conception | 3.6$^{a}$ | 2.1$^{b}$ | 2.4$^{b}$ | 2.6$^{b}$ | 0.19 |
| Conception rate % | 63.19$^{b}$ | 81.59$^{a}$ | 80.9$^{a}$ | 79.25$^{a}$ | 1.86 |

a, b: Values in the same row with different superscripts differ significantly ($P<0.05$).

## CONCLUSIONS

From these results, it could be concluded that chelated zinc and manganese methionine supplement for dairy Friesian cows improved digestibility coefficients, feed intake, rumen fermentation activity, some blood plasma parameters, milk yield and composition, feed conversion ratio and economic efficiency as well as postpartum reproductive traits.

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