Effect of Rumen Protected Methionine and/or Choline Additives on Productive Performance of Zaraibi Goats

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Abstract: Forty Zaraibi goats with average body weight of 34.64±0.79 kg and aged 3-4 years at the last month of pregnancy were divided into four similar groups (10 in each). The goats were fed the basal ration containing 0.8 kg concentrate feed mixture, 0.2 kg barley grain and 5.0 kg berseem without additive (control) or with 2 g/head/day rumen protected methionine (RPM) or 2 g/head/day rumen protected choline (RPC) or 2 g/head/day rumen protected methionine + 2 g/head/day rumen protected choline (RPM+RPC). Average daily dry matter intake (DMI) by goats was nearly similar for the different groups. The RPM+RPC group showed significantly (P<0.05) the highest digestibility coefficients and nutritive values followed by RPM and RPC groups, while the control group had the lowest values. The yield of colostrum for RPM, RPC and RPM+RPC groups increased by 19.65, 13.87 and 32.37% compared to control group, respectively. The correspondence values for milk yield were 18.39, 11.21 and 30.04%, respectively. The RPM+RPC group showed significantly (P<0.05) the highest colostrum and milk composition followed by RPM and RPC groups, while the control group had the lowest values. Rumen protected methionine and/or choline additives increased significantly (P<0.05) body weight of goats during the different periods compared to control group. The total DM intake and total feed cost were nearly the same for the different groups. The RPM+RPC group showed significantly (P<0.05) the highest total TDN and DCP intakes followed by RPM and RPC groups, while the control group had the lowest intakes. The RPM+RPC group showed significantly (P<0.05) the lowest amounts of DM, TDN and DCP required per kg milk followed by RPM and RPC groups, while the control group had the highest values. The RPM+RPC group recorded significantly (P<0.05) the highest total and net revenue and net revenue improvement followed by RPM and RPC groups, while the control group had the lowest values. The net revenue for RPM, RPC and RPM+RPC increased by 30.02, 18.71 and 49.50% compared to control group, respectively.

[Mahmoud E. El-Gendy, Kotob F. El-Riedy, Hanaa S. Sakr, Hamed M. Gaafar. **Effect of Rumen Protected Methionine and/or Choline Additives on Productive Performance of Zaraibi Goats.** *Nat Sci* 2012;10(10):35-41]. (ISSN: 1545-0740). http://www.sciencepub.net/nature. 6

Keywords: Zaraibi goats, Rumen protected methionine and choline, digestibility, colostrum, milk, economic efficiency.

1. Introduction

Several studies have been carried out in the recent years in order to identify the limiting amino acids in milk production in goats (Madsen *et al.*, 2005). Some of the most frequently reported limiting amino acids for milk production in lactating goats are lysine and methionine (NRC, 2006). Supply of rumen bypass methionine has been shown to increase milk yield and milk protein production in dairy goats (Flores *et al*., 2009). The information in literature on dairy goats fed with rumen-protected amino acids is scarce, but Madsen *et al*. (2005) showed that the positive effects on milk yield in early lactation of goats when lysine and methionine were given in combination, concluding that mammary supply of these two amino acids were limiting for milk production when the goats were fed the basal feed ration. The NRC (2006) indicates that is a common practice to supplement goats with rumen-protected methionine (RPM) in milking periods, but the optimal dose is unknown.

Methioine metabolism is closely linked to that choline and it is important in the dairy cow because it is required for milk protein synthesis. Methioine is, also, involved in many pathways including the synthesis of phospholipids, carnitine, creatine and polyamines (Bequette *et al*., 1998; Berthiaume *et al*., 2006). In addition, methioine is the source of the methyl donor *S*-adenosyl methionine, the metabolite that provides methyl groups in a variety of reactions including the de novo synthesis of choline from phosphatidylethanolamine. In addition, choline increases the supply of methyl groups, which can affect the availability of other methyl donor compounds (Frank and Karl-Heinz, 2006). Moreover, Emmanuel and Kennelly, 1984; Lobley *et al*., 1996; demonstrated that up to one third of the total methionine supplement can be lost due the need to synthesize choline. Because of these metabolic relationships, dietary supply of choline affects methionine requirements and methionine supply can affect choline metabolism. Since choline is susceptible to rapid ruminal degradation, the amounts available for

absorption are limited (Erdman *et al*., 1984). Therefore, dairy cows may benefit from rumen protected supplementation of choline. Choline also participates, via the compound Phosphatidylcholine, in the removal of triglycerides from the liver by incorporation of triglycerides into lipoproteins (Pinotti *et al*., 2002). Lipotropic compounds have the ability to prevent and subsequent to a deficiency, correct excess fat deposition in the liver (Zeisel, 1992; NRC, 2001).

Researchers also have reported that dairy cattle can produce more milk when fed supplemental rumen protected choline (Erdman and Sharma, 1991; Pinotti *et al*., 2003). Methioine (Onodera, 1993) and choline (Atkins *et al*., 1988) are degraded by microorganisms in the rumen, so rumen protected forms are more effective at supplying the compounds to the cow than forms that are not protected. There has been extensive research conducted to develop and determine the effectiveness of technologies for protecting methionine (Schwab, 1996).

The objective of this study was to evaluate the effects of rumen protected forms of methionine and/or choline additives on colostrum and milk yield and composition of zaraibi goats.

2. Materials and Methods

The current work was carried out at Sakha Experimental Farm, belonging to the Animal Production Research Institute (APRI), Agricultural Research Center.

Forty Zaraibi goats with average body weight of 34.64±0.79 kg and aged 3-4 years at the last month of pregnancy were divided into four similar groups (10 in each). The goats were fed the basal ration containing 0.8 kg concentrate feed mixture, 0.2 kg barley grain and 5.0 kg berseem without additive (control) or with 2 g/head/day rumen protected methionine (RPM) or 2 g/head/day rumen protected choline (RPC) or 2 g/head/day rumen protected methionine + 2 g/head/day rumen protected choline (RPM+RPC). Chemical composition of used feedstuffs and basal ration are presented in Table (1).

Digestibility trial was conducted at the third month of lactation using Zaraibi goats (3 in each group) to determine nutrient digestibility coefficients and nutritive values using acid insoluble ash (AIA) as a natural marker (Van Keulen and Young, 1977). The *ad libitum* intake from tested diets was measured during the preliminary period and was restricted to 90 % of voluntary intake during the collection period to avoid any feed refusal. Animals were fed twice daily in two equal meals at 9 a.m. and 4 p.m. Water was freely available throughout the day. Faecal samples were taken from the rectum of each goat twice daily at 12 h intervals during the collection period. Samples of feedstuffs were taken at the beginning, middle and end of the collection period. Representative samples of feedstuffs and feces were chemically analyzed according to the methods of AOAC (1990). Digestibility coefficients were calculated from the equations given by Schneider and Flatt (1975).

DM digestibility % =

$$100 - \left[100 \times \frac{\text{AIA \% in feed}}{\text{AIA \% in feces}}\right]$$

Nutrient digestibility % =

$$100 - \left[100 \times \frac{\text{AIA\% in feed}}{\text{AIA\% in feces}}\right] \times \left[\frac{\text{Nutrient \% in feces}}{\text{Nutrient \% in feed}}\right]$$

The yield of colostrum was determined during the first 3 days after kidding and samples were taken for chemical analysis. During the suckling period (90 days), goats were hand-milked every two weeks twice daily at 6 a.m. and 5 p.m. to determine average daily milk yield and the samples were subjected to further analysis. After the end of suckling period goats were mechanically milked twice daily up to the end of lactation (150 days) and average daily milk yield was recorded. Samples were taken from the connective evening and morning milkings and composite in proportion to milk yield for analysis. Milk samples were analyzed for fat, protein, lactose, solids not fat (SNF), and total solids (TS) by Milko-Scan, model 133B and ash by the difference.

All goats were weighed at the last month of pregnancy and biweekly thereafter until 5 months after kidding to determine the changes in body weight.

The data were subjected to statistical analysis using general linear models procedure adapted by SPSS (2008) for user's guide with one-way ANOVA. Duncan test within SPSS was done to determine the degree of significance between the means.

Table 1: Chemical composition of feedstuffs and basal ration.

Item	DM %	Composition of DM %					
		OM	CP	CF	EE	NFE	Ash
Concentrate feed mixture*	91.2	91.0	14.0	9.1	3.1	64.8	9.1
Barley grain	89.8	97.5	12.3	8.5	2.5	74.2	2.5
Berseem	17.3	87.4	15.9	27.7	2.6	41.3	12.6
Basal ration	29.6	89.9	14.8	18.1	2.8	54.3	10.1

* Concentrate feed mixture consisted of 27% undecorticated cotton seed cake, 25% wheat bran, 25% yellow corn, 13% rice bran, 5% linseed cake, 2% molasses, 2% limestone and 1% common salt.

3. Results

Average DM intake, digestibility coefficients and nutritive values as affected by rumen protected methionine and/or choline additives are shown in Table (2). Average daily dry matter intake (DMI) by goats was nearly similar for the different groups and ranged from 1773.68 to 1777.68 g/head/day. Also, results in Table (2) indicated that rumen protected methionine and/or choline additives improved nutrients digestibility and subsequently nutritive values. The RPM+RPC group showed significantly (P<0.05) the highest digestibilities of DM, OM, CP, CF, EE and NFE and TDN and DCP values followed by RPM and RPC groups, while the control group had the lowest values. Results revealed that the rumen protected methionine (RPM) additive was more effective on the digestibilities of DM, OM, CP and NFE and TDN and DCP values, while rumen protected choline (RPC) additive was more effective on CF and EE digestibilities. The added RPM+RPC was more effective in digestion than those of added RPM or RPC alone.

The yield of colostrum of goats are presented in Table (3). Rumen protected methionine and/or choline additives increased significantly (P<0.05) the colostrum yield. The RPM+RPC group showed significantly (P<0.05) the highest colostrum yield followed by RPM and RPC groups, while the control group had the lowest yield. The RPM was more affect in colostrum yield than the RPC. The yield of colostrum for RPM, RPC and RPM+RPC groups increased by 19.65, 13.87 and 32.37% compared to control group, respectively. Moreover, colostrum yield increased significantly (P<0.05) from the first to the third day postpartum. Also, results in Table (3) indicated that rumen protected methionine and/or choline additives improved colostrum composition. The RPM+RPC group showed significantly (P<0.05) the highest percentages of fat, protein, lactose, SNF, TS and ash in colostrum followed by RPM and RPC groups, while the control group had the lowest percentages. Results revealed that the rumen protected methionine (RPM) additive was more effective on the contents of protein and SNF, while rumen protected choline (RPC) additive was more effective on the contents of fat, lactose, TS and ash. The added RPM+RPC was more effective in colostrum composition than that of added RPM or RPC alone.

The average daily milk yield of goats are shown in Table (4). Rumen protected methionine and/or choline additives increased significantly (P<0.05) the average daily milk yield. The RPM+RPC group showed significantly (P<0.05) the highest milk yield followed by RPM and RPC groups, while the control group had the lowest yield. The RPM was more affect in milk yield than the RPC. The milk yield for RPM, RPC and RPM+RPC groups increased by 18.39, 11.21 and 30.04% compared to control group, respectively. Moreover, milk yield increased significantly (P<0.05) until the second month of lactation and decreased gradually with progress of lactation period. The milk composition of goats presented in Table (4) indicated that rumen protected methionine and/or choline additives improved milk composition. The RPM+RPC group showed significantly (P<0.05) the highest percentages of fat, protein, lactose, SNF and TS in milk followed by RPM and RPC groups, while the control group had the lowest percentages. Results revealed that the rumen protected methionine (RPM) additive was more effective on the content of protein, while rumen protected choline (RPC) additive was more effective on the contents of fat, lactose, SNF, TS and ash. The added RPM+RPC improved milk composition than that of added RPM or RPC alone. All milk constituents decreased significantly (P<0.05) from the first to the second month of lactation and increased significantly thereafter showing inverse relationship with milk yield.

Table 2: Effect of rumen protected methionine and/or choline additives on nutrients digestibility and nutritive values by Zaraibi goats.

Item	Experimental groups				SEM
	Control	RPM	RPC	RPM+RPC	
DM intake (g/day)	1773.68	1775.68	1775.68	1777.68	8.75
Nutrients digestibility %					
DM	65.09b	67.12ab	66.41ab	68.28a	0.48
OM	65.77b	67.83ab	67.10ab	69.00a	0.49
CP	68.59c	72.07ab	70.45bc	73.42a	0.65
CF	64.66c	66.31bc	67.70ab	69.45a	0.63
EE	71.13b	72.90ab	73.45a	73.88a	0.41
NFE	68.51b	71.70a	69.90ab	71.87a	0.54
Nutritive values %					
TDN	63.46b	66.12a	65.19ab	67.04a	0.51
DCP	10.12b	10.63ab	10.39ab	10.83a	0.11

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

Table 3: Effect of rumen protected methionine and/or choline additives on colostrum yield and composition of Zaraibi goats.

Item	Yield	Composition %					
	Kg/day	Fat	Protein	Lactose	SNF	TS	Ash
Experimental groups							
Control	1.73c	4.95b	8.67b	4.35b	13.86b	18.81b	0.84b
RPM	2.07b	5.32ab	9.24ab	4.48ab	14.58ab	19.90ab	0.86ab
RPC	1.97b	5.73a	8.82ab	4.74ab	14.44ab	20.17ab	0.88ab
RPM+RPC	2.29a	5.76a	9.70a	4.84a	15.43a	21.20a	0.89a
SEM	0.04	0.15	0.28	0.09	0.37	0.52	0.01
Days postpartum							
1	1.90b	6.49a	11.17a	5.09a	17.16a	23.64a	0.89a
2	2.01ab	5.30b	8.85b	4.70b	14.42b	19.73b	0.87b
3	2.13a	4.53c	7.30c	4.01c	12.15c	16.68c	0.84c
SEM	0.04	0.15	0.28	0.09	0.37	0.52	0.01

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

Table 4: Effect of rumen protected methionine and/or choline additives on milk yield and composition of Zaraibi goats.

Item	Yield	Composition %					
	Kg/day	Fat	Protein	Lactose	SNF	TS	Ash
Experimental groups							
Control	2.23c	4.39c	2.50c	4.22b	7.43c	11.81c	0.71b
RPM	2.64b	4.55b	2.64ab	4.28b	7.65b	12.20b	0.72ab
RPC	2.48b	4.69a	2.58b	4.39a	7.70ab	12.38ab	0.73a
RPM+RPC	2.90a	4.81a	2.68a	4.44a	7.83a	12.64a	0.72ab
SEM	0.05	0.03	0.01	0.02	0.03	0.06	0.002
Lactation period (month)							
1	2.65ab	4.80b	2.62b	4.31c	7.64b	12.44b	0.72b
2	2.79a	4.18e	2.42d	4.12d	7.24d	11.42d	0.70c
3	2.58ab	4.46d	2.53c	4.20d	7.43c	11.90c	0.71bc
4	2.51b	4.69c	2.65b	4.41b	7.79b	12.47b	0.72b
5	2.39b	4.92a	2.79a	4.63a	8.15a	13.07a	0.74a
SEM	0.05	0.03	0.01	0.02	0.03	0.06	0.002

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

Results of body weight change during the different physiological stages of goats as affected by rumen protected methionine and/or choline additives are presented in Table (5). Body weight of goats increased gradually with the progress of pregnancy for the different groups. Rumen protected methionine and/or choline additives significantly increased (P<0.05) body weight of goats during the different periods compared to control group. These increase in body weight may attributed the improvement of digestibility and metabolism by rumen protected methionine and/or choline additives.

Feed intake presented in Table (6) revealed that the total DM intake was nearly the same for the different groups. While, the RPM+RPC group showed significantly (P<0.05) the highest total TDN and DCP intakes followed by RPM and RPC groups, while the control group had the lowest intakes. Rumen protected methionine and/or choline additives improved feed conversion, which the RPM+RPC group showed significantly (P<0.05) the lowest amounts of DM, TDN and DCP required per kg milk followed by RPM and RPC groups, while the control group had the highest values.

The total feed cost was nearly similar for the different groups as shown in Table (6). While, rumen protected methionine and/or choline additives significantly (P<0.05) improved the total and net revenue and net revenue improvement. The RPM+RPC group recorded significantly (P<0.05) the highest total and net revenue and net revenue improvement followed by RPM and RPC groups, while the control group had the lowest values. The net revenue for RPM, RPC and RPM+RPC increased by 30.02, 18.71 and 49.50% compared to control group, respectively.

Table 5: Effect of rumen protected methionine and/or choline additives on body weight change of Zaraibi goats.

Period (day)	Experimental groups				SEM
	Control	RPM	RPC	RPM+RPC	
Before kidding					
30	34.74	34.63	34.61	34.57	0.79
15	35.45b	36.45a	36.87a	37.20a	0.91
At kidding	29.65b	30.90a	31.93a	32.10a	0.62
After kidding					
15	30.24b	31.52a	32.57a	32.74a	0.64
30	30.85b	32.15a	33.22a	33.40a	0.65
45	31.46b	32.79a	33.88a	34.06a	0.66
60	32.09b	33.45a	34.56a	34.75a	0.67
75	32.74b	34.12a	35.25a	35.44a	0.69
90	33.39b	34.80a	35.96a	36.15a	0.70

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

Table 6: Effect of rumen protected methionine and/or choline additives on feed intake and economic efficiency of Zaraibi goats.

Item	Experimental groups				SEM
	Control	RPM	RPC	RPM+RPC	
Concentrate feed mixture					
Intake (kg/head)	120	120	120	120	
Price (LE/head)	273	273	273	273	
Barley grain					
Intake (kg/head)	30	30	30	30	
Price (LE/head)	54	54	54	54	
Berseem					
Intake (kg/head)	750	750	750	750	
Price (LE/head)	105	105	105	105	
Additive					
Intake (kg/head)	0.0	0.3	0.3	0.6	
Price (LE/head)	0	9	3	12	
Total DM intake (kg/head)	266.05	266.35	266.35	266.65	1.31
Total TDN intake (kg/head)	168.84b	176.11a	173.63ab	178.76a	1.36
Total DCP intake (kg/head)	26.92c	28.31ab	27.67bc	28.88a	0.25
Total milk yield (kg/head)	334.50c	396.00b	372.00b	435.00a	10.62
DM kg/kg milk	0.80a	0.67c	0.72b	0.61d	0.02
TDN kg/kg milk	0.50a	0.44b	0.47b	0.41c	0.01
DCP g/kg milk	80.48a	71.49b	74.38b	66.39c	1.64
Total feed cost (LE/head)	432	441	435	444	2.6
Total revenue (LE/head)	1037.0c	1227.6b	1153.2b	1348.5a	18.4
Net revenue (LE/head)	605.0c	786.6b	718.2b	904.5a	35.1
Net revenue improvement %	00.00d	30.02b	18.71c	49.50a	5.42

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

4. Discussion

The similar average daily DM intake by animals in the different groups (Table 2) may be attributed to the same amounts of concentrate feed mixture, barley grain and berseem intake being 0.8, 0.2 and 5.0 kg/head/day, respectively. These results agreed with those obtained by Wang *et al.* (2010) who found no significant difference in dry matter intake across treatment groups due to methionine supplementation.

The improvements in nutrients digestibility and nutritive values due to rumen protected methionine and/or choline additives (Table 2) agreed with those obtained by El-Ganiny *et al.* (2007) who reported that nutrients digestibility and nutritive values increased with protected methionine supplementation. Mohsen *et al.* (2011) found that the digestibility coefficients and nutritive values significantly increased (P<0.05) with added RPC. Lobley *et al.* (1996) demonstrated that up to one third of the total methionine supplement can be lost due the need to synthesize choline. Because of these metabolic relationships, dietary supply of choline affects

methionine requirements and methionine supply can affect choline metabolism.

The effect of to rumen protected methionine and/or choline additives on the yield and composition of colostrum (Table 3) agreed with those obtained by Annett *et al.* (2005) who found that feeding ewes during dry period affect the yield and composition of colostrums.

The effect of to rumen protected methionine and/or choline additives on milk yield and composition (Table 4) agreed with those obtained by Poljicak-Milas and Marenjak (2007) who reported that the milk production was statistically higher in rumen protected methionine group of goats than control group. Flores *et al.* (2009) found that there were quadratic ($P<0.05$) effects on milk yield and milk fat and protein as RPM increased. Elek (2008) stated that milk yield and fat and protein contents in milk of cows were significantly higher in the rumen protected choline group compared to the control group. Soltan *et al.* (2012) indicated that dietary rumen protected methionine and/or choline additive improved milk yield and composition of dairy cows.

The increase body weight of goats with rumen protected methionine and/or choline additives (Table 5) reflected on the increase in milk yield as shown previously in Table (4). These results agree with those obtained by Soltan *et al*. (2012) who found that cows fed on basal diet supplemented by both RP-MET and RP-CHOL was mobilizing less body tissue in the post-partum period.

The total DM intake and total feed cost were nearly similar for the different groups may be due to the similar intake of concentrate feed mixture, barley grain and berseem (Table 6), which are in accordance with those obtained by Wang *et al.* (2010) who found no significant difference in dry matter intake across treatment groups due to methionine supplementation.

Feed conversion improved by rumen protected methionine and/or choline additives (Table 6) due to improved feed digestibility and metabolism, which are in agreement with those obtained by El-Ganiny *et al.* (2007) who reported that cows fed rations supplemented with protected methionine were more efficient than those fed unsupplemented rations. Mohsen *et al.* (2011) found that rumen protected choline supplementation increased TDN and DCP intakes and decreased the quantities of DM, TDN and DCP per kg milk.

The increase total and net revenue by rumen protected methionine and/or choline additives attributed to increase milk yield (Table 6), which are in accordance with those obtained by El-Ganiny *et al.* (2007) who found that animals fed rations supplemented with protected methionine were more economically efficient than those fed unsupplemented rations. Mohsen *et al.* (2011) reported that the income of milk yield increased with rumen protected choline supplementation.

Conclusion

Adding 2 g/head/day rumen protected methionine plus 2 g/head/day rumen protected choline for Zaraibi goats showed the best results concerning the digestibility, yield and composition of colostrum and milk, feed conversion and economic efficiency.

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References

1. Madsen TG, Nielsen L, Nielsen MO. Mammary nutrient uptake in response to dietary supplementation of rumen protected lysine and methionine in late and early lactating dairy goats. Small Ruminant Res. 2005, 56: 151-164.
2. NRC. Nutrient requirements of small ruminants. Sheep, goats, cervids, and new world camelids. National Research Council. The National Academies Press, Washington, DC, USA, 2006.
3. Flores A, Mendoza G, Pinos-Rodriguez JM, Plata F, Vega S, Bárcena R. Effects of rumen-protected methionine on milk production of dairy goats. Ital. J. Anim. Sci. 2009, 8: 271-275.
4. Bequette BJ, Backwell FRC, Crompton LA. Current concepts of amino acid and protein metabolism in the mammary glad of the lactating ruminant. J. Dairy Sci. 1998, 81: 2540-2559.
5. Berthiaume R, Thivierge MC, Patton RA, Dubreuil P, Stevenson M, McBride BW, Lapierre H. Effect of ruminally protected methionine on splanchic metabolism of amino acids in lactating dairy cows. J. Dairy Sci. 2006, 89: 1621-1634.
6. Frank B, Karl-Heinz S. Rumen protected choline for dairy cows: The *in situ* evaluation of a commercial source and literature evaluation of effects on performance and interactions between methionine and choline metabolism. Anim. Res. 2006, 55: 93-104.
7. Emmanuel B, Kennelly JJ. Kientics of methionine and choline and their incorporation into plasma lipids and milk components in lactating goats. J. Dairy Sci. 1984, 67: 1912-1918.
8. Lobley GE, Connell A, Revel D. The importance of transmethylation reactions to methionine metabolism in sheep: Effects of supplementation with creatine and choline. Br. J. Nutr. 1996, 75: 47-56.

9. Erdman RA, Shave RD, Vandersall JH. Dietary choline for the lactating cow: Possible effects on milk fat synthesis. J. Dairy Sci. 1984, 67: 410-415.
10. Pinotti L, Baldi A, Dell'Orto V. Comparative mammalian choline metabolism with emphasis on the high-yielding dairy cow. Nutr. Res. Rev. 2002, 15: 315-332.
11. Zeisel SH. Choline: An important nutrient in brain development, liver function and carcinogenesis. J. Am. Coll. Nutr. 1992, 11: 473-481.
12. NRC. Nutrient Requirements of Dairy Cattle. (7th Rev. Ed.). National Academy Press, Washington, D.C., USA, 2001.
13. Erdman RA, Sharma BK. Effect of dietary rumen protected choline in lactating dairy cows. J. Dairy Sci. 1991, 74: 1641-1647.
14. Pinotti L, Baldi A, Politis I, Rebucci R, Sangalli L, Dell'Orto V. Rumen protected choline administration to transition cows: Effect on milk production and vitamin E status. J. Vet. Med. A. 2003, 50:18-21.
15. Onodera R. Methionine and lysine metabolism in the rumen and the possible effects of their metabolites on the nutrition and physiology of ruminants. Animo Acids 1993, 5: 217-232.
16. Atkins KB, Erdman RA, Vandersall JH. Dietary choline effects on milk yield and duodenal flow in dairy cattle. J. Dairy Sci. 1988, 71(1): 109-116.
17. Schwab CG. Rumen protected amino acids for dairy cattle: Progress towards determining lysine and methionine requirements. Anim. Sci. Feed Technol. 1996, 59: 87-101.
18. Van Keulen J, Young BA. Evaluation of acid insoluble ash as a digestibility studies. J. Anim. Sci. 1977, 44: 282.
19. AOAC. Official Methods for Analysis, 15th ed. Association of Official Analytical Chemists. Washington, D.C., USA, 1990.
20. Schneider BH, Flatt WP. The evaluation of feeds though digestibility experiments. The University of Georgia press Athens 1975, 3:.602.
21. SPSS. Statistical package for the social sciences, Release: 16, SPSS INC, Chicago, USA, 2008.
22. Wang C, Liu HY, Wang YM, Yang ZQ, Liu JX, Wu YM, Yan T, Ye HW. Effects of dietary supplementation of methionine and lysine on milk production and nitrogen utilization in dairy cows. J. Dairy Sci. 2010, 93: 3661–3670.
23. El-Ganiny Shahera MM, El-Ashry MA, El-Mekass AAM, Khorshed MM, Ibrahim SA. Effect of feeding different concentrate: corn silage ratios with or without protected methionine supplement on performance of dairy cows. Egyptian J. Nutrition and Feeds 2007, 10: 1-17.
24. Mohsen MK, Gaafar HMA, Khalafalla MM, Shitta AA, Yousif A.M. Effect of rumen protected choline supplementation on digestibility, rumen activity and milk yield in lactating Friesian cows. Slovak J. Anim. Sci. 2011, 44(1): 13-20.
25. Annett RW, Carson AF, Dawson LER. The effect of digestible undegradable protein (DUP) content of concentrates on colostrum production and lamb performance of triplet-bearing ewes on grass-based diets during late pregnancy. Anim. Sci. 2005, 80: 101-110.
26. Poljicak-Milas N, Marenjak TS. Dietary supplement of the rumen protected methionine and milk yield in dairy goats. Arch. Tierz., Dummerstorf 2007, 50(3): 273-278.
27. Elek P. Decrease of losses due to disorders in lipid metabolism of high producing dairy cows by feeding of rumen protected choline. Ph. D. Thesis, University of Pannonia, Keszthely, Hungary, 2008.
28. Soltan MA, Mujalli AM, Mandour MA, El-Shinway Abeer M. Effect of Dietary Rumen Protected Methionine and/or Choline Supplementation on Rumen Fermentation Characteristics and Productive Performance of Early Lactating Cows. Pakistan Journal of Nutrition 2012, 11(3): 221-230.

6/6/2012