

EFFECT OF RUMEN-PROTECTED CHOLINE SUPPLEMENTATION ON PRODUCTIVE PERFORMANCE OF LACTATING DAIRY COWS

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SUMMARY

Nine Holstein lactating cows, with an average live body weight of 550 ±50 kg, at 1st to 3rd seasons of lactation, were selected and randomly assigned to three similar groups (three cows each). Cows were used in a lactation study for a total of 12 weeks (4-week prepartum to 8-weeks postpartum) to investigate the effect of feeding two levels of rumen protected choline (RPC) supplementation, at 40 or 50 grams RPC /cow /day, or with no supplement (control) on compare milk production parameters and performance of dairy cows. Results showed insignificant differences ($P>0.05$) among groups in the digestibility coefficients of DM, OM, CF, EE and NFE, and also in nutritive value as TDN %, while CP digestibility coefficient and nutritive value as DCP% in RPC groups were significantly ($P<0.05$) higher than the control group. The milk yield of treated groups with 40 and 50 gm of RPC were higher than control (11.39% and 22.62%) and fat corrected milk (4%) at 10.88% and 21.45% higher than the control group. Insignificant ($P>0.05$) differences were observed between the groups in their average daily DM and TDN intake, while results of DCP intake were significantly ($P<0.05$) higher in favor of groups fed both levels of RPC. The treated group with 50 gm RPC was significantly ($P<0.05$) better than control for feed conversion, DM, TDN and DCP. No significant differences ($P>0.05$) were observed in change of body weight through the experimental period among all the three groups. However RPC groups showed numerically lower weight losses compared to the control. Insignificant differences were found among the groups in the content of milk protein, fat, SNF, TS and lactose. No significant differences were noted between the groups in AST, ALT and cholesterol contents, while RPC groups recorded significant ($P<0.05$) low values of triglycerides and LDL and significantly ($P<0.05$) higher values of HDL compared with the control. The groups of 50 and 40 gm RPC recoded lower feed cost for production of 1 kg milk being 3.17, 3.47 compared to control at 3.77 LE, and increase in the daily net milk revenue being 58.76, 47.76, compared to control at 37.78 LE, and economic feed efficiency being 89.3%, 73.0% for the control at 59.2%. Relative economic efficiency were 156%, 126.4% and 100% compared with the control group, respectively. The obtained results indicated that RPC supplementation at 40 or 50 g/head/day could improve digestibility, milk yield and composition, feed conversion, and economic efficiency in lactating Holstein cows. More researches are needed with higher number of dairy animal.

Keywords: Rumens, feed conversion, economic efficiency, protected choline, milk yield

INTRODUCTION

The NRC (2001) establishment of choline requirements for lactating dairy cow and transitional cow in the late dry period and in early lactation, requires more extensive feeding experiments than currently available in the scientific literature to date 2016. Choline is sometimes classified as a B vitamin; even though it does not fulfill the standard definition of vitamins, it is an essential nutrient when excess amounts of methionine and folate are not available (NRC 2001). Choline is a tri-methylated quaternary amine involved in metabolism and transport of fat from the liver. It provides labile- methyl groups for trans-methylation reactions and is required for the synthesis of phosphatidyl choline found in cell membranes (Hartwell *et al.*, 2000; Zahra *et al.*, 2006). It has the ability to increase milk fat synthesis (Erdman *et al.*, 1984) and to treat cows suffering from fatty livers after parturition (Cooke *et al.*, 2007). However, extensive degradation of unprotected dietary choline by rumen bacteria require the use of rumen-protected supplements containing choline chloride, which is subsequently released and absorbed as choline in the small intestine (Atkins *et*

al., 1988; Erdman and Sharma, 1991; Deuchler *et al.*, 1998; Pinottiet *et al.*, 2003; Cooke *et al.*, 2007; Zom *et al.*, 2011).

The elevated fat in the liver is associated with poor reproductive performance (Bobe *et al.*, 2004). When feeding transition cows RPC, the reduction in liver fat content occurs and is accompanied by improvement in health and production. Feeding lactating cows RPC from 25 days pre-partum to 80 days post-partum resulted in reduced incidences of clinical ketosis, mastitis, and morbidity (Lima *et al.*, 2011). According to Bobe *et al.* (2004), 50 to 60% of transitional cows - in several studies- have shown experience moderate to severe fatty liver. At birth, concentrations of non-esterified fatty acids (NEFA) usually increase from 5 to 10 times which is a result of the hormonal changes leading to an intense period of fat mobilization of fat tissue during this critical time (Grummer, 1993). The NEFA remain elevated, although to a lesser extent, during early lactation when cows experience negative energy balance. Blood flow to the liver doubles as a cow experience transition from the dry period to lactation (Reynolds *et al.*, 2003). The NEFA concentration and blood

flow are the two main factors affecting how much NEFA is taken up by the liver. Consequently, daily fatty acid uptake by the liver increases 13-fold at calving, from approximately 100 to 1300 g/day (Reynolds *et al.*, 2003).

It is now clear that choline deficiency is a limiting factor for very low density lipoprotein (VLDL) triglyceride export from the liver. The rate of VLDL export is highly related to the rate of hepatic choline synthesis which has been shown in many species; using a wide variety of experimental approaches (Cole *et al.*, 2011). For the effect of addition RPC on milk yield and composition of dairy cows, Xu, *et al* (2006) reported that, addition RPC by dose of 25g/d to dairy cows resulted in increasing milk production by 0.92kg and 0.82kg more than that of the control group, with little difference in contents of milk fat and milk protein. Also, Mohsen, *et al* (2011) reported that RPC supplementation at 30 g/head/day to lactating Friesian cows improved digestibility, milk yield and composition, feed conversion, and economic efficiency.

The objective of this study is to evaluate the effect of RPC supplementation at 40 and 50 g/head/day to lactating Holstein cows on digestibility, milk yield and composition, blood constituents, feed conversion and economic efficiency.

MATERIALS AND METHODS

The experimental work of this research was conducted at the dairy farm, Agricultural Experiments Station, Faculty of Agriculture, Cairo University. Milk analyses were conducted at Cattle Information System/Egypt (CISE) and blood samples were analyzed at laboratories of Hormones, at Faculty of Agriculture Research Park (FARP). The chemical analyses of feeds, feces, were conducted at laboratories of Regional Center for Food and Feed, Agriculture Research Centre, Ministry of Agriculture, Egypt.

Nine Holstein lactating cows, in their first to third season of lactation, and one month prenatal were randomly allotted to three matched experimental groups. First group served as a control, while the second and third groups were supplemented with two

levels of RPC, 40 and 50 gm/day/cow, respectively. The RPC supplementation began during last month of transitional period and 2 months postpartum. Rations were weighed for each group two times a day, at 7 AM and 7 PM. The quantities of daily feed /day/cow were (on average) 12 kg concentrate feed mixture (CFM) + 4 kg Egyptian clove hay+3 kg rice straw. The offered feeds were assessed to cover the nutrient requirements for each dairy cow according to NRC (2001). The concentrate to roughage ratio in all rations was offered at approximately 63: 37% on DM basis. Drinking water was made available all the time during the day.

Formulation and chemical composition of experimental rations and feed ingredients are shown in Tables (1 and 2). Feed refusals were recorded once daily. Feeding allowances were adjusted every week according to changes in body weight and milk production. Rumen-protected choline (**Choline-Save®**) in the form of choline chloride, was produced at PACTA-Italy, and distributed in Egypt by DPA SERVICE Company. The product is consisted of 250 gm choline chloride and 750 gm palm oil and de-gummed, refined and hydrogenated. Dairy cows were machine milked twice a day at 6.00 am and 6.00 pm. The milk yield was daily recorded. Fat corrected milk (4%) was calculated according to the following formula of Gaine (1928): FCM % = actual milk yield (kg) x 0.4 + 15 x fat yield (kg). Milk samples were collected from three cows of each dietary treatment, to determine its composition using Milk-Scan (Model 133 B). Blood samples were taken via jugular vein in non-heparinized vacuotainer tubes from three cows in each dietary treatment just before morning feeding. Blood samples were centrifuged for 15 minutes at 4000 r.p.m to obtain the plasma then stored at -20 °C till the time of assay. Aspartic transaminase (AST) and/or alanine transaminase (ALT) were assayed in the plasma as described by Reitman and Frankel (1975). Plasma total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL) and triglycerides (mg/dl) were determined using bio-Merieux kits (Mary01, Eliot Charbnniere –Les –Beins, France).

Table 1. Feed formulation of concentrate feed mixture (CFM)

| Ingredients | % |
|----------------------|------|
| Yellow corn grains | 45 |
| Soybean meal 44 % | 22.5 |
| Sunflower meal 36% | 7.5 |
| Wheat bran | 20 |
| Limestone | 2.4 |
| Sodium chloride | 1 |
| Vit. &Min. Mix.* | 0.3 |
| Sodium bicarbonate | 0.8 |
| Di calcium phosphate | 0.5 |
| Total (%) | 100 |

*Each 3 kg vitamins and minerals mixture contains: Vit A 4800000 IU; Vit D3 1000000 IU; Vit E 28000 mg; Zinc 100000 mg; Manganese 80000 mg; Iron 75000 mg; Copper 30000 mg; Iodine 750 mg; Cobalt 200 mg; Silinum 300 mg; Calcium bicarbonate up to 3 kg.

Table 2. Chemical analysis of CFM, Egyptian clover hay, rice straw and total mixed ration supplemented with choline on DM basis

| Item | DM % | Composition % | | | | | |
|--------------------------------|-------|---------------|-------|-------|------|-------|-------|
| | | OM | CP | CF | EE | NFE | ASH |
| Concentrate feed mixture (CFM) | 93.2 | 92.6 | 18.53 | 6.73 | 4.81 | 62.53 | 7.4 |
| Egyptian clover hay | 91.55 | 88.19 | 14.25 | 27.86 | 2.12 | 43.95 | 11.81 |
| Wheat straw | 90.00 | 81.22 | 4.50 | 33.11 | 1.11 | 43.95 | 18.78 |
| Total Mixed Ration (TMR) | 92.40 | 89.60 | 14.90 | 15.50 | 3.60 | 55.60 | 10.40 |

Digestibility trials:

At the end of the feeding trial, a digestibility trial was conducted to determine the digestion coefficients and the feeding value of experimental rations by applying Acid Insoluble Ash (A.I.A) technique as a natural internal marker as described by Van Kerulen and Young (1977). Fecal grab samples were taken from the rectum twice daily at 8 am and 8 pm for 5 days. Feces samples were kept frozen at -18°C for further chemical analysis. Chemical analysis of feeds for both digestibility and feeding trials and feces were carried out according to A.O.A.C (1995). Dry matter digestibility and digestion coefficient were calculated according to the equations of Schneider and Flatt (1975) as follows:

DM digestibility (%) = $100 - [100 \times \text{AIA \% in feed} / \text{AIA \% in feces}]$

Digestion coefficient of nutrient = $100 - (100 \times \text{AIA \% in feeds} \times \text{Nutrient in feces}) / (\text{AIA \% in feces} \times \text{Nutrient \% in feeds})$.

Statistical analysis:

Analysis of variance (one-way, ANOVA) was performed to compare between different groups. Statistical analysis was carried out using SAS (2003) and Duncan's multiple range test (Duncan, 1955) was used to separate the means when the main effect was significant. The following model was used:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where: Y_{ij} = Individual observation, μ = overall mean, T_i = effect of treatment, e_{ij} = random error.

RESULTS AND DISCUSSION**Digestibility Coefficients:**

Results of digestibility coefficients (Table 3) of DM, OM, EE, CF and NFE, showed insignificant

($P > 0.05$) differences among control and RPC supplemented groups. On the other hand, RPC groups recorded significantly ($P < 0.05$) higher CP digestibility compared with the control. Regarding the nutritive value of experimental rations, although no significant differences ($P > 0.05$) were detected among control and RPC groups in TDN, the 50 and 40 g RPC groups recorded consistently higher values compared with the control (74.74, 74.33 and 70.50 respectively). Results of DCP showed that RPC groups were significantly ($P < 0.05$) higher compared with the control. The results of this study were consistent with those reported earlier by Jayaprakash *et al.* (2016) who found that increasing choline supplements produces more volatile fatty acid (VFA) acetate and rumen pH tends to increase digestibility coefficient of nutrients in rumen. Also, Mohsen *et al.* (2011) found significant increase in digestibility coefficient of DM, OM, CP, CF, EE, and NFE. This might be because of RPC enhances the protozoa population in the rumen. El-Gendy *et al.*, (2012) indicated that rumen-protected methionine (RPM) and/or choline additives improved nutrients digestibility and subsequently nutritive values in dairy goats, which is consistent with the results of our findings. Mohsen *et al.*, (2011) also reported that the quadratic analysis showed that RPC supplementation at 30 g produced the highest TDN (65.07% $R^2 = 0.71$) and DCP (9.65%, $R^2 = 0.60$). Donkin, (2002) and Pinottiet *al.* (2002) stated that choline is a quasi-vitamin that has a variety of functions in mammalian metabolism.

Table 3. Digestion coefficients and nutritive values of the experimental rations (on DM basis)

| Items | Experimental rations | | | |
|----------------------------------|----------------------|--------------------|--------------------|------|
| | R ₁ | R ₂ | R ₃ | ±SE |
| Apparent digestibility, % | | | | |
| Dry matter | 61.54 | 67.13 | 67.41 | 2.89 |
| Organic matter | 67.79 | 70.88 | 71.38 | 2.57 |
| Crude protein | 73.22 | 83.89 | 83.15 | 1.94 |
| Ether extract | 79.04 | 85.02 | 85.55 | 2.29 |
| Crude fiber | 53.24 | 58.21 | 60.14 | 3.68 |
| N-free extract | 75.89 | 77.90 | 78.42 | 2.08 |
| Nutritive value, % | | | | |
| Total digestible nutrients (TDN) | 70.50 | 74.33 | 74.74 | 1.42 |
| Digestible crude protein (DCP) | 10.91 ^b | 12.50 ^a | 12.39 ^a | 0.36 |

a,b,c means on the same row with different super script are significantly ($p < 0.05$) different

Milk Yield and Feed Efficiency:**Milk Yield:**

Average daily milk yield and fat corrected (4%) milk (FCM) for the whole experimental period are given in Table 4. The obtained results revealed that groups supplemented with RPC recorded significantly ($P < 0.05$) higher yield of both actual and fat corrected milk (4%) than the control. Ardalan *et al.* (2010) reported that cows which received 18 g/d of RPM, 60 g/d of RPC had a more persistent ($P < 0.05$) at early-lactation, higher milk yield, lowest health problems and no negative energy balance was observed compared to control group. Which agree with the results of the present study. Similar results which agree with results of this study were also reported by Elek (2008) and Soltan *et al.* (2012) who indicated that dietary RPM and/or choline additive, improved milk yield of dairy cows. Mohsen *et al.* (2011) reported that lactating cows fed ration supplemented with 15 or 30 g/head/day of RPC recorded increase ($P < 0.05$) in actual milk yield by 1.32 and 2.24 kg/head/day for 15 and 30 g RPC compared with un-supplemented RPC, respectively. Zahra *et al.* (2006) reported that Holstein cows that received 56 g/day of RPC produced on average 1.2

kg/day more milk yield through 60 days compared with animals that did not receive any supplements. Erdman and Sharma (1991) found that addition of choline to rations of Holstein cows at levels of 0, 0.078, 0.156, and 0.234% RPC resulted in a linear increase in 3.5% FCM, and feeding 0.156 and 0.234% choline increased FCM by 2.4 and 1.7 kg/day, respectively, over the control group, these results are in agreement with our results. Guretzky *et al.* (2006) reported that feeding Holstein and Jersey cows' diets supplemented with 60 g RPC product resulted in increasing daily milk yield of 3.5% FCM by 2 kg/day, compared with the control group, which partially agree with the results of this study.

Jayaprakash *et al.* (2016) reported that supplementation of RPC increases the milk production as a result of higher digestibility and increased total VFA concentration, decreased $\text{NH}_3\text{-N}$, and prevention of metabolic disorders such as ketosis and fatty liver syndrome. On contrary to findings in this study, Leiva *et al.* (2015) reported that no treatment effects for cows supplemented with RPC were detected ($P \geq 0.43$) for milk yield parameters, such as fat-corrected or solids-corrected milk

Table 4. Average daily feed intake, milk yield and feed efficiency

| Items | Experimental rations | | | |
|--------------------------------------------------------|----------------------|---------------------|--------------------|------|
| | R1 | R2 | R3 | ±SE |
| Average daily feed intake kg (as fed) kg/ h/d | | | | |
| Concentrate feed mixture | 12 | 12 | 12 | |
| Clover hay | 3 | 3 | 3 | |
| Rice straw | 4 | 4 | 4 | |
| Average daily feed intake (on DM basis) kg/ h/d | | | | |
| Total DMI | 17.53 | 17.53 | 17.53 | |
| TDN | 12.36 | 13.03 | 13.10 | 0.25 |
| DCP | 1.91 ^b | 2.19 ^a | 2.17 ^a | 0.06 |
| Milk yield (kg/ h/d) | | | | |
| Actual daily milk yield | 16.93 ^b | 18.86 ^{ab} | 20.76 ^a | 0.63 |
| 4% fat corrected milk | 15.71 | 17.42 ^b | 19.08 ^a | 0.52 |
| Feed conversion | | | | |
| DM kg / kg 4% FCM | 1.12 ^a | 1.01 ^b | 0.92 ^c | 0.02 |
| TDN kg / kg 4% FCM | 0.787 | 0.748 | 0.687 | 0.03 |
| DCP g / kg 4% FCM | 0.122 | 0.126 | 0.114 | 0.01 |

a, b, c means on the same row with different super script are significantly ($p < 0.05$) different.

Feed efficiency:

As shown in (Table 4) results of DCP intake were ($P < 0.05$) significantly higher in favor of groups that were supplemented with RPC, compared with the control animals.

Regarding feed conversion ratio (FCR) in terms of the amount of DM, TDN and DCP used for producing one Kg actual or fat corrected milk (4%), the 50 and 40 gm RPC supplemented groups recorded significant differences ($P < 0.05$). These positive results of FCR in favor of the groups supplemented with RPC could be attributed to the increase in TDN and DCP digestibility values as affected with RPC supplementation as given in Table 3. Piepenbrink and Overton (2003) and Guretzky *et*

al. (2006), reported that RPC supplementation for cows did not affect DMI either pre-partum or during the first 3 weeks postpartum. This result disagrees with the results found in the present study. On the other hand, Mohsen *et al.* (2011) reported that RPC supplementation decreased the quantities of DM, TDN and DCP per kg 4% FCM ($P < 0.05$), which is in agreement with the results reported here in.

Changes in Body Weight:

As illustrated in Table 5 analyses of variance showed insignificant ($P > 0.05$) differences among groups fed rations supplemented with 40 or 50 gm./cow /day RPC and the control in the change of live body weight at 15, 30, 45 and 60 days postnatal. The recorded values in the change of live body

weight were found to be (-) 2.15, (-) 4.51 and (-) 7.53% ; (-) 1.76, (-) 3.87 and (-) 5.28; (-) 1.53, (-) 0.95 and (+) 1.15% from the initial body weight at 30, 45 and 60 days postnatal for the control compared with group fed 40 or 50 gm. RPC, respectively.

It should be noted that groups fed ration supplemented with RPC showed lower negative body change during 15, 30, 45 and 60 days of lactation period compared with the control. Furthermore, group fed 50 gm RPC recorded (+) increase in the body weight during last period (60 days) postnatal compared with other groups. This low negative as well as positive change in body weight in groups fed RPC could be attributed to the effect of RPC in improving the efficiency of utilizing either energy of

the feed, or more efficient mobilization of stored fat energy in the body in the groups fed RPC, resulting in faster recovery than the control group.

Soltan *et al.* (2012) found that cows fed on basal diet supplemented with both RPM and RPC were mobilizing less body tissue in the post-partum period. In early lactation on dairy animals, the majority of fatty acids secreted by mammary gland could lead to increase animal weight loss, increased incidence of fatty liver, and increasing the chance of sub-clinical and clinical ketosis that agreed with the results obtained in this current study (Bindel *et al.* (2000), Pinotti *et al.* (2003), Cooke *et al.* (2007), Zom *et al.*, (2011), Rahamani *et al.* (2014), and Jayaprakash *et al.* (2016)).

Table 5. Change in body weight

| Item | Experimental rations | | | ±SE |
|-----------------------------------|----------------------|----------------|----------------|-------|
| | R ₁ | R ₂ | R ₃ | |
| Change in Live body weight | | | | |
| Weighing time (days): | | | | |
| 15 | 495.67 | 473.33 | 523.33 | 30.98 |
| 30 | 485.00 | 465.00 | 515.33 | 33.56 |
| 45 | 473.33 | 455.00 | 518.33 | 28.17 |
| 60 | 458.33 | 448.33 | 529.33 | 29.24 |

a,b,c means on the same row with different super script are significantly ($p < 0.05$) different.

Milk composition:

As shown in (Table 6) results showed insignificant ($P > 0.05$) differences among groups that were supplemented with RPC and the control in the content of milk protein, fat, SNF, TS and lactose. However, it could be noticed that RPC groups had higher milk protein and fat contents, while lactose content decreased with increasing level of RPC supplement compared with the control. Results of ash and moisture showed that group fed RPC had ($P < 0.05$) higher ash content than the control. These results are in agreement with results reported by Ardalan *et al.* (2010). El-Gendy *et al.* (2012) reported that RPC was more effective in increasing the contents of fat, lactose, SNF, TS and ash in milk than the control. Also, Elek (2008) stated that milk yield, fat and protein contents in milk of cows were significantly higher with supplementation of RPC compared with the control. Soltan *et al.*, (2012) indicated that dietary RPM and/or RPC improved

milk yield and composition of dairy cows. Similar results were reported by Mohsen *et al.* (2011) who found that the contents of fat and TS, and the yield of all milk constituents, except ash, significantly ($P < 0.05$) increased with RPC supplementation.

The aforementioned results of the current study on milk composition were found to be in agreement with those reported by Sharma and Erdman, (1988); Erdman and Sharma, (1991); Zahra *et al.* (2006) and Ambrosio *et al.* (2007). Jayaprakash *et al.* (2016) reported that during the transition period, RPC supplemented cows changed plasma NEFA concentration, and increased hepatic fat export, and this may result in decreasing the risk for metabolic disorders and increase in milk and change in milk composition. On the contrary, Leiva *et al.* (2015) reported that cows supplemented with RPC had greater ($P < 0.01$) milk protein, TS ($P < 0.01$), and milk fat concentrations ($P = 0.09$) compared with control.

Table 6. Milk composition of the experimental groups

| Item | Experimental rations | | | ±SE |
|----------|----------------------|-------------------|-------------------|------|
| | R ₁ | R ₂ | R ₃ | |
| Protein | 2.58 | 2.74 | 2.64 | 0.09 |
| Fat | 3.46 | 3.49 | 3.52 | 0.05 |
| SNF | 8.01 | 7.47 | 7.65 | 0.24 |
| TS | 11.47 | 10.96 | 11.17 | 0.23 |
| Lactose | 4.95 | 4.31 | 4.50 | 0.19 |
| Ash | 0.48 ^{ab} | 0.42 ^b | 0.51 ^a | 0.02 |
| Moisture | 88.53 | 89.04 | 88.83 | 0.21 |

a,b,c means on the same row with different super script are significantly ($p < 0.05$) different

Blood constituents:

Results of blood analyses are shown in Table 7. Statistical analyses for AST, ALT and cholesterol contents of the blood showed no significant ($P>0.05$) differences between RPC groups and the control, while RPC supplementation groups recorded ($P<0.05$) low values of triglycerides and LDL compared with the control. On the other hand, RPC recorded significantly ($P<0.05$) higher values of HDL compared with the control. However, all recorded values of blood constituents for the three tested groups were found to be within the normal range. Zom *et al* (2011) reported that choline supplementation decreased the concentration of liver triacylglycerol during the first 4 weeks after parturition. Cooke *et al* (2007) implied that RPC

could prevent, and possibly alleviate development of fatty liver because of increased rate of triacylglycerol depletion from the liver, at least when induced by feed restriction. Piepenbrink and Overton (2003) suggested that feeding RPC to transition cows increased the rate of VLDL secretion by the liver. Cooke *et al* (2007), reported that feeding RPC (15 g/d) decreased liver triglyceride accumulation during induction of fatty liver through feed restriction. It also enhanced triglyceride depletion from liver. Mohsen *et al* (2011) reported that RPC supplementation in dairy cow led to a significant decrease ($P<0.05$) in the concentrations of plasma cholesterol and triglycerides, while AST and ALT were insignificant affected.

Table 7. Blood constituents of the experimental groups

| Item | Experimental rations | | | ±SE |
|---------------|----------------------|--------------------|--------------------|------|
| | R ₁ | R ₂ | R ₃ | |
| AST | 66.00 | 65.417 | 64.58 | 2.62 |
| ALT | 18.33 | 18.833 | 20.92 | 0.93 |
| Cholesterol | 102.58 | 108.50 | 102.58 | 6.21 |
| Triglycerides | 22.67 ^b | 25.75 ^a | 14.41 ^c | 0.67 |
| HDL | 19.08 ^b | 23.00 ^a | 22.75 ^a | 0.93 |
| LDL | 74.78 ^a | 72.80 ^a | 53.72 ^b | 4.86 |

a,b,c means on the same row with different super script are significantly ($p<0.05$) different.

Economic efficiency:

Results in Table 8 show that RPC 50 and 40gm supplementation resulted in a linear decrease in the cost of the feed used for producing one Kg of 4 % FCM, being 3.77, 3.47 and 3.17LE, and linear increase in the net revenue of daily milk yield, being 47.76 and 58.76 compared to 37.78 LE for the control. Results also revealed that supplementation with RPC at 40 and 50 gm achieved the highest relative economic efficiency (126.4 and 156 %) compared with the control (100 %). These positive results of economic efficiency as a result of RPC

supplementation could be attributed to the improvement in the digestibility and productive performance of dairy cow in the current study. The obtained economical evaluation results are found to be very close to those reported earlier by Mohsen *et al* (2011) who found that average daily feed cost per kg 4% FCM was decreased significantly ($P<0.05$) with increasing level of RPC by 5.20 LE, and net revenues were increased by 2.92 and 4.88 LE for 15 and 30g RPC supplementation, respectively, compared with the un-supplemented treatment.

Table 8. Effect of experimental rations on economic efficiency

| Items | Experimental rations | | |
|--------------------------------------|----------------------|----------------|----------------|
| | R ₁ | R ₂ | R ₃ |
| Actual daily milk yield | 16.93 | 18.86 | 20.76 |
| Fat corrected milk (4%) | 15.71 | 17.42 | 19.08 |
| Total DMI | 17.53 | 17.53 | 17.53 |
| Daily feed cost (LE) | 63.8 | 65.4 | 65.8 |
| Feed cost (LE)/ kg milk | 3.77 | 3.47 | 3.17 |
| Av. Revenue daily of milk yield (LE) | 101.58 | 113.16 | 124.56 |
| Net feed revenue (LE) | 37.78 | 47.76 | 58.76 |
| Economic feed efficiency % | 59.2% | 73.0% | 89.3% |
| Relative Economic efficiency % | 100 | 126.4% | 156% |

market price at the time of experimentation for 1 ton CFM were 4500 LE., 1 ton Egyptian clover hay= 2000 LE, 1 ton rice straw =600 L.E, 40 LE per 1 Kg protected choline and 6LE/ Kg of milk.

CONCLUSION

The results obtained in the present study, support the conclusion that rumen-protected choline (RPC) supplementation, at 40 g or 50 /head/day to lactating cows, improved nutrient

digestibility, milk yield and composition, feed conversion and economic efficiency. The supplementation of 50 gr/head/day had better effect on economic evaluation and animal performance than 40g supplementation.

The authors suggested that more studies are needed with high number of dairy animal.

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