Evaluation of Feeding a Fibrolytic Enzyme to Lactating Dairy Cows on Their Lactational Performance during Early Lactation

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ABSTRACT : Twenty eight multiparous lactating cows were utilized in an experiment to evaluate the response to an exogenous fibrolytic enzyme on their lactational performance during early lactation period (in terms of milk production, milk composition, feed intake, milking efficiency, body weight change) and the exact time of this response. Cows were randomized into two groups (14 each) with similar parities and were fed a concentrate ration of barley, ground corn, soybean meal, and wheat bran and roughage ration of alfalfa hay. One of the two groups was supplemented with the fibrolytic enzyme immediately after parturition up to 100 post partum. The experiment was of two phases with 50 days each. The enzyme, which has a cellulase/hemicellulase activity (derived from *Trichoderma* group), was added to the concentrate part of the ration in a dry powder form. Milk production, 3.5% fat corrected milk, energy corrected milk were higher ($p<0.05$) for cows fed treated diet. At the same time, No differences were observed in percentages of milk components, feed intake, body weight, body weight change, or rectal temperature for the whole experimental period or during any of the two phases. Efficiency of milk production was higher ($p<0.05$) for treatment group cows than for that of the control ones. However, efficiency was better during the second phase than during the first phase. Feeding enzyme treated diets to dairy cows improved lactational performance during early 100 day of the lactation period. However, the first 50 days of lactation looked to be the critical. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 5 :677-684)***

Key Words : Dairy Cows, Enzyme, Lactation Performance

INTRODUCTION

The digestion of fibrous substrate in the rumen is slow or incomplete and can limit production. The availability of new enzyme products combined with high cost of livestock production has prompted researchers to examine the role of exogenous enzymes in ruminant production (Yang et al., 2000). Until recently, enzymes were not generally used as a routine procedure because of the inconsistency of response and because fibrolytic activity within the rumen of the adult ruminant is normally very high (Rode et al., 1999). On the other hand, it is presumed that ruminal fibrolytic activity cannot be significantly increased by the addition of exogenous enzymes because it is usually assumed that as these enzymes are soluble, they cannot survive proteolysis in the rumen (Beauchemin et al., 1999ba; Rode et al., 1999).

A number of earlier studies involving sheep and cattle showed that enzymes substantially improved feed digestibility and animal performance, but results were often inconsistent (Yang et al., 1999). The reason for this inconsistency was mainly due to many factors including physiological condition of animals treated, diet composition, enzyme used, and amount of enzyme provided, enzyme stability and method of application (Beauchemin et al., 1999b; Yang et al., 2000).

The positive effects of adding exogenous fibrolytic enzyme mixtures to diets of ruminants have been reported recently for some commercial products fed to growing cattle and lactating dairy cows. Using fibrolytic enzyme mixture with alfalfa hay diets improved live weight gain of cattle by as much as 35% and feed conversion by up to 10% as a result of enhanced total tract digestion (Beauchemin et al., 1995). A similar enzyme mixture was added to a high grain feedlot finishing diet resulted in an improvement of 11% in feed conversion ratio, 6% in weight gain, and a 5% decrease in feed intake (Beauchemin et al., 1997). In another study, an enzyme mixture added to a high concentrate diet of growing feedlot heifers increased average daily gain by 9% and numerically improved feed to gain ratio by 10% but had no effect on dry matter intake (Beauchemin et al., 1999a).

Several studies using enzyme additives in ruminant diets containing mainly forages have reported improvements in digestibility (Beauchemin et al., 1995; Lewis et al., 1996; Yang et al., 1999). Feng et al. (1996) reported that addition of a fibrolytic enzyme mixture to grass hay before feeding improved digestibility. Furthermore, Hristov et al. (1998) indicated that addition of fibrolytic enzymes to ruminant diets had increased ruminal and total tract digestibility of dry matter and NDF.

While some studies showed no effect of adding fibrolytic enzymes on feed intake (Beauchemin et al., 1999b; Lewis et al., 1999; Schingoethe et al., 1999; Zheng et al., 2000), others concluded that feed intake of beef steers or dairy cows fed mature cool season grass treated with exogenous fibrolytic enzymes was increased (Feng et al., 1996). Similarly, dairy cows fed forage treated with

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Table 1. Ingredient composition (%) and proximate analysis of ration fed (DM) of the concentrate part of the ration

Ingredient	%	
Barley	63	
Ground corn	10	
Soyben meal	15	
Wheat barn	10	
Limestone	1.0	
Dicalcium phosphate	0.5	
Salt	0.4	
Vitamins & minerals*	0.1	
Total	100	
Proximate analysis (DM Basis)		
	Concentrate mix	Alfalfa hay
Dry matter	89.35	89.55
Crude protein	15.62	19.61
Crude fiber	5.64	37.42
NDF	15.87	48.20
ADF	7.17	35.26
Ash	2.93	8.97
ME (MJ/Kg DM)**	11.60	8.71

*1 g contains: 7.5 MIU Vitamin A, 1.9 MIU Vitamin D3, 4 mg Vitamin E (50%), 200 mg Magnesium Sulfate, 6.4 mg Iron Sulfate, 1.03 mg Cobalt Carbonate, 12.96 mg Zinc Sulfate, 4.84 mg Manganese Oxide, 0.79 mg Potassium Iodide, 0.23 mg Sodium Silinate and 12 mg Copper Sulfate in addition to Antioxidant.
** Obtained from NRC (1989).

different fibrolytic enzyme additive eat more feed (Lewis et al., 1999; Beauchemin et al., 2000) and in some cases produced 5 to 25% more milk (Beauchemin et al., 1999b; Lewis et al., 1999; Rode et al., 1999).

Rode et al. (1999) and Schingoethe et al. (1999) concluded that fibrolytic enzymes had the potential to enhance milk production of dairy cows in early lactation with no effect during mid or late lactation. Therefore, cows in negative energy balance such as those in early lactation are likely to benefit greatly from using such enzymes. The objectives of the present study were to investigate the effect of fibrolytic enzyme for cows in early lactation and the actual time of their action.

MATERIALS AND METHODS

A total of 28 multiparous Frisian lactating dairy cows were selected and assigned into two treatment groups of equal numbers to evaluate the effect of direct supplementing fibrolytic enzyme on their milking performance. Cows selected were in their 3rd to 5th lactation season and were randomized to have similar parities in each group. Treatments were either a control with no enzyme supplement or a treatment enzyme supplanted group. Cows in the treatment group were supplemented with a commercial fibrolytic enzyme in their ration (*Maxicel 200L®*, George A. Jeffreys Company, Inc., Salem, VA, USA) started immediately after calving and lasted to 100 day postpartum. Treatment period included two sub periods of 50 days each (0-50 and 51-100) in an effort to check the exact time of enzyme response.

Cows were held in a free stall open shaded area with free access to unshaded dry lot and fed individually according to the NRC recommendations for dairy cattle (1989). Ration offered was composed of barley grain, ground corn, soybean meal, and wheat bran. In addition, alfalfa hay was provided *ad lib* and feed intake for each group was recorded daily. Percent composition and proximate analysis of the concentrate ration are presented in table 1. Diets were fed twice daily after milking at 08:00 and at 17:00. Intake of both parts of the diet was measured separately. Rations offered were either supplemented or not with a commercial cellulase enzyme at the level of 150 g/ton of forage consumed. Enzyme supplied was a cellulase in a dried powder form derived from *Trichoderma* group with a cellulase/hemicellulase activity. Each one ton requirements were diluted in a 500 g of ground corn, mixed with the micronutrient part of the ration and added to the concentrate part.

Mineral blocks (98% NaCl and 2% trace minerals) and fresh clean water were available all the time. Blocks were offered to avoid any deficiency or imbalances of micronutrients during the experiment. Rations were mixed approximately every other day and stored in a closed room at ambient temperature till time of feeding. Feed samples were collected at mixing time and sent directly for analysis. Samples of the ration were analyzed for DM, CP, CF, and ash content (AOAC, 1984), and for NDF and ADF content. The macro Kjeldahl method for N analysis was used for crude protein content determination utilizing a 1031 Kjeltec analyzer unit and multiplying the result by 6.25. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Goering and Van Soest (1970).

Daily milk production was recorded individually from calving up to 100 days post calving. Two weekly milk samples from each cow were taken for analysis and each sample was analyzed in duplicate. Samples were preserved with 2-3 drops of Potassium dichromate and stored at -4°C for analysis. Milk samples were analyzed for composition of protein, fat, solids non fat (SNF), and total solids (TS) (Richardson, 1985). Fat percent analysis was performed according to the Gerber method, while protein was analyzed according to the Kjeldahl method utilizing a 1031 Kjeltec auto analyzer unit and multiplying the results by 6.38.

Cows were weighed individually at calving and every 28 day thereafter to the end of the experiment. Rectal temperature was measured for each cow in the experiment at the day of milk sample collection between 09:00 and 10:00 h while they were constrained in self locked stanchions using a regular mercury glass thermometer. All cows had rectal temperatures recorded within 1 h and order

Table 2. Effect of enzyme supplementation on lactation performance of dairy cows

	Treated group	Control group	SE	P
Milk production (kg/d)				
Total 100 days				
Actual	29.50[a]	21.47[b]	1.42	0.027
3.5% FCM*	27.26[a]	19.85[b]	1.31	0.026
ECM**	32.23[a]	22.58[b]	1.70	0.024
0-50 days				
Actual	30.66[a]	22.93[b]	1.72	0.010
3.5% FCM*	28.36[a]	21.21[b]	1.59	0.010
ECM**	34.35[a]	25.61[b]	1.87	0.008
51-100 days				
Actual	28.61	20.31[b]	1.72	0.006
3.5% FCM*	26.47	18.79[b]	1.58	0.006
ECM**	30.63	20.21[b]	1.91	0.003
Milk composition				
Total 100 days				
Fat (%)	3.86	3.73	0.28	0.75
Fat (kg/d)	1.13[a]	0.79[b]	0.09	0.03
Protein (%)	3.73	3.39	0.18	0.21
Protein (kg/d)	1.10[a]	0.73[b]	0.08	0.006
Total solids (%)	13.08	12.91	0.31	0.72
Solids non fat (%)	8.22	8.18	0.20	0.91
0-50 days				
Fat (%)	3.83	4.14	0.34	0.53
Fat (kg/d)	1.15	0.94	0.09	0.14
Protein (%)	4.24[a]	3.64[b]	0.23	0.09
Protein (kg/d)	1.30	0.83[b]	0.11	0.01
Total solids (%)	12.37	12.51	0.48	0.83
Solids non fat (%)	8.53	8.36	0.27	0.67
51-100 days				
Fat (%)	3.87	3.41	0.26	0.22
Fat (kg/d)	1.11[a]	0.68[b]	0.09	0.01
Protein (%)	3.33	3.20	0.18	0.61
Protein (kg/d)	0.95[a]	0.65[b]	0.06	0.01
Total solids (%)	12.84	12.44	0.23	0.24
Solids non fat (%)	7.97	8.03	0.18	0.79

* Kg/d 3.5% fat corrected milk = milk yield (0.15 fat % − 0.4).

** Kg/d energy corrected milk = (0.327* milk yield) − (12.95* fat yield) − (7.2* protein yield).

of measurement did not vary during the trial. Prices for daily milk income and feed cost were calculated according to the prices in the market at the time of trial conduction. Values were expressed in the national Jordanian currency that equal to 0.7 Jordanian dinners per $1.

Statistical analysis of data was performed utilizing the General Linear model of SAS (1998). The model was designed to determine the effect of treatment on parameters measured throughout the experiment. Least square means for all variables in the study were calculated and the protected LSD test was used to determine significant differences. Furthermore, week effect was introduced in the model in a repeated measure design to study treatment effect throughout the experiment (Steel and Torrie, 1986).

RESULTS AND DISCUSSION

Means of milk production, percentage components of milk, and yield of components of the whole 100 day experimental period and for each period are presented in Table 2. Enzyme treatment resulted in higher ($p<0.05$) production of actual milk yield, 3.5% fat corrected milk, or energy corrected milk for cows received enzyme treatment than those of the control (table 2). The rate of increase in milk production reached about 37 and 43% for 3.5% fat corrected and energy corrected milk, respectively. This increase in milk production was consistent during the whole experimental period and also during the peaking period (0-50 days) and during the post peaking period (51-100 days). However, the amount produced was numerically higher during the first 50 days than for later period. Increased milk production has been observed in other studies (Beauchemin et al., 1999b; Yang et al., 1999; Kung et al., 2000; Zheng et al., 2000). Schingoethe et al. (1999) stated that fibrolytic

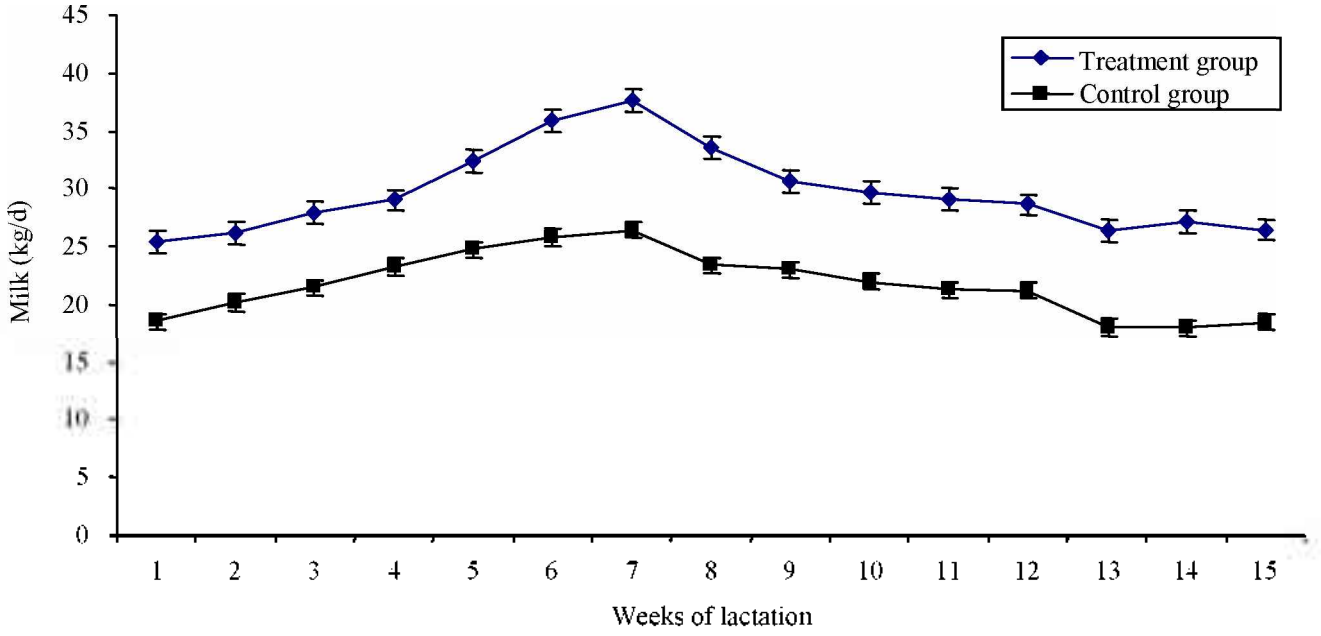

Figure 1. Effect of fibrolytic enzyme treatment of milk production of early lactation Freisian cows.

enzyme treatment improved milk production of cows started treatment during the first 100 day postpartum, but not for cows that were in midlactation. Meanwhile, Lewis et al. (1999) reported that fibrolytic enzyme treatment improved lactational performance of early and midlactation. However, Beauchemin et al. (2000) reported no increase in milk production of dairy cows received enzyme treatment when were in positive energy balance during late lactation. In the above studies, the rate of improvement in milk production was lower than obtained in the present study. It looks that as milk production is higher, the response to treatment would be less.

Increased milk production of cows fed treated diet was most likely an indication of increased available nutrients for milk production. This response could be attributed to improved nutrients digestion after enzyme supplementation since no increase in feed intake was observed (see table 3). This response is in agreement with Rode et al. (1999). Kung et al. (2000), and Zheng et al. (2000) who reported that supplementing dairy cows with fibrolytic enzyme mixture increased milk production without changing feed intake. Kung et al. (2000), Yang et al. (2000), and Zheng et al. (2000) reported improved milk production as a result of increased digestibility. Contrary to that, Beauchemin et al. (2000) concluded that increased milk production of dairy cows fed treated diets was due to increased feed intake. Some of those studies speculated that an increase in particulate rate of passage caused by enzyme treatment might have accounted for increased dry matter intake. The different mode of enzyme action observed indicated that the mode of action differs with different enzyme supplements (Beauchemin et al., 1999b).

Figure 1 shows the enzyme×week interaction of milk production. Analysis of variance results showed a significant ($p<0.05$) week enzyme interaction. The enzyme treatment started immediately after calving and the increase in milk production occurred within the first week of lactation and continued to the end of the treatment period. Treatment group cows produced more ($p< 0.05$) milk than control cows starting the first week to the end of treatment. The noticeable response to enzyme treatment within the first week of treatment was also reported in other studies (Rode et al., 1999; Yang et al., 2000). The level of increase in milk production at peaking time was higher in treatment group cows than in the control ones. Afterwards, the level of increase was higher than during the beginning period. This might be due to reduced nutritional stress condition and increase voluntary feed intake during this period. The persistency in maintaining improved production was also observed by Schingoethe et al. (1999).

Increased milk yield for cows fed the enzyme treated diet was not accompanied by a significant increase in percentages of milk composition except for that of protein during the first 50 days of the treatment (table 2). However, yields of fat and protein were higher ($p<0.05$) across all 100 d period and during the last 50 d period, while only protein yield was higher ($p<0.05$) during the first 50 days of the experiment. Similar results were reported by Lewis *et al.* (1999), Yang et al.(1999). Beauchemin et al. (2000) and Kung et al. (2000) who reported no effect of enzyme

treatment on milk fat or solids non fat percentages and increased percentage of milk protein. However, the numerically higher milk fat concentration of the cows fed treated diet was reflected in higher fat corrected milk observed for the treatment group cows. The lack of response on fat and protein concentration is not necessarily a negative consequence of adding fibrolytic enzymes. Due to the negative relationship between milk yield and composition, the lack of enzyme treatment effect might be due to the marked increase of milk production or might be due to the no response observe on feed intake. Rode *et al.* (1999) revealed that the lack of difference in milk component percentages were probably because the marked increase in milk yield was not accompanied by an increase in dry matter intake.

Other possibilities for the no response on fat percentages might be due to the increased fiber digestibility which reduced the effective NDF content of the diet. Yang et al. (1999) obtained increased total tract NDF digestibility by enzyme addition. Furthermore, this might be a result of a change in ruminal VFA ratios which affected milk fat synthesis. Rode et al. (1999) and Yang et al. (2000) observed changed ruminal VFA following treatment with fibrolytic enzyme mixtures. On the other hand, the increased protein yield and concentration observed during the experiment phases were probably a result of increased microbial protein synthesis. Zheng et al. (2000) reported increased microbial protein synthesis in the rumen due to the use of enzyme additive. The significant change in fat and protein yields observed within the second phase (51-100 d) of the experiment would probably be due to the drop in milk production and the increase in feed intake occurred during this period. The numerically higher concentrations of total solids (51-100 d) when cows were fed enzyme treated diets reflecting the higher fat and protein yield of those cows. Meanwhile, lower solids non fat percentage of cows fed the treated diet during the same period could reflect higher fat concentration of those cows while higher percentages during the first 50 d could reflect higher lactose concentration of those cows. It is possible that cows received enzyme treated diet were higher producers than cows received the control diet. However, the large increase in milk production of the treatment group cows along with changes observed in milk composition would suggest that this response was in fact due to enzyme supplement.

Total dry matter feed intake was not different across the periods between cows fed treated diets and control cows (table 3). Likewise, no differences were observed in feed intake of the concentrate mix or alfalfa hay during all phases of the study except in the second phase (51-100 d) when intake of alfalfa hay was higher ($p<0.05$) for cows in the treatment group than those in the control one (table 3). Similar results were also observed in earlier studies reported that treatment with exogenous fibrolytic enzymes had no effect on feed intake of dairy cows (Beauchemin et al., 1999b; Lewis et al., 1999; Zheng et al., 2000), or on for that of feedlot cattle (Beauchemin et al., 1999a). On the other hand, some results showed that fibrolytic enzyme supplementation significantly increased feed intake of dairy cows received a total mixed ration (Beauchemin et al., 2000), or beef steers received cool season grass forage (Feng et al., 1996). The difference between present results and those reported increased feed intake due to enzyme supplementation indicated that the mode of action likely differs for different enzyme supplements used. Yang et al. (1999) revealed that the response of treated animals to enzyme treatment is affected by the type of enzyme used, differences in diet composition, or type of feed used. Furthermore, Beauchemin et al. (2000) reported that some, but not all, enzyme supplements may increase feed intake of dairy cows.

No differences in feed intake indicated increased digestibility and nutrient utilization in the cows fed the treated diet due to enzyme addition, although not measured in this study. The precise mode of action of exogenous enzymes in ruminant diets had not yet been demonstrated. However, a great body of evidence suggests improved nutrients digestibility when a variety of feeds were treated with fibrolytic enzymes. Feng at al. (1996) observed increased digestibility of in vitro dry matter and NDF of treated forages as well as increased in vivo digestibility following application of enzyme before feeding. In the same fashion, many studies reported improved total tract and ruminal digestibility of dry matter and organic matter and increased fiber solubilization following fibrolytic enzymatic treatment (Hristov et al., 1998; Beauchemin et al., 1999b; Lewis et al., 1999; Rode et al., 1999; Yang et al., 1999 Beauchemin et al., 2000).

Yang et al. (1999) reported that improvements in digestibility caused by enzymatic treatment were related to increased microbial colonization as there is a positive relationship exists between microbial colonization and dry matter disappearance. Attachment of ruminal microorganisms to the substrate is a perquisite for digestion of feed particles in the rumen and increased microbial colonization would increase attachment and thereafter increase digestion. For example, Beauchemin et al. (2000) revealed that exogenous fibrolytic enzymes may aid in exposing additional cell wall cites for bacterial attachment and thereby permitting more complete digestion of the diet. Increased microbial population and colonization as a result of exogenous enzymatic treatment was well documented in several studies (Feng et al., 1996; Lewis et al., 1996; Hristov et al., 1998; Rode et al., 1999; Beauchemin et al., 2000). The increase of nutrients digestibility would possibly

Table 3. Effect of enzyme supplementation on feed intake, feed efficiency, body weight change and rectal temperature of dairy cows

	Treated group	Control group	SE	P
Body weight (kg)	681.3	647.4	1.27	0.34
Feed intake (kg DM/d)				
100 days				
total	22.33	22.30	1.36	0.98
% of body weight	3.30	3.44	0.17	0.92
Concentrate	14.16	15.23	0.56	0.41
Alfalfa hay	7.70	7.07	0.35	0.17
0-50 days				
total	21.22	21.84	1.61	0.79
% of body weight	3.12	3.37	0.14	0.80
Concentrate	13.36	14.83	0.63	0.23
Alfalfa hay	7.86	7.01	0.34	0.19
51-100 days				
total	23.67	23.11	1.58	0.90
% of body weight	3.47	3.56	0.12	0.85
Concentrate	14.88	15.76	0.72	0.78
Alfalfa hay	8.79	7.35	0.36	0.04
Feed efficiency**				
Total 100 days	1.63[a]	1.19[a]	0.08	0.02
0-50 days	1.70[a]	1.27[b]	0.09	0.03
51-100 days	1.59[a]	1.13[a]	0.09	0.01
Body weight change (kg/d)				
Total 100 days	-0.44	-0.45	0.01	0.84
0-50 days	-0.45	-0.43	0.01	0.31
51-100 days	-0.44	-0.46	0.01	0.29
Rectal temperature (°C)	38.3	37.7	0.88	0.22

provides more nutrients that were available to support higher milk production.

Treatment with fibrolytic enzyme improved ($p<0.05$) feed efficiency (expressed as kg of milk production per kg of dry matter intake) relative to cows fed control diet Table 3). Within experimental phases, efficiency was highly significant during the post peaking period (51-100 day) compared to the first 50 days of the experiment. These findings are in agreement to that of Lewis et al. (1999) who reported higher efficiency of dairy cows during early lactation fed low or high concentrations of a fibrolytic enzyme mixture, but not for those fed medium concentrations. However, many other results observed no improved or only a numerical improvement in milking efficiency of cows following feeding enzyme treated diets (Beauchemin et al., 1999b; Yang et al., 1999; Kung et al., 2000; Rode et al., 1999; Yang et al., 2000).

The reason for the observed unimproved efficiency in those studies could likely be due to increased feed intake associated with the increased milk production following application of exogenous fibrolytic enzymes. In the present study, the improved efficiency was mainly a result of improved milk production obtained in cows given the fibrolytic enzyme in their diets along with the no differences observed in feed intake.

Body weights and change in body weight measured in kg were not different between treatment groups (table 3). These results are in line with those obtained for dairy cows fed total mixed rations treated with different fibrolytic enzyme mixtures during early lactation period (Rode et al., 1999), or in positive energy balance (Beauchemin et al., 2000). Meanwhile, Lewis et al. (1999) observed that dairy cows gained body condition when supplemented with enzyme treatment while control cows lost body condition. Cows fed enzyme treated ration produced more milk than control cows with no differences in body weight change. This would probably indicate that more nutrients were available to cows in treatment group for milk production which enable them not to drive nutrients from their body weights to sustain higher milk production. Lewis et al. (1999) concluded that enzyme treatment resulted in more available nutrients to cows for energy deposition to body reserves above that used for increased milk production. On the other hand, it was reported that changed ruminal VFA ratios due to addition of enzymes would resulted in increasing adipose tissue lipogensis (Rode et al., 1999).

No differences were observed in rectal temperatures between cows fed treated or untreated rations (table 3). The author is not aware of any results regarding the effect of fibrolytic enzymes on rectal temperature to compare to present results. However, rectal temperature was measured in an effort to check for any differences in heat production in the body between cows fed treated ration and those fed untreated ration. Rectal temperature was measured after the

Table 4. Estimated daily milk income and feed costs per cow of dairy cows fed fibrolytic enzymes in their diets*

	Treated group	Control group	SE	P
Milk income				
Total	7.37	5.36	0.001	0.02
0-50	7.66	5.37	0.001	0.01
51-100	7.15	5.08	0.001	0.01
Feed cost				
Total	2.28	2.27	0.001	0.96
0-50	2.37	2.42	0.001	0.81
51- 100	2.21	2.14	0.001	0.78
Ratio of income over ratio				
Total	3.24	2.35	0.001	0.01
0-50	3.27	2.38	0.001	0.01
51- 100	3.19	2.30	0.001	0.02

* All values were calculated in the national Jordanian currency where1 kg milk=0.25 JD. 1 ton feed mix=102 JD, I ton alfalfa hay=90 JD, $1=0.7JD.

morning milking when ruminal activity expected to be minimal. This time might be not good enough to give indication of heat production in the body.

Table 4 illustrates daily relative values for milk produced income, feed consumed costs and income over cost ratio. Milk prices and feed costs were those present at the time of the study. Income from milk was higher ($p<0.05$) for cows received the enzyme treatment. The income was higher during the first phase of the study than during the second phase. Daily income increased by 37.5, 33.7, and 40.7% for the total period, first 50 days, and last 50 day, respectively. This increase in income was mainly a result of increased milk production because of the enzyme treatment. At the same time, no differences were obtained in feed cost during any phase since feed intake during the experiment was not different between treatment group cows and control cows. The ratio of income over cost was higher ($p<0.05$) for the treatment group than for the control group. The increase in milk production reached about 37 % over the control because of enzyme treatment.

It is concluded that addition of fibrolytic enzymes to dairy cows is beneficial for milk production. Responses were maintained during the early 100 day of the lactation period, although positive results were highest from parturition to peaking when cows were in negative energy balance. Positive response was a little bit less during the post peaking period. However, enzyme treatment resulted in better lactation persistency. Therefore, dairy producers would benefit most if they started application as early in the lactation as immediately after parturition. Improved production because of the addition of enzymes was most likely a result of improved digestibility rather than a change in feed intake.

The improvement observed in milk production has the potential to be economically beneficial. It is mostly profitable to feed enzyme treated diets to dairy cows unless the cost of the enzyme is very high. Further research using a larger number of cows for a longer duration is needed to determine the optimal period for enzyme application. With the magnitude of response obtained in this study and other studies, there is no doubt that exogenous enzymes will be routinely used by dairy producers in the not so far future.

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