EFFICACY OF ESSENTIAL OILS AS DIETARY SUPPLEMENTS FOR DAIRY COWS

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Summary

Effects of essential oils (EO) on rumen microbial fermentation in vitro are well established in the literature, but the impact of dietary EO supplementation on ruminant animal performance has been equivocal (Calsamiglia et al., 2007). Seven reports on the effects of EO supplemented in diets fed to lactating dairy cows were reviewed herein. Averaged across all treatment comparisons, EO increased DMI and yields of milk, FCM, fat and protein by 0.4, 0.9, 1.4, 0.07, and 0.03 kg/cow/d over control; these responses to EO increased milk income minus feed cost \$0.27 to \$0.42/cow/d depending on the milk component and feed prices evaluated. Milk fat and protein percentage and feed efficiency responses to EO were positive on average. Other reported ($P < 0.10$) in vivo responses were increased ruminal OM and N digestibility (Yang et al., 2007), increased ruminal pH and reduced total VFA (Benchaar et al., 2007), and increased total tract ADF digestibility and ruminal pH (Benchaar et al., 2006). Unpublished results of a recent UW-Madison trial to evaluate transition cow and 15-wk postpartum lactation performance responses to dietary EO supplementation were reported herein. Treatments were a control diet and an EO diet supplemented with 1.2 g/cow/d EO mixture (CRINA Ruminants) fed to 20 multiparous Holstein cows per treatment from 4 wk prepartum through 15 wk of lactation. Transition cow measurements were unaffected by EO. Lactation DMI was 1.8 kg/cow/d lower for EO ($P < 0.04$). Milk yield was numerically lower for EO during lactation wk 1-5 (-2.4 kg/cow/d), similar during wk 6-10, and numerically higher (+2.1 kg/cow/d) for EO during wk 11-15. Average feed efficiencies (Milk/DMI and FCM/DMI) tended to be greater for EO ($P < 0.08$ and $P < 0.07$, respectively). Feed efficiency was unaffected by treatment during lactation wk 1-5, but was greater for EO during wk 6-10 and wk 11-15 ($P < 0.04$ and $P < 0.02$, respectively). In a meta analysis performed on combined data from the literature review and the UW-Madison trial, milk, fat and protein yields were 1.2 ($P < 0.04$), 0.06 ($P < 0.03$) and 0.05 ($P < 0.06$) kg/d, respectively, higher for EO. More dairy cattle research regarding potential interactions between basal diet, stage of lactation and dietary EO supplementation is warranted.

Introduction

Newbold et al. (2006) and Calsamiglia et al. (2007) described EO as follows: volatile aromatic compounds with an oily appearance extracted from plant materials typically by steam distillation; alcohol, ester or aldehyde derivatives of phenylproponoids and terpenoids; some of the more common EO compounds available include thymol (thyme and oregano), eugenol (clove), pinene (Juniper), limonene (dill), cinnamaldehyde (cinnamon), capsaicin (hot peppers), terpinene (tea tree), allicin (garlic), anethol (anise), etc.; antimicrobial activity; modify rumen microbial fermentation. With regard to EO as modifiers of rumen microbial fermentation, Calsamiglia et al. (2007) from an extensive review of the literature (primarily in vitro, in situ or continuous culture based) concluded the following: inhibition of deamination and methanogenesis, which results in lower ammonia-N, methane and acetate and higher propionate and butyrate concentrations; effects may vary depending on the specific EO or combination of EO supplemented; effects of some EO are pH and diet dependent. Readers are referred to Calsamiglia et al. (2007) for an in depth review of EO and effects on rumen microbial fermentation. The purpose of this paper is to review and summarize the available reports involving EO as dietary supplements for dairy cows and effects on lactation performance.

Literature Review

Seven reports on the effects of EO supplemented in diets fed to lactating dairy cows were reviewed. Six of these reports involved the CRINA ruminants (CRINA S.A., Gland, Switzerland) mixture of natural and synthesized EO including thymol, eugenol, vanillin, guaiacol, and limonene. The other report involved EO (Axiss France SAS, Bellegarde-sur-Valserine, France) from garlic (allicin) and juniper berry (pinene) fed separately. The seven experiments are described in Tables 1 (EO tested, experimental design, and cows), 2 (Diet ingredient and nutrient composition and control DMI and milk yield), and 3 (Experimental measurements). There were 9 and 10 treatment comparisons, respectively, for intake and production related measurements across the seven experiments.

DMI, milk yield, composition and component yield, and feed efficiency responses to EO relative to control are presented in Table 4. Averaged across all treatment comparisons, EO increased DMI and yields of milk, FCM, fat and protein by 0.4, 0.9, 1.4, 0.07, and 0.03 kg/cow/d over control. Milk fat and protein percentage and feed efficiency responses to EO were positive on average.

To calculate the economic value derived from EO at the average response, the following milk and feed prices were used: $3.10/kg fat, $9.18/kg protein, $0.51/kg other solids, and an add-on premium of $0.036/kg milk (based on pay period ending 10/31/07 for a Wisconsin dairy), $0.18/kg TMR DM, and $0.06/cow/d cost for 1.2 g/cow/d supplemental EO (Will Seymour, DSM, personal communication). At the average response and under this milk and feed price scenario, dietary supplementation with EO increased milk income minus feed cost $0.42/cow/d. To calculate the average economic value derived from EO under a lower milk and feed price scenario, the following milk and feed prices were used: $2.91/kg fat, $4.69/kg protein, $0.42/kg other solids, and an add-on premium of $0.030/kg milk (based on 2006 average pay prices for a Wisconsin dairy), $0.15/kg TMR DM, and $0.06/cow/d cost for supplemental EO. At the average response and under this milk and feed price scenario, dietary supplementation with EO increased milk income minus feed cost $0.27/cow/d. Responses to EO were average or above average for 7/10, 5/10 and 6/10 of milk, fat and protein yield treatment comparisons, respectively.

Other significant ($P < 0.10$) in vivo responses found in these seven reports are summarized in Table 5. These responses include increased ruminal OM and N digestibility (Yang et al., 2007), increased ruminal pH and reduced total VFA (Benchaar et al., 2007), and increased total tract ADF digestibility and ruminal pH (Benchaar et al., 2006).

UW-Madison Trial

Our objective was to evaluate transition cow and 15-wk postpartum lactation performance responses to dietary EO supplementation. Forty multiparous Holstein cows were used in a completely randomized design. Treatments were a control diet supplemented with a placebo premix (57 g/cow/d) and an EO diet supplemented with 1.2 g/cow/d CRINA Ruminants (CRINA S.A., Gland, Switzerland; mixture of natural and synthesized EO including thymol, eugenol, vanillin, guaiacol, and limonene) provided through a premix (57 g/cow/d). Treatment diets were fed from 4 wk prepartum through 15 wk of lactation. Prepartum and lactation TMR ingredient and nutrient composition are presented in Table 6.

Cows were fed individually a TMR once daily in tie-stalls and the amounts fed and refused were recorded daily. Body weights and condition scores will were recorded weekly throughout the trial. Blood samples from each cow obtained prior to feeding on d -21, -7, -1, 1, 8, 15, 22, and 29 were analyzed for glucose, BHBA, NEFA, and urea-N. Milk yield was recorded daily on individual cows from throughout the lactation trial. Milk samples obtained from all cows weekly on two consecutive days of the week from am and pm harvests throughout the lactation trial were analyzed for fat, true protein, lactose and MUN concentrations.

Results are presented in Table 7 and Figures 1-3. There was no affect of EO on prepartum DMI. Lactation DMI was 1.8 kg/cow/d lower for EO ($P < 0.04$). Milk and component yields were unaffected by treatment. Milk true protein was 0.15%-units lower for EO ($P <0.03$). Milk yield was numerically lower for EO during lactation wk 1-5 (-2.4 kg/cow/d), similar during wk 6-10, and numerically higher (+2.1 kg/cow/d) for EO during wk 11-15 (Figure 1). Unfortunately, the feeding trial was not continued any further into the lactation. Average feed efficiencies (Milk/DMI and FCM/DMI) tended to be greater for EO ($P < 0.08$ and $P < 0.07$, respectively). Feed efficiency (Milk/DMI) was unaffected by treatment during lactation wk 1-5, but was greater for EO during wk 6-10 and wk 11-15 ($P < 0.04$ and $P < 0.02$, respectively; Figure 2). Average lactation energy balance tended to be lower for EO ($P < 0.06$). Energy balance was unaffected by treatment during lactation wk 1-5, but was lower for EO during wk 6-10 and wk 11-15 ($P < 0.04$ and $P < 0.03$, respectively; Figure 3). Control cows returned to positive energy balance during lactation wk 6-10 (+1.5 Mcal/d), while EO cows remained in slightly negative energy balance even during wk 11-15 (-0.4 Mcal/d; Figure 3). Prepartum and lactation body weight, body condition score, and blood sample measurements were unaffected by treatment.

Meta Analysis

Combined data from the literature review and the UW-Madison trial were analyzed using the MIXED procedure of SAS to evaluate animal response to dietary EO supplementation for DMI and milk, fat and protein yields. The model included the fixed effect of EO supplementation and the random effect of trial (St. Pierre, 2001). Each response was weighted according to the number of animals used to test for it using the WEIGHT statement. DMI was unaffected by treatment ($P > 0.10$). Milk, fat and protein yields were 1.2 ($P < 0.04$), 0.06 ($P < 0.03$) and 0.05 ($P < 0.06$) kg/d, respectively, higher for EO.

Conclusions

Averaged across all treatment comparisons from the reports reviewed, EO increased DMI and yields of milk, FCM, fat and protein; these responses to EO increased milk income minus feed cost $0.27 to $0.42/cow/d depending on the milk component and feed prices evaluated. Milk fat and protein percentage and feed efficiency responses to EO were positive on average. In a recent UW-Madison trial: transition cow measurements were unaffected by EO; lactation DMI was lower for EO ($P < 0.04$); milk yield was numerically higher (+2.1 kg/cow/d) for EO during lactation wk 11-15; average feed efficiencies tended to be greater for EO; feed efficiency was greater for EO during lactation wk 6-10 and wk 11-15 ($P < 0.04$ and $P < 0.02$, respectively). In a meta analysis performed on combined data from the literature review and the UW-Madison trial, milk, fat and protein yields were 1.2 ($P < 0.04$), 0.06 ($P < 0.03$) and 0.05 ($P < 0.06$) kg/d, respectively, higher for EO. More dairy cattle research regarding potential interactions between basal diet, stage of lactation and dietary EO supplementation is warranted.

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Table 1. Literature review: Essential oils tested, experimental design, and cows.

Trial	Essential Oils Product	Experimental Design	Cows
Yang et al., 2007	Garlic[1] 5 g/cow/d Juniper Berry[1] 2 g/cow/d	4x4 LS[3] 21-d periods	n=4 >113 DIM[4] Parity>1
Benchaar et al., 2007	Crina[2] 0.75 g/cow/d	4x4 LS 28-d periods	n=4 >61 DIM Parity>1
Benchaar et al., 2006	Crina 2 g/cow/d	4x4 LS 28-d periods	n=4 >98 DIM Parity>1
Offer et al., 2005	Crina 0.5, 1, and 2 g/cow/d	4x4 LS 28-d periods	n=16 >50 DIM Parity>1
Schmidt et al., 2004	Crina 1.2 g/cow/d	RCB[5] 56-d period	Parity=1 n=4 Parity>1 n=26 >50 DIM
Varga et al., 2004	Crina 1.2 g/cow/d	Unreplicated pens 120-d period	n=170 High group Parity 1& >
LaCount, 1997	Crina 1.5 g/cow/d	CRD[6] 70-d period	n=33 >42 DIM Parity>1

[1]Axiss France SAS, Bellegarde-sur-Valserine, France; Garlic standardized at 1.5% of allicin; Junniper Berry standardized at 35% of pinene.

[2]CRINA Ruminants, CRINA S.A., Gland, Switzerland; Mixture of natural and synthesized essential oils including thymol, eugenol, vanillin, guaiacol, and limonene.

[3]Latin square design. [4]Days in milk. [5]Randomized complete-block design. [6]Completely randomized design.

Table 2. Literature review: Diet ingredient and nutrient composition and control DMI and milk yield.

Trial	Diet Ingredient Composition (DM basis)	Diet Nutrient Composition (DM basis)	Control DMI kg/d	Control Milk kg/d
Yang et al., 2007	40:60 F:C[1] Barley silage& grain	16% CP, 32% NDF, & 33% Starch	20.7	29.0
Benchaar et al., 2007	50:50 F:C AS[2] or CS[3] Corn & barley grain	16% CP, 38% NDF, & 21% Starch	17.5	28.9
Benchaar et al., 2006	48:52 F:C 75:25 Grass silage:CS Corn grain -/+ 350 mg/d monensin	19% CP, 36% NDF, & 20% Starch	22.6	34.3
Offer et al., 2005	Grass silage ad lib 12 kg/d (as fed) DC[4]	19% CP & 35% NDF	20.8	31.1
Schmidt et al., 2004	50:50 F:C 50:30:20 CS:AS:AH[5] Corn grain	16% CP, 35% NDF, & 19% Starch	26.4	39.8
Varga et al., 2004	42:58 F:C 70:30 CS:AS High in byproducts	18% CP, 31% NDF, & 27% Starch	NA[6]	40.1
LaCount, 1997	51:49 F:C 50:50 CS:AS Pelleted complete feed	18% CP & 35% NDF	22.5	44.0

[1]Forage:Concentrate Ratio. [2]Alfalfa silage. [3]Corn silage. [4]18% CP (as-fed basis) Dairy concentrate. [5]Alfalfa hay. [6]Not available.

Table 3. Literature review: Experimental measurements.

Trial	Measurements
Yang et al., 2007	Ruminal fermentation parameters; Ruminal & total tract nutrient digestibility; Duodenal nutrient flows; intake & production
Benchaar et al., 2007	Ruminal microbial counts & fermentation parameters; Total tract nutrient digestibility; N balance; intake & production; milk fatty acid profiles
Benchaar et al., 2006	Ruminal fermentation parameters & protozoa counts; Ruminal in situ nutrient degradation; Total tract nutrient digestibility; N balance; intake & production; milk fatty acid profiles
Offer et al., 2005	Intake & production
Schmidt et al., 2004	Intake & production
Varga et al., 2004	Production field trial; Continuous culture fermenters
LaCount, 1997	Intake & production

Table 4. Literature review: DMI, milk yield, composition and component yield, and feed efficiency responses relative to control.

Trial	DMI kg/d	Milk kg/d	FCM kg/d	Fat %	Fat kg/d	Protein %	Protein kg/d	Milk/ DMI	FCM/ DMI
Yang et al., 2007									
Garlic	-0.3	+0.9	+2.5*	+0.32*	+0.14*	-0.08	0	+0.07	+0.14
Junniper Berry	-0.2	+0.4	+1.8*	+0.26*	+0.11*	-0.03	0	+0.03	+0.10
Benchaar et al., 2007	-0.1	-0.9	-0.7	-0.05	-0.02	+0.01	-0.04	-0.03	-0.03
Benchaar et al., 2006	+0.1	-1.3	-1.3	+0.04	-0.04	-0.01	-0.05	-0.07	-0.07
Offer et al., 2005									
0.5 g/cow/d Crina	+0.3	+1.4*	+1.2*	-0.03	+0.04*	+0.03	+0.06*	+0.04	+0.04
1.0 g/cow/d Crina	+0.2	+1.7*	+1.6*	-0.01	+0.07*	+0.02	+0.07*	+0.06	+0.07
2.0 g/cow/d Crina	+0.3	+2.0*	+1.8*	-0.03	+0.06*	+0.03	+0.08*	+0.07	+0.07
Schmidt et al., 2004	+1.9*	+1.9*	+2.7*	+0.10	+0.11*	-0.04	+0.04	-0.04	0
Varga et al., 2004	NA[1]	+1.6	+1.6	+0.02	+0.06	+0.05	+0.07	NA	NA
LaCount, 1997	+1.0	+1.6	+2.6*	+0.15*	+0.13*	+0.11*	+0.10*	-0.02	+0.04
Average	**+0.4**	**+0.9**	**+1.4**	**+0.08**	**+0.07**	**+0.02**	**+0.03**	**+0.01**	**+0.04**

*P < 0.10. [1]Not available.

Table 5. Literature review: Other significant (P < 0.10) responses reported.

Trial	Other P < 0.10 Results
Yang et al., 2007	
Garlic	ROMD[1] +5.8%; RND[2] +6.5%
Junniper Berry	ROMD +7.1%; RND +5.7%
Benchaar et al., 2007	Ruminal pH +0.10; Total VFA -9.2 mM for CS[3]
Benchaar et al., 2006	TTADFD[4] +2.9%; Ruminal pH +0.12;
Offer et al., 2005	NR[5]
Schmidt et al., 2004	NR
Varga et al., 2004	Continuous culture fermenter data
LaCount, 1997	NR

[1]Ruminal organic matter digestibility (truly) as % of intake. [2]Ruminal nitrogen digestibility (truly) as % of intake. [3]Corn silage based diet. [4]Total tract acid detergent fiber digestibility. [5]None reported.

Table 6. UW-Madison trial diet ingredient and nutrient composition (Tassoul and Shaver unpublished).

	Prefresh TMR	**Lactation TMR**
Ingredients, % DM		
Alfalfa silage	11.0	17.0
Corn silage	48.0	30.0
Mixed Alfalfa/Grass Hay	--	3.7
Wheat straw	11.0	--
Ground shelled corn	18.2	22.0
Soybean meal-48%	9.2	9.2
Distillers dried grains	--	9.2
Whole cottonseed-linted	--	5.6
Tallow	--	0.9
Minerals & Vitamins	2.6	2.4
Nutrients[1]		
DM, % as fed	46.1 ± 2.9	53.6 ± 3.0
	--------------------DM basis--------------------	
CP %	12.5 ± 0.7	17.1 ± 0.8
NDF%	38.1 ± 4.6	35.3 ± 1.9
Starch%	29.9 ± 4.6	24.7 ± 2.1
Fat%	3.5 ± 0.4	6.3 ± 0.6
TDN_{1x}%	68.9 ± 1.9	--
NEL_{3x}, Mcal/kg	--	1.71 ± 0.03

[1]TMR sampled weekly, composited by month, and analyzed using wet chemistry by Dairy One (Ithaca, NY).

Table 7. UW-Madison trial results (Tassoul and Shaver unpublished).

	Control	**Crina**	**SEM**	**P<**
Prepartum DMI, kg/d	13.8	13.1	0.4	NS[1]
Lactation DMI, kg/d	24.5	22.7	0.6	0.04
Milk Yield, kg/d	48.2	48.1	1.1	NS
4% FCM, kg/d	43.9	44.0	1.2	NS
Fat				
%	3.48	3.46	0.10	NS
kg/d	1.65	1.64	0.09	NS
True Protein				
%	3.10	2.95	0.05	0.03
kg/d	1.46	1.41	0.06	NS
MUN, mg%	12.9	13.4	0.3	NS
Milk/DMI	1.99	2.15	0.06	0.08
FCM/DMI	1.83	1.98	0.06	0.07
Lactation EB[2], Mcal/d	-1.1	-3.6	0.9	0.06
Body Condition Score				
Prepartum	3.9	3.8	0.1	NS
Lactation	3.4	3.3	0.1	NS
Body Weight, kg				
Prepartum	734.2	745.3	16.0	NS
Lactation	672.0	657.7	15.5	NS
Blood Data[3]				
NEFA, mEq/L	524.1	530.9	34.5	NS
BHBA, mg/dL	6.9	7.8	0.6	NS
Glucose, mg/dL	53.8	55.0	0.9	NS
Urea-N, mg/dL	11.9	12.0	0.3	NS

[1]Not significant (P > 0.10).
[2]Energy balance = $((DMI*NEL_{Diet}) – ((0.08*BW^{0.75})+(NEL_{Milk}*Milk)))$.
[3]Averaged across -21, -7, -1, 1, 8, 15, 22, and 29 d samples.

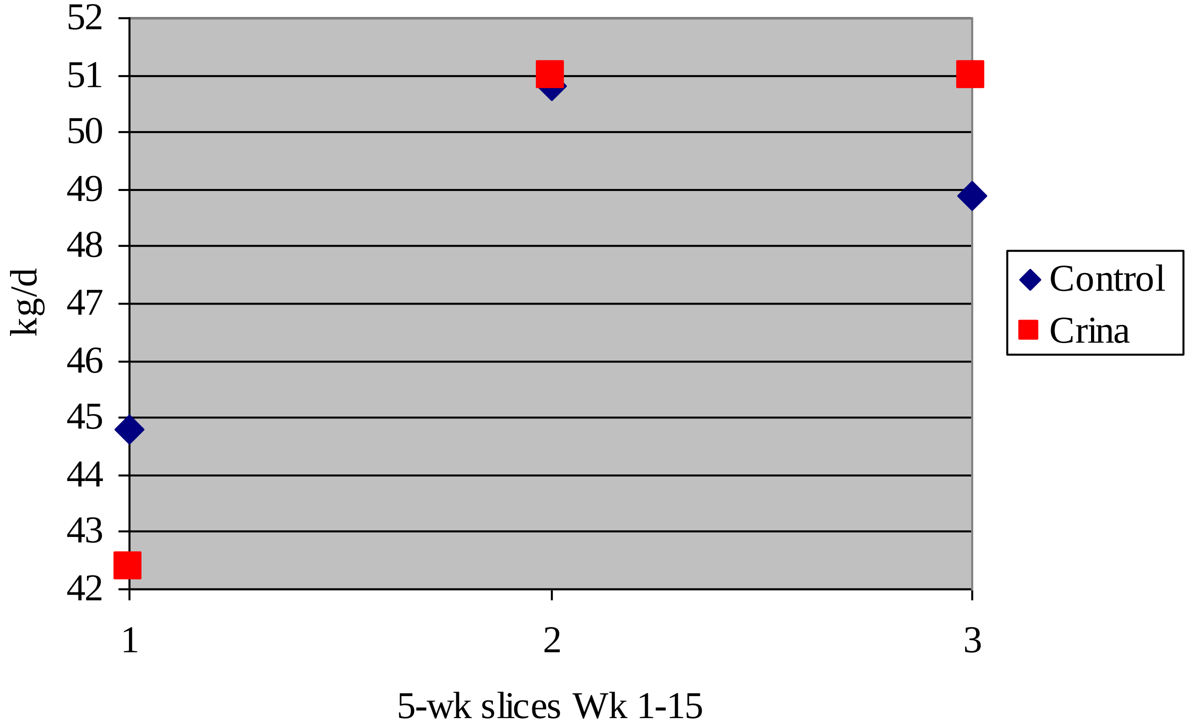

Figure 1. Milk yield (kg/d) summarized by 5-wk slices from wk 1-15 of lactation (P >0.10 differences and SEM = 1.3 kg/d for each slice).

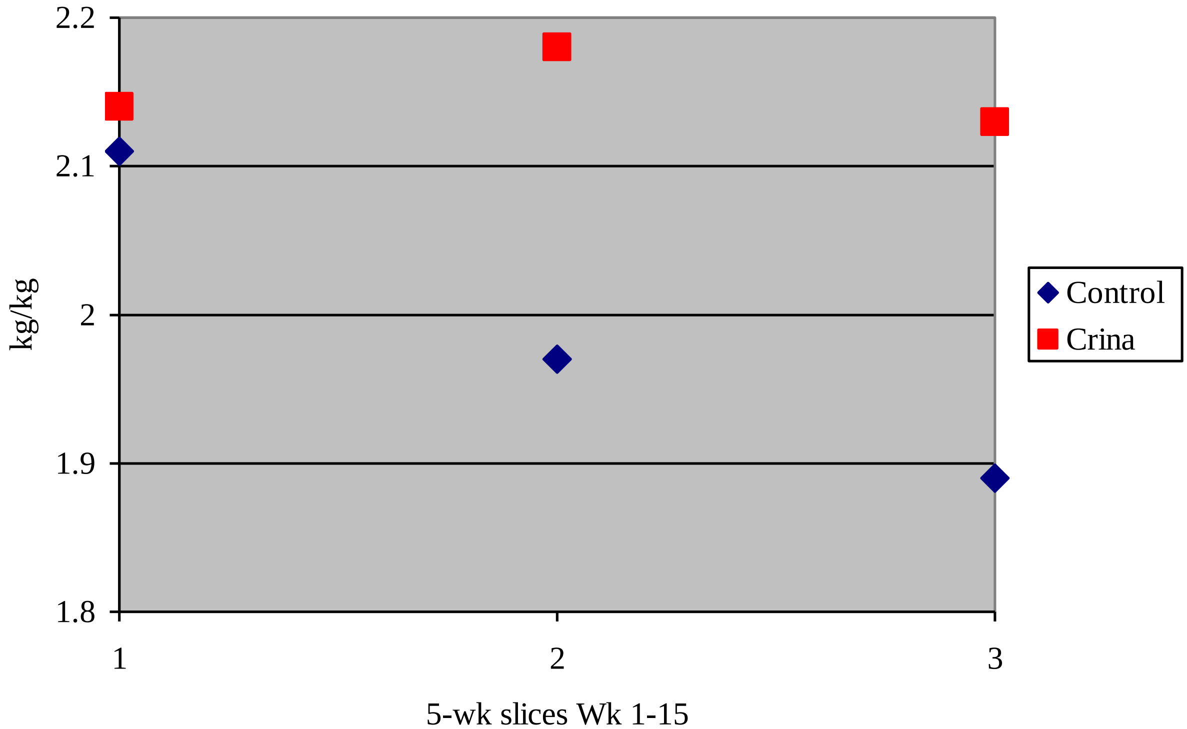

Figure 2. Feed efficiency (kg Milk/ kg DMI) summarized by 5-wk slices from wk 1-15 of lactation (Slice 1 - $P > 0.10$; Slice 2 - $P < 0.04$; Slice 3 - $P < 0.02$; SEM = 0.07 by slice).

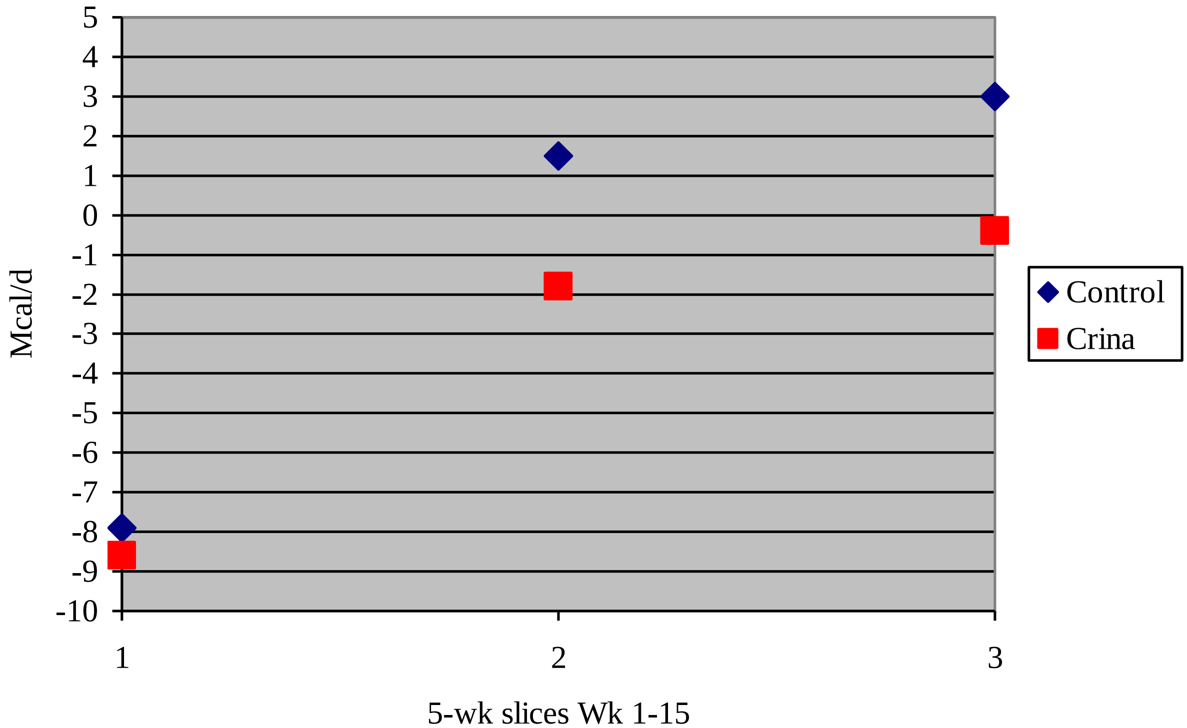

Figure 3. Energy balance (Mcal/d) summarized by 5-wk slices from wk 1-15 of lactation (Slice 1 - $P > 0.10$; Slice 2 - $P < 0.04$; Slice 3 - $P < 0.03$; SEM = 1.1Mcal/d by slice).