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Rapeseed supplementation effect on antioxidant and trace element content of winter organic and conventional milk in North East England

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Summary

A rapeseed supplement trial at Nafferton Farm (Newcastle University) with organic and conventional dairy cows, allowed us to assess the impact of feeding rapeseeds on the fat soluble antioxidant (AO) and trace element (TE) content of the milk during winter, undertaken as part of the study farm research within the Sustainable Intensification research Platform (SIP) project. Significant differences in AO and TE status between the organic and conventional milk were identified, with conventional having a higher content in most cases. Rapeseed intervention increased milk yield but suppressed most TEs and AOs, and replacing wheat with naked oats significantly increased iodine content in milk.

Key words: Antioxidants, trace elements, dairy cow, rapeseed

Introduction

The balance of milk fatty acids (and resulting dairy products) is dictated by the feeds given to dairy cows - grazing fresh pasture gives milk with more beneficial polyunsaturated fatty acids (PUFA) and these are also higher in organic than conventional milk (Stergiadis *et al.*, 2012). However, in northern Europe, grazing cannot occur throughout the year and cows are usually housed, feeding silage diets in winter. This increases the saturated fatty acid (SFA) content of the milk at the expense of PUFA although this can be mitigated if silage diets are supplemented with vegetable oils such as soya, rape, sunflower or linseed (Glasser *et al.*, 2008). These additions mimic the PUFA missing from grass consumption; however, the effect of supplementing vegetable oils on other milk constituents is fairly unknown.

The fat soluble antioxidants (AOs) in milk, vitamins E and A and carotenoid precursors can be regarded as having three important roles: a) nature's food preservatives, essential to protect vulnerable unsaturated fats from oxidation, and also protect against cellular damage and disease in b) the cow and c) consumers. The appearance of these AOs in milk reflects dietary supply, from naturally occurring sources in feeds and synthetic supplements added to cows' diets.

Mineral content is regarded as one of the most salient attributes of dairy produce – a critical provider of calcium. They are also an important source of iodine and to a lesser extent selenium. In the UK over 40% of iodine intake come from dairy products so anything that reduces the iodine content of milk is critical to iodine supply – already marginal for some groups in society (Payling *et al.*, 2015). This paper describes a study feeding home grown oilseed rape and naked oats to two dairy herds, to assess the a) impact on the AO and TE content of milk and b) feasibility of replacing imported soya and its associated environmental impact.

Materials and Methods

The feeding trial took place at Nafferton Farm in Northeast England, 26 January to 5 April 2012 with two parallel predominantly Holstein/Friesian dairy herds, calving year round, one organically (SoilAssociation, 2012) and one conventionally managed. Forty cows from each herd were selected, paired within herds for age, somatic cell count, milk fat and protein content and stage of lactation, then randomly allocated to control or rapeseed group. Analysis of Variance showed no statistical difference in the stage of lactation between the organic or conventional and the rape or control groups ($P>0.1$). In addition to the rapeseed, naked oats replaced wheat in all diets between days 36–50, Table 1 shows how diet details differed during the study.

Feeding

Before the trial, cows were fed: Organic: Total Mixed Ration (TMR) of 5 kg day^{-1} premixed concentrate and 4 kg day^{-1} of parlour concentrates; Conventional: TMR with 5 kg day^{-1} premixed concentrate and 5 kg day^{-1} of parlour concentrates.

Table 1. *Pre-mix formulation a) Wheat/barley diets (Day 1–35 and 51-64) and b) Naked Oat diets (day 36-50)*

a) Wheat/barley	Conventional herd (Kg tonne^{-1})		Organic herd (Kg tonne^{-1})	
Days 1–35 & 51–64	Control (n=20)	Rape (n=20)	Control (n=20)	Rape (n=20)
Wheat	390	170	100	100
Barley	0	0	500	400
Soya bean meal	230	100	0	0
Beans	250	200	400	100
Molasses	130	130	0	0
Rape seed (rolled)	0	400	0	400
minerals	25	25	0	0
b) Naked oats	Conventional herd (Kg tonne^{-1})		Organic herd (Kg tonne^{-1})	
Days 36–50	Control	Rape	Control	Rape
Naked oats	375	170	600	500
Soya bean meal	225	100	0	0
Beans	250	200	400	100
Molasses	125	125	0	0
Rape seed (rolled)	0	380	0	400
minerals	25	25	0	0

Milk collection

Milk, representing 24 hour production, was collected from individual cows four times during the trial on days 14, 35,49 and 63 (dates B, C, D and E respectively).

Milk analysis

Trace element analysis was carried out by the commercial lab Thompson and Joseph by Inductively Coupled Plasma Emission Spectrometry (ICP-MS). Extraction and quantification of AO was based on Lietz *et al.* (2001) with slight modifications. Detection and quantification of retinol and carotenoids used a diode-array detector at 325 ηm and 450 ηm respectively. Fluorescence detector was used for a-tocopherol at excitation and emission wavelengths at 285 ηm and 325 ηm respectively, all with echinenone as the internal standard.

Data analysis

Data analysis was completed using the package 'nlme' in the statistical computing software environment 'R'. Tests included: linear mixed-effects model (to allow for nested random effects), analysis of variance and Tukey's Honest Significant Difference (HSD). The main factors were Management (conventional/organic), Treatment (control/rapeseed) and Date (B, C, E fed wheat diets and D on oats), individual cows were treated as a random factor. All results are presented as relative values and expressed as a percentage within each factor.

Results

Milk yield

Yield did not differ between Treatment or Management groups but fluctuated slightly across sampling dates (±4%). There was an interaction between Date and Treatment with yield increasing in the rapeseed group throughout the trial but remaining constant in control cows.

Antioxidant content of milk

Table 2 shows both Management and Date had a significant effect on the concentration of all AOs and feeding rape influenced Retinol, β-carotene and Total Carotenoids. There were interactions between Management and Date for α-tocopherol, Retinol and Zeaxanthin and between Date and Treatment for α-tocopherol, Retinol, β-carotene and Total Carotenoids although there were no interactions between Management and rape feeding. Lutein was the only AO lower in milk from the conventional herd with no significant interactions. Zeaxanthin showed the largest variance between herds whilst β-carotene/Total Carotenoids had the largest influence of feeding rape. The control group had higher concentrations of AOs across the board and all AOs in all groups either fell or remained the same throughout the trial.

Trace element content of milk

Table 2 shows considerable variation in concentrations of the TEs measured. All changed over time. Management had a significant effect on all, apart from Zinc, and feeding rape influenced Molybdenum, Iodine and Selenium. There were interactions between Date and Management for all TEs apart from Copper, and interactions between Date and Treatment for Molybdenum, Iodine and Selenium, but no significant interactions between Management and Treatment. Across the TEs, Zinc showed the least variability remaining statistically the same in all groups from beginning to end of the trial. The TE content was higher in milk from control cows compared to those fed rape. Iodine saw the greatest variation across the sampling Dates, Management and Treatment groups, peaking at date D, then decreasing.

Discussion

Milk yield

The increase in milk yield by replacing other protein feeds with full fat rapeseed is most likely due to the estimated 13% boost in metabolisable energy content of the diet.

Rape vs *control diets*

All AOs in milk from control cows decreased during the trial, suggesting a depletion of reserves accumulated from summer grazing. This reflects results by Ellis *et al.* (2007), where Vitamin A in UK organic and conventional milk fell on housing. Cows generally get Vit A, its precursors and Vit E from fresh forages however, these oxidise over time, reducing their concentration in silage or hay (Noziere *et al.*, 2006). This study conducted in the latter section of winter is likely to have relatively low AO levels in silage, although this was not assessed. Rape feeding appeared to suppress AO in milk although concentrations of β-carotene and Total Carotenoids did increase over the study (not significant) but, as with control cows, other AOs diminished.

The concentration of Copper and Molybdenum in milk decreased during the study and to a greater extent for cows fed rape. Other TEs increased (not always significantly) in both groups, however not to the same extent in milk from rape fed cows. Rapeseed contains glucosinolates, and even at low levels has been shown to suppress thyroid function and reduce Iodine in milk (Papas *et al.*, 1979). Additionally, Givens *et al.* (2004) found less Selenium in rape meal than in wheat and soybean meal. Although this does not explain the full TEs examined, it suggests care is needed to avoid TE deficiency when feeding rapeseed.

Whilst both control and rapeseed groups follow similar patterns across AOs and TEs and it is unknown if the control/rapeseed groups began the trial significantly different, rape could have a slightly suppressive effect in all cases. Given this effect, care should be taken with supplementation to ensure cows (and consumers) are not deficient when using home-grown feed sources as soya is phased out to increase sustainability.

Conventional vs *organic management*

Overall, concentration of all AOs decreased across the sampling period with considerable variations between the Management groups. One potential explanation could be the lower Vitamin E, β -carotene and Lutein content of legumes compared with grasses (Danielsson *et al.*, 2008; Elgersma, 2012; Elgersma *et al.*, 2013). Organic silage was from a grass clover sward, possibly with less AOs than the grass-based conventional silage. Whilst milk Iodine and Selenium content is not an accurate reflection of cow status, extremely low levels (for some cows) could suggest deficiencies. Iodine and Selenium play an important role in vitamin metabolism, possibly affected by their deficiency (Gray *et al.*, 2004). At the beginning of the trial organic milk was very low in Iodine - potentially a contribution to lower AO content than conventional milk.

The TEs were also higher in the conventional milk, bar Zinc (not significant) and Molybdenum, unsurprising given that the conventional herd was fed a mineral supplement. This difference between herds depicts a historic shift within the dairy industry—previously feeding mineral supplements was discouraged by certifying body unless necessary whereas there are now certified products available, although without synthetic vitamins. Additionally, OMSCo issued a press release in April 2017 showing supermarket organic milk now has comparable Iodine concentrations to supermarket conventional milk.

Table 2. *Effects of Management (M), Date (D) and diet (T) on relative milk AO and TE content*

Factors	α-tocopherol	Retinol	β-carotene	Lutein	Zeaxanthin	Total carotenoids
Management						
Conventional	137%	122%	114%	92%	145%	114%
Organic	63%	78%	86%	108%	55%	86%
Date[1]						
B	107%[a]	106%[a]	98%[b]	105%[a]	108%[a]	98%[b]
C	106%[a]	103%[ab]	114%[a]	110%[a]	105%[a]	114%[a]
D	97%[b]	99%[b]	96%[bc]	96%[b]	99%[a]	96%[bc]
E	90%[c]	91%[c]	91%[c]	88%[c]	88%[b]	91%[c]
Treatment						
Control	103%	107%	122%	104%	107%	121%
Rape	97%	93%	78%	96%	93%	79%
ANOVA (*P*-values)[2]						
Management	***	***	***	*	***	***
Date	***	***	***	***	***	***
Treatment	ns	***	***	ns	ns	***
Interactions						
M × D[2]	***	***	ns	ns	***	ns
M × T	ns	ns	ns	ns	t	ns
D × T	***	***	***	ns	t	***
M × D × T	ns	ns	t	ns	*	t

Factors	Copper	Molybdenum	Iodine	Selenium	Manganese	Zinc
Management						
Conventional	111%	92%	131%	128%	108%	99%
Organic	89%	108%	69%	72%	92%	101%
Date[1]						
B	110%[a]	110%[a]	78%[d]	95%[d]	101%[a]	101%[ab]
C	96%[bcd]	100%[b]	90%[c]	98%[c]	91%[b]	98%[bc]
D	98%[bd]	97%[bc]	126%[a]	101%[b]	102%[a]	99%[b]
E	95%[d]	94%[c]	106%[b]	107%[a]	106%[a]	103%[a]
Treatment						
Control	103%	105%	108%	104%	105%	100%
Rape	97%	95%	92%	96%	95%	100%
ANOVA (*P*-values)[2]						
Management	*	**	***	***	*	ns
Date	***	***	***	***	**	*
Treatment	ns	*	*	**	ns	ns
Interactions						
M × D[2]	ns	***	***	***	***	***
M × T	ns	ns	ns	ns	ns	ns
D × T	ns	**	***	***	t	ns
M × D × T	ns	**	***	***	ns	ns

[1] [a-d] Mean values for dates in a column with different letters are significantly different, according to Tukey's honestly significant difference test (*P*-values<0.05). [2] ***: *P*< 0.001, **: *P*< 0.01; *: *P*< 0.05, t: *P*<0.1, ns: *P*>0.1.

Replacing wheat and barley with oats (date D) seemed to have a dramatic impact on Iodine concentration in milk, increasing by 20% and 85% in the conventional and organic groups respectively and by 40% and 42% in the control and rape fed cows (Fig. 1). Iodine in milk quickly decreased when oats were removed (Date E) and this pattern was not seen for other TEs or AOs. This lift in milk Iodine was shown by every single organic cow, 95% of which then had lower milk Iodine at date E. Despite continual supplementation of conventional cows 93% had an increase in milk Iodine from C–D, then 88% falling between D–E. This is surprising as generally oats contain less Iodine than wheat and there appears to be no other studies to support a direct or an indirect effect comparing wheat and naked oats on Iodine metabolism.

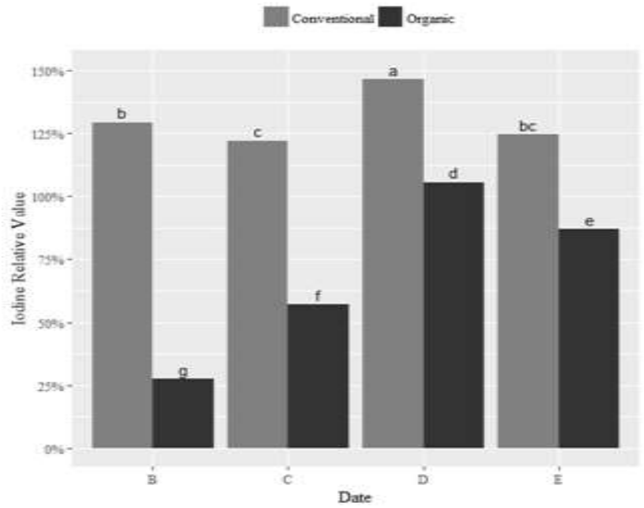

Fig. 1. Iodine content increased in both Management groups at date D (oats), then decreased again when the oats were removed.

Conclusion

Based on the results of this trial, feeding rape over-winter had a slightly suppressive effect on the vitamin and mineral content of milk. Using home grown crops, such as rapeseed and oats rather than imported soya, increases the sustainability of dairy production. Given this, locally produced crops and/or organic management should be used where possible but sustainability needs to ensure both cows and consumers receive the optimum diet, potentially through trace element supplementation of dairy diets. Taking a longer view, the sustainability of dairy production could be further improved if ruminants use marginal land and pasture based diets leaving better land to grow food for direct human consumption (rather than ruminant feed), provided local TE deficiencies are addressed.

The AO differences between the Management groups and the reasons behind the contrasting results leave additional questions to be answered. The differences between the TEs are more understandable given the supplements given in the conventional herd. It was beyond the limits of this trial to have feed analysed but future trials should have feed, forage and milk analysed to account for more differences.

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