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MANIPULATION OF THE FATTY ACID PROFILES OF MEAT AND MILK USING PROTECTED LIPID SUPPLEMENTS - A BRIEF REVIEW

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SUMMARY
This paper summarises a series of studies conducted to investigate the incorporation of dietary eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) into meat and milk in ruminants. In dairy goats and cows, EPA plus DHA was increased from undetectable levels to 1.5-1.7 % of total fatty acids. At such levels nearly a quarter of the recommended daily intake of ω-3 PUFA can be obtained from 250 ml (one cup) of milk. Feeding ω-3 PUFA supplement to lambs tripled the level of EPA and DHA in trimmed muscle cuts (*Longissimus dorsi*), such that a 100 g would provide a quarter of the recommended daily intake of ω-3 PUFA. Our studies indicate that some form of protection against ruminal biohydrogenation is required to incorporate these polyenoic fatty acids into meat or milk without affecting animal performance.

Keywords: EPA, DHA, meat, milk, protected lipid

INTRODUCTION
There is increasing epidemiological and clinical evidence (that omega-3 polyunsaturated fatty acids (ω-3 PUFA) reduce the risk of coronary heart disease (CHD) and stroke (GISSI-Prevenzione Investigators, 1999)- the leading causes of death in Australia and other developed nations. Meat and milk from ruminants, which constitute the bulk of the Western diet, are a poor source of these cardio-protective ω-3 PUFA. On the contrary, they are high in saturated fatty acids, which are deemed to increase the risk of CHD and stroke. Consequently, a constant stream of fat-modified milk products and substitutes are appearing on supermarket shelves. There has also been a shift from red meat to white meat consumption. For instance, per capita beef consumption in Australia declined from nearly 50 kg in 1982 to around 38 kg in 2001, while poultry meat consumption rose from 20 to 34.5 kg per person over the same period (Outlook® 2001).

This shift from consumption of ruminant fat may be counterproductive, as recent evidence shows that ruminant products are richer in conjugated linoleic acid (CLA, the most potent dietary anti-cancer agent) than most food products (Parodi, 1996). Hence, the strategy of choice might be manipulation of the fatty acid profile of ruminant products to improve the consumers' perception of ruminant fat. Increasing the level of ω-3 PUFA in meat and milk may provide such an option. The ω-3 PUFA with increasing evidence of cardio-protective role are eicosapentaenoic acid (EPA, C20:5) and docosahexaenoic acid (DHA, C22:6). Marine oils and algae are naturally rich in both. Over the last few years, our laboratory has been investigating ways of enriching meat and milk from ruminants with EPA and DHA by using protected tuna oil supplements. Our protection procedure is based on microencapsulation of oil droplets in a protein-aldehyde matrix (Scott *et al*. 1971). This paper summarises our results so far and the comparative efficacy of our lipid protection procedure in enabling the transfer of these polyenoic fatty acids into meat and milk without any deleterious effects on growth and/or productivity of ruminants.

OMEGA-3 ENRICHED MILK
Goat Milk
Initially, the concept of producing EPA and DHA-enriched milk was tested using dairy goats. Four multiparous goats were sequentially offered three diets: control pellets (C, lucerne hay-oat grain: 60/40,w/w), C pellets plus rumen-protected tuna oil (+RPTO), and C plus unprotected tuna oil (+UTO). In tuna oil supplemented diets, the oil constituted 3 % of total dry matter, and each supplement was fed for 7 days, with 12 days allowed between the two fish oil feeding periods to minimise carry-over effects. Treatment differences were evaluated using Student's T-test ($P<0.05$). Analytical procedures and other details are published elsewhere (Kitessa *et al*. 2001a). The main results are summarised in Table 1.

Table 1. Yield and composition of milk from goats on control (C, lucerne hay-oat grain), C plus rumen-protected tuna oil (+RPTO) or C plus unprotected tuna oil (+UTO) diets. Kitessa *et al*. 2001a

Variable	Control	+RPTO	+UTO	s.e.m.
Intake, kg/d	2.69[a]	2.23[a]	1.35[b]	0.20
Milk yield, l/d	1.88[a]	1.77[a]	1.35[b]	0.19
Fat, %	4.15	4.07	4.33	0.32
Protein, %	3.20	3.33	3.55	0.23
ω-3 PUFA % total fatty acids: EPA	0.0	0.47	0.31	0.06
DHA	0.0	1.01	1.12	0.12
ω-3 PUFA rate of transfer: EPA	-	7.62[a]	3.50[b]	1.21
DHA	-	5.05	3.53	0.69

Across rows, values with different superscripts were significantly different at $P<0.05$.

The above results indicated that it is possible to enrich milk with EPA and DHA using either protected or unprotected tuna oil, but protection is required if EPA and DHA-enriched milk is to be produced without deleterious effects on intake and milk yield. The decline in milk yield (40%) due to supplementation with free oil concurs with other studies (Cant *et al*. 1997; Wachira *et al*. 1998), though it is not possible to exclude the possibility that advance in lactation stage may also have played a part in this decline in milk yield. The magnitude of the decline (40 % over 12 days) suggested that it was mostly diet-induced. The rate of transfer of EPA and DHA from diet to milk was much lower than that reported by Cant *et al.* (1997) on fish meal fed cows. It remains to be determined if this is related to species difference or other factors.

In a subsequent study, the transfer of EPA and DHA to milk was tested in two groups of dairy cows (n=7) grazing a kikuyu/ryegrass pasture. One group (+RPTO) was fed a supplement of rumen-protected tuna oil-soybean powder (2 kg) mixed with molasses (80:20), chaffed lucerne (1 kg) and mill mix (1 kg). Tuna oil constituted 2 % of total dry matter intake. The second group (C) of cows also received lucerne chaff and mill mix, but not the oil supplement. Milk yield was recorded and milk samples were collected both at morning and afternoon milking. Treatment differences were analysed using Student's T-test. Analytical procedures were the same as those published in Kitessa *et al.* (2001a). The main findings are summarised in Table 2.

Table 2. Yield and composition of milk from cows supplemented with control (C, lucerne chaff and mill mix) or C plus rumen-protected tuna oil (+RPTO) and grazed on kikuyu ryegrass pasture.

Variable	Control	+RPTO	s.e.m.
Milk yield, l/d	35.4	33.9	0.63
Fat, %	3.62	4.04	0.08
Protein, %	2.82	3.01	0.03
ω-3 PUFA % total fatty acids: EPA	0.0	0.61	0.03***
DHA	0.0	1.09	0.04***
ω-3 PUFA rate of transfer: EPA	-	32.4	2.10
DHA	-	17.6	1.27

As in the goat study, feeding supplemental protected tuna oil significantly enriched milk with EPA and DHA without deleterious effect on milk yield. The rates of transfer of EPA and DHA from diet to milk in this study were similar to those observed by Cant *et al*. (1997). For both goat and cow milk, a cup of the enriched milk could provide more than 150 mg of EPA and DHA, i.e. at least a quarter of the recommended daily intake of 650 mg (Simopaulos, 1991). These results suggest that a significant enrichment of milk with EPA and DHA can be achieved with at a 2-3 % inclusion of protected tuna oil in ruminant diets. The CV for the transfer rates were 17.1 and 19.1 % for EPA and DHA, respectively, which may be an indication of substantial variation between cows.

OMEGA-3 ENRICHED MEAT

Modifying the fat content of meat post-slaughter provides a greater challenge than doing the same with fat in milk after milking. This is because other than subcutaneous fat (which can be trimmed), there are also intramuscular and intermuscular fat which together usually constitute 3-5 g per 100g of muscle (Kitessa *et al.* 2001b). Furthermore, fat plays a major role in the flavour, tenderness and juiciness of meat. In addition, any approach at modifying the nutritional value of red meat should not compromise its greatest advantage over other meats, i.e. its CLA content, which is part of the fat in meat. This all points to dietary manipulation of the fatty acid profile of red meat as being the best option in making it a useful source of health-enhancing nutrients.

To evaluate the incorporation of EPA and DHA from protected tuna oil into depot fat and muscle a group of lambs were fed a concentrate ration supplemented with either rumen-protected tuna oil (+RPTO) or tallow (+Tallow, used to make the diets iso-caloric) at 3 % of total dry matter. Over a 42-day feeding period, intake was recorded daily; liveweight, weekly; and final slaughter weight, hot carcass yield, eye muscle area and GR score were recorded at slaughter. Treatment differences were evaluated using Student's T-test. Other details are published elsewhere (Kitessa *et al*. 2001b). The main results are in Table 3 below.

Table 3. Performance data and selected fatty acids in different tissues of tallow or rumen-protected tuna oil-supplemented lambs. Kitessa *et al*. 2001b

Variable	+Tallow	+RPTO	s.e.m.
Initial liveweight (LW), kg	25.5	26.5	0.44
LW gain, g/day	218	196	17.5
Final LW, kg	34.8	34.2	0.71
Hot carcass yield, kg	15.9	16.8	0.31
Subcutaneous tissue:			
EPA	0.0	0.36	0.01***
DHA	0.0	0.75	0.09***
Muscle tissue:			
EPA	0.61	1.81	0.30*
DHA	0.44	1.51	0.14**

A few notable features from these results included: (1) as in the dairy studies protected tuna oil supplementation had no detectable deleterious effect on productivity traits, (2) tuna oil supplement tripled the levels of both EPA and DHA in muscle, and (3) tallow-fed lambs had no traceable EPA or DHA in their subcutaneous fat, but significant levels in their muscle. In earlier work, Ashes *et al.* (1992) could not detect enrichment of subcutaneous adipose tissue with EPA and DHA after feeding sheep with fish oil at 8-12 % total dry matter. This may be related to differences in the level of fish oil inclusion between the two studies. The presence of EPA and DHA in meat from non-supplemented group was contrary to our observation on non-supplemented goats or cows, where we found no traceable levels of EPA or DHA in their milk. The total ω-3 PUFA per 100g muscle in this study was comparable to that reported by Wachira *et al* 1998 (150 vs 158 mg, respectively), although our fish oil inclusion was 40 % lower. Further comparisons are available in Kitessa *et al* (2001b).

CONCLUSIONS

Milk and meat from ruminants can be significantly enriched with EPA and DHA without adverse effects on animal performance, provided that the oil is protected against ruminal biohydrogentation. The presence of EPA and DHA in muscle cuts from lambs not supplemented with ω-3 PUFA suggests that there may be an opportunity for selecting high and low ω-3 PUFA producing meat animals. However, it remains to be determined if selection alone would provide animals with such high ω-3 PUFA that a significant proportion of the recommended daily intake can be obtained from a reasonable size of serve. Large-scale commercial trials are required to determine the processing properties, shelf-life, consumer acceptance of EPA plus DHA-enriched milk and meat.

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