Lipid oxidation during instrumented dynamic in vitro digestion of marine oil-enriched milk

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The health benefits of n-3 long-chain polyunsaturated fatty acids (n-3 LC-PUFA) are well recognized. Foods enriched in n-3 LC-PUFA, are now available for the consumers. However, PUFA are prone to oxidation during processing and the storage of the enriched-foods, but also during their digestion, and deleterious compounds can be formed both during both gastric and intestinal steps [1].

The aim of this study was to evaluate the formation of toxic aldehydes: malondialdehyde (MDA), 4-hydroxy-2-hexenal (4-HHE), 4-hydroxy-2-nonenal (4-HNE) during the in vitro digestion of marine oil enriched milk.

**Material & Methods**

Fish oil 0.5 % (w/w)
PV = 2.4 meq/kg ; AV = 7.55
MDA: 68 nmol/g oil
4-HHE: 0.8 nmol/g lipid
4-HNE: 0.18 nmol/g oil
Tocopherols: 890 µg/g oil
EPA + DHA: 11 % total fatty acids
n-6/n-3 PUFAs: 0.26

Milk enrichment

Homogenized pasteurized milk
1% fat
Homogenization (300 bars, 2.5 min)

Marine-oil enriched milk
1% milk fat, 0.5% fish oil

Three digestions were performed independently on three marine oil-enriched milks prepared separately.

MDA, 4-HHE and 4-HNE were measured on the samples from the 3 experiments. The individual data obtained for MDA (left), 4-HHE (middle) and 4-HNE (right) during the gastric (blue symbols, G1, G2, G3) and intestinal steps (red symbols, I1, I2, I3) of each digestion are shown. The blue and red lines locate the mean values.

Total amounts in each compartment (nmol) calculated from volumes of digestive media are presented.

**Results & Discussion**

Lipid oxidation in the stomach compartment

MDA can result from the oxidation of both n-6 and n-3 PUFA. It is toxic for cells [2,3]. It was produced in fairly high concentrations (75 µM at the end of the gastric phase) which corresponds to around 4 nmol in the total digestive fluid and 1.2 nmol/g ingested lipids

MDA results from oxidation of n-3 PUFA. It is very reactive and binds to proteins. It can be absorbed by the intestinal cells and provokes oxidative stress [4]. It was produced continuously in the acid gastric environment. It represented up to 7 µM digestive medium, meaning total of 400 nmol and around 800 nmol/g lipids.

4-HHE originates from the oxidation of n-6 PUFA. This reactive compound is considered as a marker of oxidative stress in vivo [5]. In accordance with the fatty acid composition of the fish oil, poor in n-6 PUFA, its amounts remained fairly low as compared to MDA and 4-HHE: around 0.3 µM, 20 nmol, and 50 nmol/g lipids.

**Lipid oxidation in the intestine compartment**

MDA and 4-HHE concentrations increased continuously in intestinal conditions. However, their concentrations were lower than in the gastric medium. It could result from the dilution by the digestive fluids and from the binding of the reactive aldehydes to the components of the medium, including the hydrolyzed milk proteins. The decrease of MDA and 4-HHE total amounts at the end of the intestinal step is linked to the decrease of the fluid volume (emptying). 4-HHE was not appreciably produced during intestinal digestion of marine oil-enriched milk.

Oxidation and production of MDA and 4-HHE continued during the intestinal simulated digestion.

**Conclusions**

Toxic aldehydes (MDA >> 4-HHE >> 4-HNE) were formed during the gastric and intestinal steps of the in vitro digestion of the marine oil-enriched milk. Tocopherols were consumed mostly during the gastric step. Results must be confirmed by in vivo studies, to evaluate in the case of n-3 LC-PUFA enriched-foods, the health effects of the oxidative reactions during digestion.

**References**


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