Lipid oxidation in high fat omega-3 delivery emulsions

Intake of long chain n-3 polyunsaturated fatty acids (LC n-3 PUFAs) is inadequate in most Western populations due to the low consumption of fish and other seafood products. These long chain omega-3 fatty acids such as EPA (eicosapentaenoic acid, C20:5n-3) and DHA (docosahexaenoic acid, C22:6n-3) have been reported to be beneficial to health. Therefore, strategies for enrichment of food with LC n-3 PUFAs have been investigated by food scientists in order to comply with the recommended daily intake for EPA and DHA.

LC n-3 PUFAs are highly prone to lipid oxidation in the presence of heat, metal ions and oxygen. Oxidation of LC n-3 PUFAs results in loss of nutritious fatty acids, undesired off-flavors, and rancid/fishy taste. Oil-in-water delivery emulsion systems have been proposed and investigated as one of the strategies to protect these lipophilic bioactive compounds. Previous studies were mainly focused on low fat n-3 delivery oil-in-water emulsion, regardless of the great potential of the high fat n-3 delivery oil-in-water emulsion systems (e.g. for the enrichment of highly viscous foods).

The focus of this Ph.D. study was mainly on the impact of emulsion composition and combination of multifunctional emulsifiers on oil-water interfacial structure and emulsifier distribution, as well as their influence on physical and oxidative stability of high fat fish oil-in-water emulsions. The potential of X-ray and neutron techniques as well as electron paramagnetic resonance in providing useful information about the interface structure and partitioning of emulsifiers, respectively, has also been demonstrated in this study.

The fish oil content, total emulsifier content, and the ratio between emulsifiers (sodium caseinate, CAS, combined with sodium alginate, ALG, or diacetyl tartaric acid esters of mono- and diglycerides, DATEM, or phosphatidylcholine, PC) affected physical and oxidative stability of the high fat fish oil-in-water emulsions. Combinations of CAS and ALG provided high viscosity and creaming stability for the high fat emulsions, whereas combinations of CAS and DATEM or PC yielded emulsions with lower viscosity and creaming stability compared to ALG.

The effect of homogenizer type on physical and oxidative stability of high fat fish oil-in-water emulsions was investigated. Emulsions stabilized with CAS and DATEM or PC and produced with colloid mill resulted in higher viscosity, less creaming and smaller droplet sizes compared to emulsions produced with Stephan mixer. This indicated that emulsions produced with colloid mill provided better physical stability. Furthermore, emulsions produced with Stephan mixer had higher oxidative stability compared to those produced with colloid mill when evaluated by the formation of primary and secondary lipid oxidation products. This was mainly attributed to larger droplets and creaming of emulsions produced with Stephan mixer yielding less contact between prooxidants and lipids.

Surface activity of a commonly used thickener, ALG, was enhanced by the modification with short and long alkyl chains. Combination of the short chain modified ALG and CAS improved both physical and oxidative stability of the high fat fish oil-in-water emulsions compared to emulsions stabilized with CAS. On the other hand, combined use of long chain modified ALG and CAS did not improve the oxidative stability of the high fat fish oil-in-water emulsion, even though physical stability was significantly improved resulting in smaller droplets and higher viscosity.

Antioxidant and surface activity of DATEM and PC were improved by the addition of caffeic acid to the glycerol backbone and by the attachment of alkyl chains at various lengths, which had different effects on physical and oxidative stability of high fat fish oil-in-water emulsions. Emulsions produced with modified DATEMs showed better oxidative stability compared to emulsion with commercial DATEM plus an equivalent amount of free caffeic acid, confirming the advantage of covalent attachment of caffeic acid to the emulsifier. Modified DATEM with C14 alkyl chain (DATEM C14) replaced more CAS from the interface in 70% fish oil-in-water emulsion compared to modified DATEM with C12 alkyl chain (DATEM C12). Furthermore, emulsions produced with DATEM C14 had significantly decreased amounts of primary and secondary oxidation products compared to emulsions containing DATEM C12. This was mainly attributed to the higher concentration of the antioxidant DATEM C14 compared to DATEM C12 at the oil-water interface. Emulsion stabilized with modified PC with C14 alkyl chain (PC C14) led to smaller droplets and higher viscosity, whereas modified PC with C16 alkyl chain (PC C16) had higher protein surface load, which resulted in a thicker interfacial layer. Modified PCs enhanced oxidative stability compared to emulsions with PC and free caffeic acid due to the attachment of caffeic acid, which brings the antioxidant in the vicinity of interface. PC C16 led to higher oxidative stability compared to PC C14, mainly explained by the thicker interfacial layer provided by PC C16.

Finally, incorporation of n-3 delivery 70% fish oil-in-water emulsions produced with modified DATEMs into mayonnaise was investigated. The physical stability of the mayonnaise enriched with delivery emulsions was low due to the pH adjustment between delivery emulsion and mayonnaise. However, mayonnaise containing high fat emulsions stabilized with combinations of CAS and modified DATEMs had higher oxidative stability compared to mayonnaise produced with added neat fish oil, indicating the feasibility of using high fat fish oil in water emulsions to enrich food systems such as mayonnaise.