Factors Influencing the Effect of Milk-based Emulsifiers on Lipid Oxidation in Omega-3 Emulsions

Intake of fish oil, and in particular the long chained polyunsaturated omega-3 fatty acids, has over the last centuries been associated with a wide range of health beneficial effects. Nevertheless, the intake of these healthy lipids is still lower than recommended in most Western populations. An interest in omega-3 enriched foods has therefore developed. The challenge when the polyunsaturated omega-3 fatty acids are added to foods is their sensitivity towards heating, metal ions and oxygen, as these factors can lead to lipid oxidation. To avoid this, a possible approach is to incorporate and thereby protect the fatty acids in an emulsion before they are added to the food product. However, the use of these so-called delivery emulsions in different food products has shown contradictory results.

On this background, the overall goal of the present PhD work was to increase our knowledge about factors related to the choice of emulsifier, homogenization equipment and emulsification conditions that could influence lipid oxidation in simple fish oil-in-water emulsion systems. The main focus was on the use of milk proteins alone or in combination with phospholipids as emulsifiers. In addition, the aim was to utilize this knowledge for designing delivery emulsions for the addition of fish oil to foods, and thereby achieve oxidatively stable fish oil enriched products.

In simple emulsions, sodium caseinate, whey protein isolate, soy lecithin and combinations of milk proteins and milk phospholipids were investigated as emulsifiers in both 5% and 70% fish oil-in-water emulsions. The effects of the individual emulsifiers were evaluated at different pH values, emulsifier concentrations and with or without the addition of iron. Generally, protein stabilized 5% oil-in-water emulsions were more oxidatively stable at low pH than at neutral pH, whereas the opposite was observed for 70% oil-in-water emulsions. It was shown that emulsions prepared with the highly flexible milk protein casein were the least oxidized at the varying conditions, followed by emulsions with whey protein isolate. The use of soy lecithin or a combination of milk protein and milk phospholipids as emulsifier in these 5% and 70% emulsions was shown only to be advantageous in 70% emulsions at low pH. Moreover, a good quality of the emulsifier was shown to be crucial for obtaining a better oxidative stability of emulsions prepared with phospholipids than with milk proteins.

The oxidative stability of 10% oil-in-water emulsions prepared with varying ratios of individual whey protein components, α-lactalbumin and β-lactoglobulin, was furthermore investigated at different pH values. Similarly to the 5% emulsions, the oxidative stability of these 10% emulsions was better at low pH than at neutral pH, independent of the type of emulsifier. No difference was observed in the antioxidative effect of the whey protein components when emulsions were prepared at pH 4. Nevertheless, at neutral pH the lowest antioxidative effect during the emulsification process was achieved when using the emulsifier with the highest concentration of β-lactoglobulin, whereas during storage the best oxidative stability was observed in the emulsions with the highest concentration of α-lactalbumin. These differences were ascribed to the partitioning of α-lactalbumin and β-lactoglobulin between the interface and the aqueous phase in the emulsion.

It was demonstrated that the use of different high pressure homogenizers influenced lipid oxidation in emulsions prepared with whey protein isolate as emulsifier, but not emulsions prepared with sodium caseinate. Moreover, it was shown that the applied pressure during high pressure homogenization influenced the resulting oxidative stability of the emulsion dependent on the emulsifier used. Overall, it was concluded that the partitioning of proteins between the interface and the aqueous phase, and the composition of protein components at the interfacial layer played an important role for the oxidative stability of emulsions prepared on different equipments and under various conditions.

In two case studies, fish oil-in-water emulsions prepared with different milk-based emulsifiers were used as delivery emulsions in milk and cream cheese. Unexpectedly, results showed that a better oxidative stability was achieved when the fish oil was added as neat oil to the milk than as a 10% delivery emulsion. Furthermore, no difference was observed on the oxidative status of the milks dependent on the type of emulsifier used for preparing the delivery emulsions. Independent of the introduction method of fish oil to cream cheese (neat oil vs a 70% delivery emulsion), the fish oil enriched cream cheese oxidized during a 20 weeks storage period to a degree where the sensory quality of the product was significantly impacted. However, in contrast to the fish oil enriched milks, differences in the oxidative stability were observed between cream cheeses containing delivery emulsions prepared with different emulsifiers. The use of a combination of milk proteins and milk phospholipids for preparing the delivery emulsion was shown to change the macro structure of the cream cheese. Furthermore, this cream cheese was less oxidized than the cream cheeses added delivery emulsions with whey protein isolate or sodium caseinate but similarly oxidized as the cream cheese added neat fish oil. Interestingly, the use of sodium caseinate as emulsifier in the delivery emulsions was shown to result in the least oxidatively stable fish oil enriched cream cheese.

Overall, this PhD work showed that factors related to both the choice of emulsifier, homogenization equipment and emulsification conditions influence the oxidative stability of simple fish oil-in-water emulsions. These factors include the oil concentration, the type of milk protein or phospholipid used as emulsifier, the pH, the addition of iron, preheating of the protein prior to homogenization, the equipment used for homogenization and the pressure applied during high pressure homogenization. In addition, lipid oxidation in simple fish oil-in-water emulsions was shown to depend on combinations of these factors, and not any one of them alone. Moreover, it was shown that despite an attempt to optimize the above-mentioned and thereby create an oxidatively stable fish oil-in-water delivery emulsion, this was not enough to ensure a protection of the fish oil when the delivery emulsion was added to milk or cream cheese.

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